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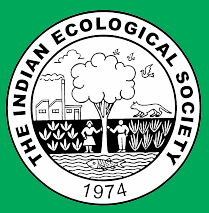

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Impact Assessment of Water Quality for Ground Water Parameters on Kalingarayan Canal, Erode District, Tamil Nadu

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Abstract: In this study, Kalingarayan canal is selected for the analysis of pollution level, i.e., the analysis to which certainty the canal is subjected to pollution. The Kalingarayan canal is crossing the major textile units. The streams carrying the untreated or semi- treated industrial effluents are mixed into the canal. In order to understand the pollution status of the canal, nine ground water samples along the canal namely Panjalingapuram towards north direction, Kolathupalayam I towards south direction, Kolathupalayam II towards north direction, Unjalur I towards north-east direction, UnjalurII (hospital) towards north-east direction, Perumparai towards north-east direction, Vadakupudupalayam I towards north direction, Vadakupudupalayam II towards north direction and Sallikadu towards north direction (GW1- GW9) were collected from the downstream side of the canal during the period 2014 – 2016.From the study, it can be concluded that the quality of water was considered to be bad at sampling stations Kolathupalayam (GW3) and Perumparai (GW6) and there were no significant changes in the characteristics of groundwater during flow and non-flow period. It can also be seen that the water is highly polluted with nitrate, calcium and magnesium, cannot be used for any kind of industrial processes and human consumption without proper treatment.

Keywords*:* Industrial effluents, Kanlingarayan canal, Pollution, Groundwater, Consumption

Water is required for many purposes, so it should be protected and ensured pure. Even though water has numerous benefits and is available freely, its wastage and the degradation of its quality threatens the futuristic need of it. In that, the primary concern of today is about the quality of water. Most of the water pollution is caused because of the anthropogenic activities and sluggish way of human behavior to follow the standards specified in the quality of water intended for a particular usage. The indisputable fact is that one third of the total water pollution is created in the form of bad effluent discharge of industries, solid waste, medical garbage and hazardous wastes. The land surface is considered as a main place for water effluent discharge. The instinctive use of synthetic fertilizers and improper waste management practices result in the deterioration of groundwater quality in many parts of India(Kundu et al 2010 , Sukhdev, 2012, Divahar et al 2019).

India is currently riding on the crest of industrialization. In Tamil Nadu by the 40 odd tanneries and approximately 500 textile dyeing units of Erode, who are discharging their untreated effluents into the nearby water channels. Particularly, the Kalingarayan canal is already receiving thousands of gallons of untreated and toxic effluents from the textile processing and tannery units in the district, which caused irreversible damage to the environment (Mohanakavitha et al 2019 a, b).

Thus, the canal which is meant for irrigation purpose becomes highly polluted and as a consequence, it brings about many undesirable results to the people who consume the canal water for drinking and agricultural purposes (Ahmad and Ahmad 2014, Bansal and Dwivedi 2018, Nandal et al 2020). The immediate corrective measure has to be arrived at to overcome these issues. In this regard, this study is executed to clearly understand various pollutants and its distribution in the canal and is concentrated on the industrial effluent disposal at various points along the canal stretch rather than the solid waste dumping. The preservation of perfect environment is necessary for the health of all beings. This paper deals with the core concept of the impacts of industrial effluents on ground water. In this study, the groundwater quality is expressed in terms of Water Quality Index (WQI). The parameters like pH, electrical conductivity (EC), total dissolved solids(TDS), Chlorides, total hardness, nitrates, sulphates, sodium, Calcium and Magnesium were analyzed to delimit areas where groundwater quality of well is unsuitable or fit for drinking, irrigation, industrial and agricultural purpose.

MATERIAL AND METHODS

Study area: The length of the canal is 92 km passing entirely through the Erode district, Tamil Nadu as per the survey conducted. The mean sea level (MSL) where the canal

begins is 534 feet and ends at 412.48 feet. The Kalingarayan Canal is situated on the western bank of the river Cauvery at 77° 40´ E to 77° 48´ E longitude and 11° 16´ N to 11° 26´ N with an area of 7621 Sq. km. Based on the latest population census in Erode district (2014), its population was 521,900. A stretch of 140-kilometre in a Kalingarayan canal in Erode district, which is fed by Bhavanisagar dam is taken for conducting the water pollution study because of the water pollution problems in it. Kalingarayan Canal, the lifeline of hundreds of farmers in the district, now faces fresh on the slaughter of pollution.

Sample collection: Ground water samples were collected from open wells at nine different locations in the surrounding irrigation fields from 2014 to 2016 once in a month throughout the year (at the time of flow and at the time of non-flow of water in the canal) (Table 1). The main sources of pollution in these sampling locations are the textile industries effluent, where the discharge of domestic sewage and washing of vehicles, bathing of animals, human activities releasing of municipal wastes which are located along the canal. The bottles were washed with detergent and dilute nitric acid before sampling. Finally, the de-ionized water was used to rinse the sampling bottles and the dried in sunlight. Samples were collected in plastic bottles from each sampling point.

Sample analysis: The pH value of the water samples was measured in the field itself. The basic water quality parameters like total dissolved solids (TDS), electrical conductivity (EC), chloride, sulphate, sodium, calcium, magnesium, total hardness and nitrate were determined in the laboratory using standard methods (APHA,1995).The WQI is calculated based on this relative weight and standards ((BIS 1991, Bhuvana and Ramesh 2012)

RESULTS AND DISCUSSION

Parametric analysis of ground water: The ground water samples collected during the study period is categorised as samples collected during the flow period and non- flow periods of the canal and these are compared with each other to understand the impact of surface water on the groundwater. During the flow period, the groundwater table raised automatically. The flow period of a year is eight months and non-flow period four months. The average values of flow and non- flow periods are compared with each other. During the non-flow period the groundwater is more polluted than during the flow period. This might be due to discharge of effluents into the canal during the flow period. But during non-flow period, it is not possible to discharge the effluents into the canal and it is discharged into the ground. This pollutes the groundwater. The parametric value also increases from 2014 to 2016 in GW1. This indicates that the discharge of pollutants increases every year. While comparing the values of flow period with that of the non-flow period, the samples collected from the non-flow period are more polluted. EC value reached a maximum of 1263 µS/cm in the non-flow period in 2016.

The pH value of groundwater samples during the flow period were acidic in nature and alkaline during the non-flow period. The EC value reached at GW2 is 1469 µS/cm. The TDS values are within the limit of that of the drinking water. The remaining parameters are also within the limit of that of the drinking water. At sampling station GW3 which is heavily pollutedin 2016, almost all the parameters exceeded the standards of the drinking water quality. During both the entire flow and non- flow periods of the canal, the nitrate value was high. The groundwater present in that location was hard in nature, had a high TDS value which made the water unsuitable for industrial usage. This location requires more attention in order to prevent further pollution.

The sampling station GW4 all the parameters are mostly within the limit of that of the drinking water. The hardness values exceeded the limit of that of the drinking water by the year 2016 (Khikeya and Singh 2019). This shows that the pollution of groundwater increases with time in this location also. The values of calcium and nitrate are higher than the average value. But the remaining parameters are within the limit (Table 5). The nitrate increased in the years 2015 and 2016 during the non-flow period in GW 5. The usage of this water will cause a disease called methemoglobinemia (blue baby disease). The water was hard in 2016. So, this water could not be used for industrial purposes since it has a tendency to produce boiler scales. The calcium content in the groundwater is about to exceed the permissible limit soon.

In GW 6 TDS, sulphates, calcium and hardness exceeded the limit of that of the drinking water in the year 2014 onwards (Table 7). This shows that the groundwater in that sampling station is more polluted and there might be some kind of waste water discharge nearby this sampling location. The value of EC indicates that from the year 2014 itself, it was doubtful the water could be used for irrigation.In the year 2015, pH value also exceeded the limit of that of the drinking water and became alkaline in nature. In general, the water present in this location cannot be used for drinking, irrigation or for any kind of industrial purpose. In 2016, the water became hard due to increase in its calcium and magnesium content during the flow and the non-flow period of the canal in GW 7 (Table 8). The water present in this region contains a higher concentration of nitrate which causes blue baby disease (Kumar and Balamurugan 2018, Vinothkanna et al 2020). The ion exchange denitrification process can be used for removal of this excess nitrogen.

Table 1. Details of ground water sampling points around Kalingarayan canal

Sample code	Latitude	Longitude	Distance from the canal (m)	Sampling location
GW1	11°26'26.37"N	77°40'41.27"E	90	Panjalingapuram towards north direction
GW2	11°23'12.49"N	77°41'43.73"E	170	Kolathupalayam I towards south direction
GW3	11°23'14.52"N	77°41'45.09"E	30	Kolathupalayam II towards north direction
GW4	11°21'50.78"N	77°42'46.87"E	100	Unjalur I towards north-east direction
GW5	11°21'51.86"N	77°42'49.24"E	150	UnjalurII (hospital) towards north-east direction
GW6	11°21'50.21"N	77°43'20.56"E	50	Perumparai towards north-east direction
GW7	11°21'32.69"N	77°44'13.54"E	85	Vadakupudupalayam I towards north direction
GW8	11°21'33.29"N	77°44'16.51"E	200	Vadakupudupalayam II towards north direction
GW9	11°19'42.82"N	77°45'9.44"E	150	Sallikadu towards north direction

Table 2. Physico-chemical parameters of groundwater sample at GW1 a distance of 90m away from the canal

Parameters	At the time of flow			At the time of non-flow		
	2014	2015	2016	2014	2015	2016
pH	6.4	6.8	6.6	7.4	7.9	7.8
EC (µS cm^{-1})	906	956	1,094	1001	1076	1,263
TDS (mg l^{-1})	580	612	700	640	688	808
Chloride (mg l^{-1})	269	289	337.6	306	324	375.8
Sulphate (mg l^{-1})	59	63	84.9	76	80	102.0
Sodium (mg l^{-1})	95	102	112.6	108	114	124.8
Calcium (mg l^{-1})	97	104	101.4	106	112	110.3
Magnesium (mg l^{-1})	33	35	50.9	30	35	57.3
Hardness (mg l^{-1})	377	405	462.4	389	424	510.6
Nitrate (mg l^{-1})	22.8	27.4	25.7	25.4	26.9	28.2

Table 3. Physico-chemical parameters of groundwater sample at GW2 a distance of 170m away from the canal

Parameters	At the time of flow			At the time of non-flow		
	2014	2015	2016	2014	2015	2016
pH	6.4	6.8	6.70	7.6	8.1	7.93
EC (µS cm^{-1})	1071	1138	1,263	1206	1347	1,469
TDS (mg l^{-1})	686	728	809	772	862	940
Chloride (mg l^{-1})	412	440	487.0	463	492	540.8
Sulphate (mg l^{-1})	98	106	126.1	117	124	145.8
Sodium (mg l^{-1})	27	30	41.4	36	38	50.8
Calcium (mg l^{-1})	86	92	90.5	94	100	98.3
Magnesium (mg l^{-1})	27	30	44.2	29	31	45.2
Hardness (mg l^{-1})	327	354	407.4	356	378	430.7
Nitrate (mg l^{-1})	28.2	32.2	31.1	34.3	36.4	37.2

Table 4. Physico-chemical parameters of groundwater sample at GW3 a distance of 30m away from the canal

Parameters	At the time of flow			At the time of non-flow		
	2014	2015	2016	2014	2015	2016
pH	7.2	7.6	7.56	8.2	8.7	8.53
EC (μS cm^{-1})	3581	3799	3,759	3947	4198	4,200
TDS (mg l^{-1})	2292	2431	2,406	2526	2687	2,688
Chloride (mg l^{-1})	801	853	840.5	882	938	926.3
Sulphate (mg l^{-1})	679	721	711.0	744	791	778.8
Sodium (mg l^{-1})	571	607	598.4	630	670	660.5
Calcium (mg l^{-1})	174	185	181.5	191	203	199.0
Magnesium (mg l^{-1})	63	68	93.7	68	73	100.9
Hardness (mg l^{-1})	695	742	838.0	757	805	911.3
Nitrate (mg l^{-1})	32.8	37.0	36.1	38.2	40.7	41.1

Table 5. Physico-chemical parameters of groundwater sample at GW4 a distance of 100m away from the canal

Parameters	At the time of flow			At the time of non-flow		
	2014	2015	2016	2014	2015	2016
pH	6.5	6.8	7.27	7.5	7.9	8.30
EC (μS cm^{-1})	1084	1156	1,847	1317	1362	1,875
TDS (mg l^{-1})	694	740	1,182	843	872	1,200
Chloride (mg l^{-1})	186	214	414.8	228	243	365.0
Sulphate (mg l^{-1})	136	145	285.3	171	182	267.2
Sodium (mg l^{-1})	178	190	275.2	212	226	274.9
Calcium (mg l^{-1})	132	140	148.7	146	155	168.5
Magnesium (mg l^{-1})	38	40	61.8	42	44	69.2
Hardness (mg l^{-1})	484	516	625.2	536	570	704.9
Nitrate (mg l^{-1})	29.5	32.6	32.4	37.2	39.6	40.1

Table 6. Physico-chemical parameters of groundwater sample at GW5 a distance of 150 m away from the canal

Parameters	At the time of flow			At the time of non-flow		
	2014	2015	2016	2014	2015	2016
pH	6.9	7.3	7.40	7.6	8.1	8.29
EC (μS cm^{-1})	1207	1337	1,976	1480	1573	1,795
TDS (mg l^{-1})	772	856	1,265	947	1007	1,149
Chloride (mg l^{-1})	233	288	461.8	297	316	315.7
Sulphate (mg l^{-1})	136	145	281.4	176	187	179.5
Sodium (mg l^{-1})	205	219	309.5	240	255	295.0
Calcium (mg l^{-1})	132	140	149.7	145	155	191.5
Magnesium (mg l^{-1})	36	38	58.5	40	43	71.4
Hardness (mg l^{-1})	477	508	614.2	527	561	771.4
Nitrate (mg l^{-1})	29.2	32.0	32.1	44.0	46.8	46.9

Hardness can be removed by using any water softening methods(boiling, lime-soda process, etc.).

In sampling station GW 8 except nitrate, all the remaining parameters are within the permissible limit of that of the drinking water (Table 9). During the non- flow period the amount of nitrates in the groundwater is high while comparing with that of the flow period. This may be due to cultivation in areas where the soil layer is relatively thin, or has a poor nutrient buffering capacity, or where there are changes in the use of the land; over fertilization of crop for intensification of agricultural activity; spread cultivation of crops which require a high fertilize doses which leave the soil bare over long periods and drainage systems which lead to drainage of fertilizers. The water should be treated with the ion exchange denitrification process before it is used for drinking.

During the flow period, the groundwater is slightly acidic in nature and during the non- flow period, it is alkalinein GW 9 (Table 10). In this sampling station all the parameters are within the permissible limit of that of the drinking water range except nitrate. In this region also, water is contaminated with nitrate during the non-flow period of the canal. This indicates that the reduction in groundwater table makes water, insufficient for dilution of these contaminants. By using an ion exchange denitrification process, excess nitrates can be removed easily.

Water Quality Index (WQI)

The percentage of water samples under the 'unsuitable for drinking' category gradually increases with respect to time (year) (Table 11). This indicates that the pollution of groundwater in this region increases day by day. In the year 2015 and 2016, none of the samples fell under the good category which shows that all the groundwater samples have

Table 7. Physico-chemical parameters of groundwater sample at GW6 a distance of 50 m away from the canal

Parameters	At the time of flow			At the time of non-flow		
	2014	2015	2016	2014	2015	2016
pH	7.4	7.8	7.71	8.1	8.6	8.45
EC (μS cm^{-1})	3256	3464	3,383	3586	3814	3,821
TDS (mg l^{-1})	2084	2217	2,165	2295	2441	2,446
Chloride (mg l^{-1})	770	820	807.5	842	895	884.0
Sulphate (mg l^{-1})	742	786	776.0	812	863	850.0
Sodium (mg l^{-1})	296	315	315.6	339	361	361.0
Calcium (mg l^{-1})	199	212	207.5	213	227	222.8
Magnesium (mg l^{-1})	66	71	98.1	73	77	107.3
Hardness (mg l^{-1})	770	822	920.8	831	884	996.9
Nitrate (mg l^{-1})	31.4	36.1	34.3	37.0	39.4	39.9

Table 8. Physico-chemical parameters of groundwater sample at GW7 a distance of 85 m away from the canal

Parameters	At the time of flow			At the time of non-flow		
	2014	2015	2016	2014	2015	2016
pH	7.0	7.5	7.57	7.5	7.9	8.28
EC (μS cm^{-1})	1092	1166	1,505	1379	1467	1,571
TDS (mg l^{-1})	699	747	963	883	939	1,005
Chloride (mg l^{-1})	272	290	391.4	343	364	405.7
Sulphate (mg l^{-1})	82	86	91.1	135	144	94.4
Sodium (mg l^{-1})	131	140	189.0	166	176	195.9
Calcium (mg l^{-1})	144	154	224.3	157	167	232.5
Magnesium (mg l^{-1})	36	39	98.2	39	42	107.9
Hardness (mg l^{-1})	508	544	963.2	554	590	1,023.7
Nitrate (mg l^{-1})	42.4	44.1	45.3	54.3	57.8	57.2

Table 9. Physico-chemical parameters of groundwater sample at GW8 a distance of 200 m away from the canal

Parameters	At the time of flow			At the time of non-flow		
	2014	2015	2016	2014	2015	2016
pH	6.5	6.9	7.04	6.9	7.4	7.65
EC (µS cm^{-1})	918	1035	1,354	1113	1197	1,358
TDS (mg l^{-1})	587	662	866	712	766	869
Chloride (mg l^{-1})	239	277	402.3	269	284	395.9
Sulphate (mg l^{-1})	91	98	114.8	136	148	113.0
Sodium (mg l^{-1})	79	86	102.4	102	112	100.7
Calcium (mg l^{-1})	124	132	168.2	135	145	165.5
Magnesium (mg l^{-1})	31	33	62.4	33	36	61.4
Hardness (mg l^{-1})	436	467	676.1	474	509	665.4
Nitrate (mg l^{-1})	41.5	42.7	44.4	47.6	50.3	50.2

Table 10. Physico-chemical parameters of groundwater sample at GW9 a distance of 150 m away from the canal

Parameters	At the time of flow			At the time of non-flow		
	2014	2015	2016	2014	2015	2016
pH	6.5	6.8	6.91	7.0	7.5	7.50
EC (µS cm^{-1})	965	1078	1,435	1150	1192	1,427
TDS (mg l^{-1})	618	690	919	736	763	913
Chloride (mg l^{-1})	265	306	431.1	293	311	443.9
Sulphate (mg l^{-1})	94	101	173.0	125	133	125.3
Sodium (mg l^{-1})	107	114	128.7	127	135	130.6
Calcium (mg l^{-1})	98	104	117.5	105	112	130.5
Magnesium (mg l^{-1})	26	28	48.0	28	30	53.3
Hardness (mg l^{-1})	352	377	490.4	378	402	544.8
Nitrate (mg l^{-1})	36.8	38.1	39.7	42.3	45.1	45.2

Table 11. Quality of ground water based on WQI values

Sample code	2014		2015		2016	
	WQI values	Quality	WQI values	Quality	WQI values	Quality
GW1	113	Poor	121	Poor	130	Poor
GW2	121	Poor	130	Poor	138	Poor
GW3	325	Unsuitable for drinking	346	Unsuitable for drinking	343	Unsuitable for drinking
GW4	143	Poor	153	Poor	197	Poor
GW5	150	Poor	160	Poor	202	Very Poor
GW6	312	Unsuitable for drinking	329	Unsuitable for drinking	327	Unsuitable for drinking
GW7	143	Poor	152	Poor	318	Unsuitable for drinking
GW8	124	Poor	132	Poor	155	Poor
GW9	112	Poor	120	Poor	138	Poor

undergone some kind of pollution threats. In 2016, water samples that came under the category of 'very poor' are 15.7%, while it is only 1.85% in the year 2015. So, the groundwater was contaminated more in the year 2016.The quality of groundwater based on the Water Quality Index (Table 11).

The groundwater sampling locations GW1, GW2, GW4, GW8, and GW9 come under the poor category throughout the study period. The WQI of the sampling stations GW5 and GW7increases and the water quality class was poor in the years 2014 and 2015. In the year 2016, this sampling station GW5 came under 'very poor' category and GW7 fell under 'unsuitable for drinking'. This uncovers that the sampling station GW7 was heavily contaminated in the year 2016. The remaining sampling station GW3 and GW6 come under the 'unsuitable for drinking' throughout the study period. Figure 1 shows the variation in the WQI values throughout the study period. During the study period, sampling stations GW3 and GW6 reach the maximum value while comparing with other sampling stations. So, the groundwater withdrawn from these two wells could not be used for any purpose. In addition to that the sampling stations GW3 is located 30 m away from the canal and GW6 is located at 50 m away from the canal. The value of WQI increases with time in all the sampling stations. This gives a warning that the pollution of groundwater in that region must be prevented.

There were no significant differences in the characteristics the ground water samplings at GW1, GW2, GW3, GW4, GW5, GW6, GW7, GW8 and GW9 during the time period between 2014 and 2016 both during the flow and non-flow periods of the Kalingarayan Canal This is an indication that the flow and the non-flow period of the canal during monsoon or summer season have no influence on the characteristics of the ground water. The WQI of the ground water samples at different time period (2014-2016) showed no significant variations in the characteristics of the samples, indicating that the water samples had almost the same characteristics through at the period of study.

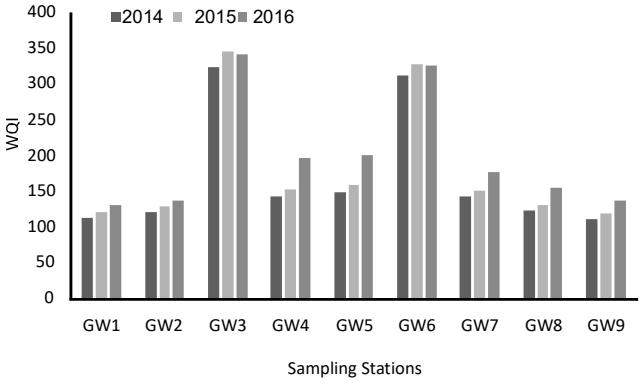

Fig. 1. Variation in the WQI values

CONCLUSION

The quality of ground water has deteriorated over the period of time. The ground water samples collected from sampling stations GW3 and GW6 became very worst in its quality. These two sampling stations are located within a distance of 50m away from the canal. The values of Water Quality Index (WQI) reveal that the groundwater quality is getting deteriorated over the period of time. The groundwater is contaminated mainly with nitrate and the water is very hard in nature and calcium and magnesium content in groundwater is very high at certain stations. The seepage of canal water into the groundwater may also change its quality to some extent either it improves or deteriorates the quality and the direct discharge of effluents in the surrounding area may also affect the ground water quality and there are no significant changes in characteristics of ground water during the flow and the non-flow period of the canal. This means that there must be some other kind of anthropogenic activities (direct discharge of industrial effluent into the ground), cannot be used for any kind of industrial processes and human consumption without proper treatment.

REFERENCES

Abhishek Nandal, Naveen Kaushik, Yadav SS, Rao Neetu Singh AS and Gulia SS 2020. Water quality assessment of pond water of Kalanaur Block, Rohtak, Haryana. *Indian Journal of Ecology* **47**(1): 1-6.

Ahmad A and Ahmad F 2014. Study on assessment of underground water quality. *International Journal of Current Microbiology and Applied Sciences* **3**(9): 612-616.

APHA 1995. *Standard Methods for Examination of Water and Wastewater'*, 19 Ed., American Public Health Association, American Water Works Association.

Bhuvana Jagadeeswari P and Ramesh K 2012.Water quality index for assessment of water quality in south Chennai coastal aquifer, Tamil Nadu, India. *International Journal of Chem Tech Research* **4**(4): 1582-1588.

BIS 1991. *Indian Standard for Drinking Water Specifications IS: 10500*, Bureau of Indian Standards, New Delhi.

Divahar R, Aravind Raj PS, Sangeetha SP and Mohana Kavitha T 2019. Impact of industrial wastewater disposal on surface water bodies in Kalingarayan canal, Erode district. *Indian Journal of Ecology* **46**(4): 823-827.

Bansal J and Dwivedi AK 2018. Assessment of ground water quality by using water quality index and physico chemical parameters: Review paper. *International Journal of Engineering Sciences & Research Technology* **7**(2): 1-9.

Khikeya Semy and Singh MR 2019. Assessment on the water quality of Tsurang River, Nagaland affected by coal mining drainage. *Indian Journal of Ecology* **46**(4): 845-849.

Kumar PS and Balamurugan P 2018. Evaluation of groundwater quality by using water quality index near magnesite mines, Salem District, Tamilnadu, India. *Indian Journal of Ecology* **45**(2): 380-383.

Kundu S, Thakur D, Gill GS, Tuli N and Yadav SS 2010. A comparative study of seasonal variation in groundwater quality along the Ghaggar river in Haryana and Punjab. *Indian Journal of Environmental Sciences* **1**(3): 269-277.

Mohana Kavitha T, Divahar R, Meenambal T and Keredin Temam Siraj 2019. Assessment of water quality of surface water in Kalingarayan canal for heavy metal pollution, Tamil Nadu. *Indian Journal of Ecology* **46**(1): 49-54.

Mohana Kavitha T, Divahar R, Meenambal T, Shankar K, Vijay Singh Rawat, Tamirat Dessalegn Haile and Chimdi Gadafa 2019. Dataset on the assessment of water quality of surface water in Kalingarayan Canal for heavy metal pollution, Tamil Nadu. *Data in Brief* **22**: 878-884.

Sukhdev Kundu 2012. Application of statistical analysis in assessment of seasonal and temporal variations in groundwater quality. *Bulletin of Environment, Pharmacology and Life Sciences* **1**(3): 07-11.

Vinothkanna S, Rajee R and Senthilraja K 2020. Assessing ground water quality for the suitability of irrigation in Dindigul District, Tamil Nadu, India. *Indian Journal of Ecology* **47**(1): 23-29.

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Appraisal of River Water Quality Based on Field Observations: A Case Study on Narmada River

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Abstract: The present research is concerned with the evaluation of water quality of the Narmada River. Water samples throughout its stretch right from origin point at Amarkantak to Badwani covering 10 sampling stations with 34 sub-sites of Narmada was sampled for water quality. The physiochemical parameters such as pH (8.38), EC (356 µS cm^{-1}), TDS (252.8 mg l^{-1}), Alkalinity (157.8 mg l^{-1} as $CaCO_3$), Chloride (58.7 mg l^{-1}), Total Hardness (161.9 as $CaCO_3$ mg l^{-1}), D.O (4.7 mg l^{-1}), B.O.D (2.4 mg l^{-1} for 5 days at 20 ºC), and nitrate (1.8 mg-NO_3 L^{-1}) were within the permissible limits as prescribed by the regulatory agencies. The interpreted comprehensive pollution index was 0.05-0.11; indicating that the river is clean.

Keywords: Narmada river, Water quality comprehensive pollution index (CPI), Principal cluster analysis (PCA), Hierarchical cluster analysis (HCA)

Narmada river is a perennial river in central India with religious believe and aesthetic values. It originates from Amarkantak hills in Maikala range of Madhya Pradesh and gets merged into Arabian Sea at Bharuch, Gujarat (Gupta and Chakrapani 2005). The population density of Narmada basin is around 100 per km^2 and 500 per km^2 in rural and urban areas respectively. Narmada River during its flow forms a vast area of fertile land which is very important from social, cultural, and economic perspective but due to variations in water quality, decline in its diversity has been observed (Saini and Dube 2017). Narmada has large number of tributaries and drains which carry significant load of sewage/effluents, runoffs discharged from industries, households and agricultural lands etc. These loads are putting immense pressure on physicochemical parameters of Narmada River. Ultimately affecting the flora and fauna, and the water quality of river. If Narmada lose its aesthetic and cultural values due to pollution this will cause economic threat to the society. Monitoring of rivers concerning its water quality on regular time interval is very important (Hany et al 2017, Pradeep et al 2018) and such studies covering the entire stretch of Narmada river is important for evolving a holistic river water management.

Considering the size and importance of the Narmada River, the studies conducted so far are limited in number and relevance. Most of the studies conducted on river Narmada which are focused on few locations and a complete study on Narmada River is still lacking. During past two decades the whole central India has witnessed a rapid growth in terms of population, industrialization and modernization of agriculture. These activities have directly affected the water quality of Narmada thereby causing stress to the river. Considering the size and ecological importance of the Narmada it is necessary to study the water quality of river Narmada. In spite of, several reports by Sharma et al (2008), Soni et al (2013), Sharma et al (2013), and Gupta et al (2017) available on water quality of Narmada, recent data has been lacking in the last half-decade. Sampling site are confined and uneven which does not give a clear scenario of water quality. Therefore, a study was conducted on current water quality status of Narmada covering its stretch from its origin point i.e., Amarkantak to Badwani.

MATERIAL AND METHODS

Study area: Narmada River flows between the Vindhya (north) and Satpura (south) ranges, originating from Amarkantak hills in Anuppur district of Madhya Pradesh and it merges in Arabian Sea at Bharuch, Gujarat. The river flows in westward direction with total length of 1312 km, to join the Arabian Sea. The Narmada basin lies between 72º32'E to 81º45'E longitude and 21º20'N to 23 º 45'N latitude, drainage area of 98,796 km^2 (Gupta and Chakrapani 2005) and its catchment area covers four states i.e., Madhya Pradesh (86.18%), Gujarat (11.6%), Maharashtra (1.5%) and Chhattisgarh (0.72%) (Fig. 1). The river is fed by precipitation with annual rainfall of about 1,178 mm in the basin.

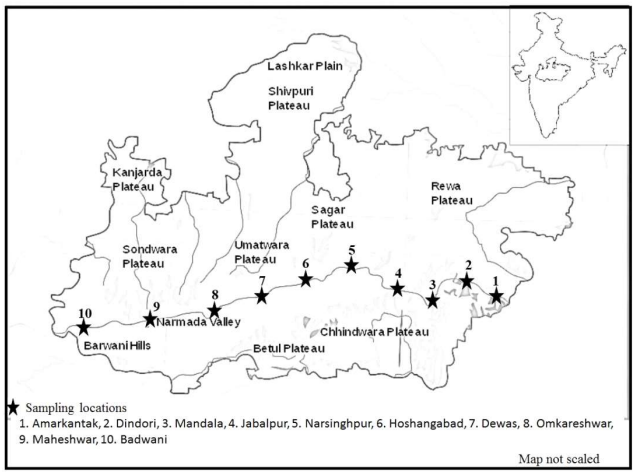

Fig. 1. Map of Narmada River

Data collection: The study was conducted during 2017-2018, for the detailed investigation of water quality, 10 major locations were along the Narmada river banks were fixed for collection of water samples. These locations were further divided in 33 sub-sites (sampling points) for the study (Table 2). Water samples were collected from the bank at a depth of 1-1.5 m below the water surface in acid washed PET bottles having 1-liter capacity for analysis of physicochemical parameters, BOD bottles were used to collect samples for dissolve oxygen (DO) and Biological oxygen demand (BOD). Water samples as well were stored in ice box until taken to the laboratory for further analysis.

Physical parameters (temperature, pH, electrical conductivity, and total dissolve solid) were analyzed at the sampling site using portable Oakton Multi parameter Tester. DO samples were also analyzed at the site. Dissolve oxygen (DO) and biological oxygen demand (BOD) tests were performed by following Winkler method, chloride test was carried out by argent metric titration, alkalinity & acidity was analyzed through titrimetric methods, and total hardness was analyzed by EDTA method (APHA 2012). Nitrate (NO_3^-) was estimated by spectrophotometric method (Thermo Fisher scientific, Evolution 300 UV-Vis spectrophotometer). The standard protocols (APHA 2012) were followed for all the experiments.

Classification of Water Quality

Comprehensive pollution index: Comprehensive pollution index was applied to the water quality parameter for its classification to understand the existing water quality status (Mishra et al 2015).

Pollution Index (PI) =Ci/Si……(1).

Comprehensive Pollution Index (CPI) =$1/n\sum PI_{i=0} + PI_{i=2} + PI_{i=3} + \ldots\ldots + PI_{i=n}$……(2).

Where, PI = pollution index of i^{th} parameter, Ci = measured concentration of i^{th} parameter, S_i = water quality permissible standard of i^{th} parameter, n = number of selected parameters. On the basis of pollution levels comprehensive pollution index (CPI) was classified as, clean (≤0.2); sub-clean (0.21-0.40); slightly polluted (0.41-1.0); moderately polluted (1.01-2.0); and severely polluted (≥2.01)(Mishra et al 2015).

Methods: Comprehensive pollution index (CPI) (Mishra et al 2015), has been used to evaluate the pollution status of Narmada River at different sampling stations. Multivariate statistical tools such as principal component analysis (PCA) and cluster analysis (CA) has been performed. These techniques have been used to identify the probable sources which may alter the water quality of the study area. CPI and statistical techniques are considered to be the most efficient and reliable techniques to know the water quality status at instant (Reghunath et al 2002, Dalakoti et al 2018). Microsoft office 2013 and SPSS (Statistical Package for Social Sciences, version-10.0) was used to calculate comprehensive pollution index and to extract multivariate analysis (CA and PCA) respectively.

RESULTS AND DISCUSSION

Physicochemical variations of various parameters: Physicochemical characteristics of a river mainly dependent on bed rock through which the water is flowing along with different biotic and abiotic interactions taking place in the riverine ecosystem. The observed physicochemical parameters of water samples of Narmada River is shown in (Table 1). The pH of Narmada river water under present study ranged from (7.5-8.7) (Fig. 2) which was within the permissible limits of Indian standard (BIS 2012). Although pH was found slightly alkaline at some locations of Narsinghpur, Hoshangabad and Dewas but alkaline pH is considered better as compare to acidic nature of water. The contribution to rise in pH values might be due to presence of high carbonate and bicarbonate of ions in water (Amarasooriya and Kawakami 2019). Its sources may be the effluents discharged from industries in the command areas of some study sites, such as SPM drain situated in Hoshangabad. Household effluents might also have contributed towards alkaline nature of water. The conductivity of water ranged from 93.8-580.3 in µS/cm (Fig. 2) and was within the permissible limit. Seven sampling station out of ten sampling stations has EC < 500 µS/cm, indicating the water at those sites were of fresh water type.

The total dissolve solids (TDS) values were ranged from 66.6-412 in mg L^{-1} (Fig. 2) and these values were largely governed by topographical and climatic conditions of the study area. At Amarkantak values were very low, such low value might be due absence of any pollution sources and

contribution of water through rain (Semy et al 2019). TDS at the plains of Narmada basin was high as compare to its origin. TDS is mainly governed by bicarbonates and carbonates, chloride, sulfate, calcium, magnesium, potassium, sodium, and silicate (Singh et al 2018, Boyd 2015). During its course at plains the river might have been loaded with weathering of rocks and agricultural runoff inputs leading to increase in TDS concentration at plains. In Narmada river alkalinity values were ranged from 120-600 mg L^{-1} (Fig. 2). High alkalinity was found in Hoshangabad region while low alkalinity was found at Amarkantak region. Concentration of chloride ranges from 36.7-77.4 mg L^{-1} with an average of 58.7 mg L^{-1} (Fig. 2). The obtained chloride concentration was within the permissible limit i.e., <250 mg L^{-1} (Table 1) indicates low organic content in river (Bharathi et al 2016). The concentration of hardness in water samples varied from 54-234.7 mg L^{-1} as $CaCO_3$ (Fig. 2). Dissolve oxygen concentration in Narmada River ranged from 2.8-8.8 mg/L (Fig. 2). Biological oxygen demand value ranged from (0.4-4.2 mg L^{-1}) (Fig. 2). In our study the DO as well as BOD values were within the permissible limits however, it was reported to be higher than permissible limit in some of the previous study (Sharma et al 2013). The concentration of nitrate ranged between 0.4-4.2 in mg L^{-1} (Fig. 2). Sources of nitrate in rivers are generally from agricultural runoffs, fertilizers, municipal waste and sewage discharge in rivers (Thatai et al 2019). The Narmada flows through intense agricultural region and run-off from these regions might have contributed towards nitrate in the river water.

Table 1. Physicochemical parameters of Narmada River

Parameters	Permissible range (BIS, 2012)	Values encountered in present study (Mean + SD)
pH	6.5-8.5	8.38±0.4
Conductivity (µS/cm)	300-2000	356±169.8
TDS [mg/l]	500-2000	252.8±120.5
Alkalinity [mg/l as $CaCO_3$]	120-600	157.8±64.7
Chloride [mg/l]	250-1000	58.7±15
Total Hardness [mg/l as $CaCO_3$]	300-600	161.9±65.8
D.O [mg/l]	5	4.7±1.6
B.O.D [mg/l] [5 days at 20 ºC]	5	2.4±1.6
Nitrate [mg-NO3/l]	45-100	1.8±1.1

*BIS- Bureau of Indian Standards, TDS- Total dissolved solids, DO- Dissolved oxygen, BOD- Biological Oxygen Demand

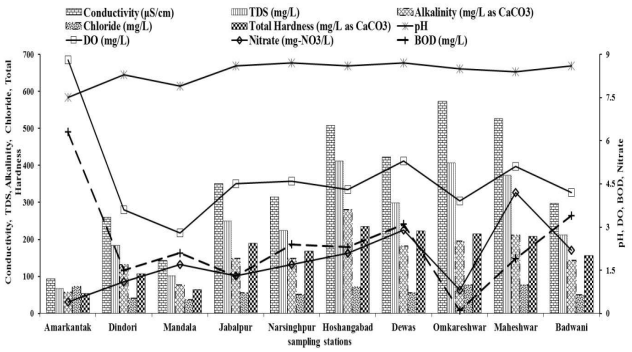

Fig. 2. Represents the pH, DO, BOD, nitrate, conductivity, TDS, alkalinity, chloride, and total hardness of Narmada River

Table 2. List of sampling station with their sub-sites

Sampling station (GPS locations)	Sub-sites
1Amarkantak (22º40.371´ N 81º45.547´ E)	Narmada Main Kund, Ram ghat, Vivekanandghat, and KapilDhara
Dindori (22º56.812´ N 81º04.627´ E)	Chandanghat, Dindori Bus stand, Manode
Mandala (22º36.320´ N 80º21.760´ E)	Sangamghat, Raptaghat, Ranrezghat
Jabalpur (23º06.531´ N 79º52.415´ E)	Gwarighat, Tilwaraghat, Bhedaghat, Saraswatighat
Narsinghpur (23º06.562´ N 79º35.184´ E)	Barman ghat, Jhasighat, Bandarbhanghat
Hoshangabad (22º45.774´ N 77º42.954´ E)	Budhnighat, Sethanighat, SPM drain
Dewas (22º29.619´N 76º58.718´ E)	Neelkanthghat, Nemwararghat, Khedighat
Omkareshwar (22º14.772´N 76º08.645´E)	Omkareshwar dam outlet, Nagar ghat, STP Omkareshwarghat
Maheshwar (22º10.386´N 75º39.587´E)	Mandleshwarghat, Maheshwarghat, Maheshwarghat (drain), Khedaghat, Khedaghat drain
Badwani (22º06.294´N 74º48.452´E)	Koteshwarghat, Raj ghat

Comprehensive pollution index (CPI): The water quality of Narmada based on CPI can be ranked as clean(CPI=0.05-0.11) (Fig. 3). The results obtained from CPI is similar to (Gupta et al 2017); they had conducted physiochemical analysis of water samples in year 2009/2012 from middle Narmada basin at six sampling stations and found the water quality suitable for human use. Since, in this present study water samples were also collected from the drains, some of their parameters were above permissible limit. However, the water quality of the sampling stations was the average value of their respective sub-sites and comprehensive quality was clean, it means that Narmada has self-purification capacity. The pollutants which was contributed by the drains were assimilated by the river, without causing adverse deterioration to its quality.

Cluster analysis: Three clusters were formed (Fig. 4), the first cluster includes (Narsinghpur, Badwani, Jabalpur, Dindori and Dewas) and these sampling stations are densely populated region. The water characteristics at these stations were being governed by anthropogenic activities, and municipal effluents which were directly discharged through drains in untreated state. Second cluster constitute of Amarkantak and Mandala and these two locations are situated at the uppermost part of Narmada basin. Major sources of pollution observed at these regions were due to washing of vehicles and bathing of devotees, and other religious activities. Third cluster was comprised of Omkareshwar, Maheshwar and Hoshangabad and are mostly visited by the devotees of Narmada and they have great belief towards the temples.

PCA analysis: The relationship among the water quality parameters and to classify its contribution sources, PCA was executed. KMO value was 0.77, as KMO value is >0.5 thus, PCA can be proceeded. PCA and then Varimax normalized rotation (VNR) was applied to the datasets of different parameters generated from water samples of Narmada (Table 3). Principal components with eigen values>1 was considered. Overall two principal components (PCs) was extracted with 84.51% of the total variance in the dataset (Table 3). The loading > 0.7 has been taken into account for the interpretation of the data. PC1 explains nearby 56.89% of the total variance with negative loading of DO and BOD with high loading of pH, conductivity, TDS, alkalinity, total hardness, and nitrate was observed. This might be due to effect of sewage, agricultural runoff, or industrial effluents discharged in river. PC 2 explains 27.61% of the total

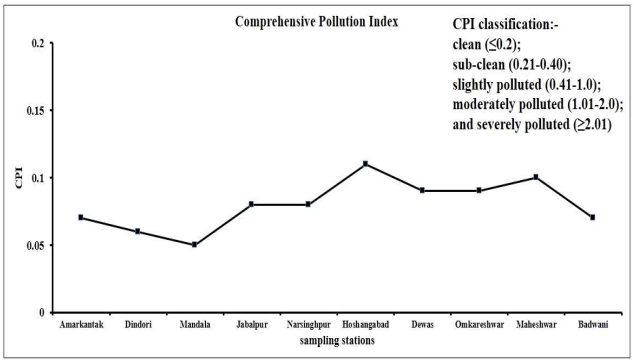

Fig. 3. CPI at each sampling stations over Narmada River

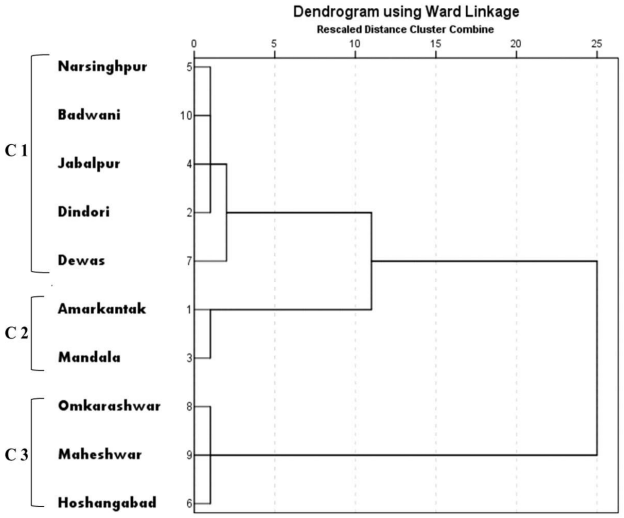

Fig. 4. Cluster Analysis (CA) representation with the help of "Dendrogram" for various sampling locations of Narmada river (n=17)

Table 3. Rotated component matrix of Narmada water quality

Parameters	PC(1)	PC(2)
pH	0.816	-0.211
Conductivity	0.979	-0.032
TDS	0.978	-0.031
Alkalinity	0.925	-0.181
Chloride	0.320	0.905
T. Hardness	0.971	0.027
D.O	-0.156	0.909
B.O.D	-0.280	0.870
Nitrate	0.732	0.063
Variance (%)	56.897	27.616
Cumulative (%)	56.897	84.513
KMO and Bartlett's Test		
Kaiser-Meyer-Olkin Measure of Sampling Adequacy		0.778
Bartlett's Test of Sphericity	Approx. Chi-Square	334.637
	Df	36
	Sig.	0.000

variance with negative loading of pH, conductivity, TDS and alkalinity with high loading of chloride, DO and BOD.

CONCLUSION

All the physicochemical parameters related to the water quality were within the permissible limits as prescribed by BIS, 2012. Comprehensive pollution index was implemented and thus clean water was found in Narmada River. Statistical applications identified that pH, conductivity, TDS, alkalinity, hardness is governing the water quality whereas BOD and chloride has been influencing water quality at densely populated regions. This study may offer useful and relevant findings for Narmada River and its management.

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REFERENCES

Amarasooriya AAGD and Kawakami T 2019. Removal of fluoride, hardness and alkalinity from groundwater by electrolysis. *Groundwater for Sustainable Development* **9**, p.100231.

APHA 2012. *Standard Methods for Examination of Water and Wastewater Investigations*. APHA, AWWA, Washington, DC.

Bharathi HR, Manjappa S, Suresh T and Suresh B 2016. Evaluation of water quality index of water bodies Channarayapatnataluk, Karnataka region, India. *International Journal of Applied Sciences and Biotechnology* **4**(4): 475-482.

BIS, Bureau of Indian Standard 2012. *Indian Standard (IS-105002)* second revision. New Delhi, pp. 1-11.

Boyd CE (2015). pH, Carbon Dioxide, and Alkalinity. In: *Water Quality.* Springer, Cham. https://doi.org/10.1007/978-3-319-17446-4_8

Dalakoti H, Mishra S, Chaudhary M and Singal SK 2018. Appraisal of water quality in the Lakes of Nainital District through numerical indices and multivariate statistics. *International Journal of River Basin Management* **16**(2): 219-229.

Received 27 August, 2020; Accepted 20 October, 2020

Gupta H and Chakrapani GJ 2005. Temporal and spatial variations in water flow and sediment load in Narmada River Basin, India: natural and man-made factors. *Environmental Geology* **48**(4-5): 579-589.

Gupta N, Pandey P and Hussain J 2017. Effect of physicochemical and biological parameters on the quality of river water of Narmada, Madhya Pradesh, India. *Water Science* **31**(1): 11-23.

Hany HM, Dalal A and Gupta S 2017. Phytoplankton assemblages in the river Barak, South Assam, India: A study to know its composition in changing space and time. *Indian Journal of Ecology* **44**(3): 492-499.

Mishra S, Kumar A and Shukla P 2015. Study of water quality in Hindon River using pollution index and environmetrics, India. *Desalination and Water Treatment* **57**(41): 19121-19130.

Pradeep T and Kumar Ananda S 2018. geochemical studies on surface water quality in lower Noyyal sub-basin, Cauvery River, Tamil Nadu, India. *Indian Journal of Ecology* **45**(1): 140-145.

Reghunath R, Murthy TS and Raghavan BR 2002. The utility of multivariate statistical techniques in hydrogeochemical studies: an example from Karnataka, India. *Water Research* **36**(10): 2437-2442.

Saini D and Dube KK 2017. Fish diversity studies of river Narmada, Jabalpur Region (MP). *International Journal of Fisheries and Aquatic Studies* **5**(5):13-16.

Semy K and Singh MR 2019. Assessment on the water quality of Tsurang river, Nagaland affected by coal mining drainage. *Indian Journal of Ecology* **46**(4): 845-849.

Sharma A, Bora CR and Shukla V 2013. Evaluation of seasonal changes in physico-chemical and bacteriological characteristics of water from the Narmada River (India) using multivariate analysis. *Natural Resources Research* **22**(4): 283-296.

Sharma S, Dixit S, Jain P, Shah KW and Vishwakarma R 2008. Statistical evaluation of hydrobiological parameters of Narmada River water at Hoshangabad City, India. *Environmental Monitoring and Assessment* **143** (1-3): 195-202.

Singh S, Sorokhaibam P, Kaur R and Singh R 2018. Assessment of physicochemical parameters to investigate pollution status of white Bein: A tributary of Sutlej river. *Indian Journal of Ecology* **45**(4): 898-900.

Soni V, Khwaja S and Visavadia M 2013. Preimpoundmental studies on water quality of Narmada river of India. *International Research Journal of Environmental Sciences* **2**(6): 31-38.

Thatai S, Verma R, Khurana P, Goel P and Kumar D 2019. Water Quality Standards, Its Pollution and Treatment Methods. In: Naushad M. (eds) *A New Generation Material Graphene: Applications in Water Technology*. Springer, Cham.

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Development of Different Irrigation Systems Calculator using VB6

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Abstract: A computer program has been developed for design of surface and pressurized irrigation systems. The program includes two main parts: crop water requirements and hydraulic calculations of the system. It has been developed in Visual Basic 6.0 and gives opportunity for selecting some parameters from tables such as: agro- physical soil properties, characteristics of the corresponding crop, climatic data. It allows the user of the program to assume and set a definite value, for example the emitter discharge, plot parameters and etc. It includes the design of lateral, manifold, main line and pump calculations. The program has been compiled to work in Windows. This software is user-friendly and provides interaction at all stages of the design process and a solution based on individual's requirements and the information base available within the software. The individual not only can suit to his requirement but can also compare his design with several other alternate designs with different inputs. Design of system arrived by this software was tested with manual calculations at developer's level and results were found satisfactory.

Keywords: Visual basic 6.0, Crop water requirement, Surface irrigation system, Pressurized irrigation systems

Irrigation may be defined as the process of supplying water to land by artificial means for the purpose of cultivation. In order to achieve this objective of irrigation, an irrigation system is required to be developed, which involves planning, designing, construction, operation and maintenance of various irrigation works viz., a source of water supply, a distribution system for carrying water from the source to the agricultural land and its application on the land and various other associated works. An irrigation engineer is associated with every phase of an irrigation system right from its inception and hence it is primarily his responsibility to develop an efficient and economic irrigation system to suit the natural conditions and the potential of the region (Modi 2004). The common methods of irrigation are surface irrigation (Border, Basin and Furrow Irrigation), drip irrigation and sprinkler irrigation. There are several ways of increasing efficiency in irrigation. One way is changing from surface to pressurized methods (Suresh et al 2013). Albaji et al (2015) revealed that the sprinkler and drip irrigations methods were more effective and efficient than the surface irrigation methods for improving land productivity. They may vary from location to location, crop to crop, year to year and farmer to farmer. In general, these considerations will include the compatibility of the method with other farm operations, economic feasibility, topographical characteristics, social properties, crop characteristics, water supply (quality as well as quantity of the source of water), and social constraints. A range of indicators is used when defining irrigation efficiency (IE) using conventional or traditional methods (Magayane et al 2004). The measurements of conventional IE parameters are difficult and time consuming.

Some of the early developed software in the field of surface irrigation include: BASCAD (Boonstra and Jurriens 1988), BICADM (Maheshwari and McMahon 1991), FISDEV (Zerihun and Feyen 1992), BASIN (Clemmens et al 1995), BORDER (Strelkoff et al 1998) and SURDEV (Jurriens et al 2001). During the process of designing an irrigation pipe network, agricultural engineers face the problem of determining the diameters of the pipes forming the distribution network. From a mathematical viewpoint, the design problem is highly complex due to the large number of parameters (Cesar and Bibiana 2012). For this reason, the search for a sufficiently satisfactory solution must use approximate procedures. Bautista et al (2009) analyzed hydraulics of surface irrigation systems using Win SRFR software. Teshome et al (2018) revealed that very poor conveyance efficiency was observed on traditional surface irrigation channels due to high losses, long path and not in accordance with the discharge that they have to convey. The hydraulic calculations, capacity of the pump and water application of a system can be operated according to theoretical data available from Magayaneet al (2004). Sirisha et al (2014) developed software for surface irrigation and water conveyance systems using visual basic 6.The main objective of this paper is to describe the developed program for different irrigation systems design. It is accomplished in user interface by visual basic 6.0 software. The main design methods are first defined and briefly explained.

MATERIAL AND METHODS

The designed software for different irrigation systems was developed using Microsoft Visual Basic 6.0. Successful operation of different irrigation methods requires that the system is designed and operated properly. The data are to be collected before the design are survey of land, type of crop, soil type, land slope, climatic record, source of water and water quality.

Design of border irrigation: The infiltration rate, inflow rate and slope for different type of soils are taken from the Table 1 with the following equations.

$$In\ flow\ rate\ q'\ (cm^3/\min/\ cm) = \frac{q \times 10^6 \times 60}{w \times 100} \quad .....1$$

q = Inflow rate (m^3/sec/m)

w = Border width (m)

Average depth (m) = $0.665y_0$ ……..(2)

$$y_0 = \left(\frac{n \times \frac{q}{w}}{\sqrt{S}} \right)^{0.6} \quad .....3$$

S = Slope (fraction)

n = 0.55425 – (0.0001386 × q') …. (4)

$$Border\ Length = \frac{q}{I}(1 - e^{-\left(\frac{D}{Y}\right)}) \quad .....5$$

q = Inflow rate (m^3/sec/m), I = Infiltration rate (m/sec), D= Root zone depth (cm)

Y **=** Average depth (m)

$$Irrigation\ \ time\ (\sec) = \left(\frac{D}{100 \times 1} \right) \quad .....6$$

Design of check basin irrigation: By knowing the rate of flow of water into the basin and duration of flow of irrigation stream, high values of application and storage efficiencies was obtained. The calculations required for the basin are as follows.

Area = 1× w, …… (7)

l = Length (m) and w = Width (m)

Net irrigation requirement :-It can be calculated by using the following formula:

Net Irrigation Requirement (NIR) (m) = (FC – SMC) × G × D …..(8)

FC = Field capacity (%)

SMC = Average soil moisture content (%)

G = Apparent specific gravity

D = Root zone depth (m)

Volume of water required (m^3) = (Area × NIR) …..(9)

Time of Operation (hr) = (V × 1000) / (S × 3600) ….. (10)

V = Volume of water to be irrigated (m^3)

S = Stream discharge (lps)

Design of Furrow Irrigation

Efficient irrigation by the furrow method is obtained by selecting proper combinations of spacing, length and slope of furrows, suitable size of the irrigation stream and duration of water application. The average depth of water applied during an irrigation can be calculated from the following relationship:

$$\text{Initial Avg. depth (cm)} = \frac{ID \times 360 \times IT}{I \times S \times 60} \quad ..... (11)$$

$$\text{Initial Avg. depth (cm)} = \frac{FD \times 360 \times FT}{I \times S \times 60} \quad ..... (12)$$

ID = Initial discharge (lps), IT = Initial time (min), FD = Final discharge (lps)

FT = Final time (min), l = Furrow length (m), S = Spacing (m)

Total Avg. depth (cm) = (Initial Avg. depth (cm) + Final Avg. depth (cm) …. (13)

Design of drip irrigation system: Brouwer et al (1985) reported standard plant and row spacing of different types of vegetableswhich was used in the study (Table 2).

Collection of climatic data: For the 16 locations daily climatic data as maximum and minimum temperature, relative Humidity, wind speed, sunshine hours are collected (Table 3).

Calculation of Design Daily Irrigation Requirement

Designed daily irrigation requirement:- The designed daily irrigation requirement value for a farm is determined

Table 1. Border irrigation characteristics

Soil type	Infiltration rate (m/sec)	Discharge (m^3/s/unit width of border)	Slope
Sand	0.00000694	0.01	0.005
Loamy sand	0.00000611	0.008	0.004
Sandy loam	0.00000444	0.006	0.003
Clay loam	0.00000222	0.004	0.002
Clay	0.00000111	0.002	0.001

Source: www.fao.org

Table 2. Field characteristics

Vegetable	Plant spacing (cm)	Row spacing (cm)	K_c
Tomato	70	100	0.8
Potato	30	70	0.75
Chillies	45	60	0.7
Brinjal	50	80	0.85
Capsicum	40	70	0.75
Cabbage	50	70	0.95
Cauliflower	60	70	0.9

Source: www.fao.org

Table 3. Location details

Location	Latitude (˚N)	Longitude (˚E)	Elevation (m)
Akola	20.7	77.01	282
Anand	22.556	72.91	39
Ananthapur	14.68	77.6	335
Banglore	12.966	77.56	920
Bhuvaneswar	20.27	85.84	45
Dapoli	17.75	73.18	240
Faizabad	26.78	82.13	97
Hisar	29.15	75.7	213
Jabalpur	23.16	79.93	403
Ludhiana	30.91	75.85	244
Mohanpur	23.27	73.41	240
Palampur	32.11	76.53	1220
Parbhani	19.5	76.75	347
Solapur	17.68	75.91	458
Thrissur	10.52	76.21	49
Udaipur	24.58	73.68	600

from several years of Daily Irrigation Requirement (DIR) data.

The most important parameters in estimating ET_o are temperature and solar radiation.

According to (Hargreaves and Samani 1985). The simplified equation is:

$$ETo = 0.0135\,(KT)\,(R_a)\,(TD)^{0.5}\,(TC + 17.8) \ldots (14)$$

Where,

ET_o = Evapotranspiration

Hargreaves (1994) recommended using KT = 0.162 for "interior" regions and KT = 0.19 for coastal regions.

R_a = extra-terrestrial radiation (mm/day); TD = T_{max}-T_{min} (ºc), TC = average daily temperature (ºc)

Estimation of designed daily irrigation requirement based on return period: For analysis, the data of the given series is first arranged in descending order of magnitude and then the probability of each event being equalled to or exceeded is calculated by the formula:

$$\text{Return period (Years)} = \frac{100}{\text{Probability (\%)}} \quad \ldots\ldots (15)$$

$$Probability\ (\%) = \left(1 - \frac{R}{M+1}\right) * 100 \quad \ldots\ldots (16)$$

Where,

R= Rank of design daily irrigation requirement (values in ascending order)

M= No. of design daily irrigation requirement values

Using above equation, design daily irrigation requirement for the return period of 5,10,15,20 years were computed and presented in Table 4.

In the design of drip irrigation, the gross irrigation requirement, total plants, discharge per plant and operation time can be calculated by using the formula discussed below.

Gross irrigation requirement: The total amount of water inclusive of water in the field applied through irrigation is termed as gross irrigation requirement, which in other words is net irrigation requirement plus application and other losses.

$$\text{Gross Irrigation Requirement (lit)} = \frac{\text{Area} \times \text{DDIR} \times K_c \times f \times 1000}{1000} \quad \ldots(17)$$

$$\text{Total Plants} = (\text{Area} \times 10000) / (x \times y) \ \ldots (18)$$

$$\text{Discharge per plant (lit)} = \frac{GIR \times n}{P} \ldots. (19)$$

Operation Time (hrs) = Discharge per plant (lit)/Total discharge (lph) … (20)

Where,

DDIR = Design Daily Irrigation Requirement(mm/day)

K_c = Crop Co-efficient, f = Frequency of Operation (days), x = Plant spacing (cm)

y = Row spacing (cm),GIR= Gross irrigation Requirement (lit). n = No. of Drippers

p = Total plants

Design of sprinkler irrigation system: The infiltration, field

Table 4. Climatic data

Location	Potential evapotranspiration			
	Return period (years)			
	5	10	15	20
Akola	24.41	25.05	25.64	26.05
Anand	11.93	13.03	14.12	14.25
Ananthapur	19.07	20.69	22.18	22.67
Banglore	11.92	12.37	12.51	12.55
Bhuvaneswar	13.32	14.72	14.86	14.91
Dapoli	7.98	9.1	10.26	10.3
Faizabad	14.38	15.34	NIL	NIL
Hisar	22.51	24.22	26.05	26.97
Jabalpur	18.27	18.73	19.33	19.56
Ludhiana	17.78	18.99	NIL	20.68
Mohanpur	10.01	15.57	19.85	NIL
Palampur	13.62	14.95	15.99	NIL
Parbhani	22.88	24.71	25.15	25.47
Solapur	18.67	19.3	21.02	21.67
Thrissur	13.75	15.26	16.28	16.4
Udaipur	17.21	17.96	23.51	36.68

capacity, PWP, available water are taken from Table 5. After that required type of crop is selected and the corresponding value of k_c was taken from Table 6.

Depth of irrigation: The depth of irrigation is calculated on the basis of available moisture holding capacity of the soil in its different layers and the soil moisture extraction pattern of the crop in its root zone depth.

$$\text{Depth of irrigation} = \frac{\text{AWC}}{2} \quad \ldots. (21)$$

Crop evapotranspiration: It is the amount of water that is lost through evapotranspiration.

Crop PET = K_c × Max.PET … (22)

Where,

AWC = Available water capacity, PET = Peak evapotranspiration

Table 5. Soil characteristics

Soil type	Infiltration (mm/day)	Field capacity (% vol)	PWP (% vol)	Available water (mm/m)
Sand	5041	10	5	50
Loamy sand	1469	12	5	65
Sandy loam	622	18	8	100
Loam	317	33.9	16.7	175
Silt loam	165	37.1	13.7	237
Sandy clay loam	104	34.1	21.5	128
Clay loam	55	38.1	22.8	155
Silt clay loam	37	40.1	22.3	180
Sandy clay	30	38.8	27	120
Silt clay	24	40.5	27.5	130
Clay	12	41.4	30.8	108

Source: www.fao.org

Table 6. K_c values

Crop	K_c
Potato	1.15
Chick pea	1.00
Green gram	1.05
Groundnut	1.15
Lentil	1.10
Soya bean	1.15
Cotton	1.15
Sun flower	1.10
Barley	1.15
Wheat	1.15
Maize	1.15
Sorghum	1.05
Sweet sorghum	1.20

Source: www.fao.org

The design characteristics of sprinkler Irrigation system are as follows.

Total area (m2) = 1 × W … (23)

l = Maximum length (m), w = Maximum width (m)

Volume of water to be irrigated (m^3) = (A × D) … (24)

A = Total area (m^2)

D = Depth of irrigation (or) PET (m),

$$\text{No. of nozzles length wise} = \frac{\text{l}}{\text{S}} \times 2 \quad \ldots (25)$$

$$\text{No. of nozzles widht wise} = \frac{\text{W}}{\text{S}} \times 2 \quad \ldots (26)$$

S = Spacing

Total no. of nozzles = LW × WW …. (27)

LW = No. of nozzles length wise

WW = No. of nozzles width wise

$$\text{Total discharge (lps)} = \frac{\text{V} \times 1000}{\text{t} \times 3600} \quad \ldots. (28)$$

V = Volume of water to be irrigated (m^3)

t = Time of operation (hrs.)

Pipe dimensions:

Total Discharge <= 1; Suggest: Pipe dimension = 1inch

1 < Total Discharge <= 2; Suggest: Pipe dimension = 2inch

2 < Total Discharge <= 4; Suggest: Pipe dimension = 2.5inch

4< Total Discharge <= 6; Suggest: Pipe dimension = 3inch

6 < Total Discharge <= 10; Suggest: Pipe dimension = 4inch

Total Discharge > 10; Suggest: Pipe dimension = not feasible

$$\text{Discharge through each nozzle (lps)} = \frac{\text{Total discharge (lps)}}{\text{Total no. of nozzles}} \quad (29)$$

Maximum nozzle discharge was considered as 0.5 lps. If it more than 0.5 lps the following principle was adopted.

Discharge through each Nozzle > 0.5; Suggest: Either split the field or Change the operating time.

Length wise discharge (lps) = Discharge through each nozzle (lps) × No. of nozzles length wise…. (30)

Width wise discharge (lps) = Discharge through each nozzle (lps) × No. of nozzles widht wise…. (31)

Total head (m) = 0 + S + D + (n × 1)…. (32)

Where, O = Operating Pressure(m), S = Suction head(m),D = Delivery head (m), n = Slope (fraction), l = Maximum Length (m)

Losses (m) = Total head (m) * 0.1….. (33)

Total gross head (m) = Total head (m) + Losses (m) … (34)

Bread horse power = GH × D / 75 × P × M … (35)

GH = Total gross head (m), D = Total discharge (lps), P = Pump efficiency (fraction), M = Motor efficiency (fraction)

Pump capacity: The range of BHP will vary from as follows:

BHP <= 1.5; Suggest: pump capacity = 1.5;1.5< BHP <= 3; Suggest: pump capacity = 3; 3 < BHP <= 5; Suggest: pump capacity = 5; 5 < BHP <= 7.5; Suggest: pump capacity = 7.5 and 7.5 < BHP <= 10; Suggest: pump capacity = 10

Break horse power along length wise = GH × D / 75 × P × M … (36)

LD = Lengthwise discharge (lps)

Break horse power along width wise = GH × WD / 75 × P × M … (37)

WD = Width wise discharge (lps)

Diameter of mainpipe (inch) = Length wise discharge pipe dimension + 0.5 … (38)

Total length of submanipipe (m) = Maximum width × No. of nozzles width wise … (39)

Length of submainpipe (m) = Total length of submain pipe / No. of submain pipes … (40)

The conveyance and field application efficiency of different types of soils in different irrigation methods were taken from the fao.org website. The irrigation efficiency can be calculated as

Irrigation efficiency (%) = (EC × EA) …. (41)

EC = Conveyance efficiency (%), EA = Field application efficiency (%)

RESULTS AND DISCUSSION

This software totally comprised of 14 pop-up windows that gives information regarding drip irrigation, sprinkler irrigation, surface irrigation (border, basin & furrow irrigation). The user needs to select the type of irrigation or irrigation efficiency from the pop-up window as shown in Fig. 1.The drip irrigation system design window displays as shown in Fig. 2. Firstly the user can select crop from the available list of crops in combo box. The plant and row spacing will be displayed according to the selection of crop. The user has to enter the length and the width of his field and frequency of operation. The designed irrigation requirement will be calculated by selecting the location of the irrigation system. Drip design characteristics window displays as shown in Fig. 3. Select the discharge and no. of drippers from the available list of combo box *viz.,* 2, 4 and 8 lph. The frequency of operation, area and the selected crop specifications are taken from the previous drip irrigation design (window 2). Calculation of gross irrigation requirement was displayed according to the input parameters and suggestion for selection of filter also displayed. Click ok button to get discharge per plant, operation time and total no. of plants for the designed layout. The final layout of drip irrigation system was shown in Fig. 4.

The information regarding design of sprinkler irrigation system was shown in Fig. 5. The user has to enter the values of length and width of the field. The infiltration, field capacity, PWP, available water and K_c values are displayed in corresponding text box by selecting type of soil and type of crop from the available list. The user has to enter the Maximum PET in the respective text box. Irrigation requirement can be found out by clicking either depth of irrigation or crop PET. The user can select the source of water either 'bore water' or 'farm pond'. The design irrigation

Fig. 1. Selection of irrigation types

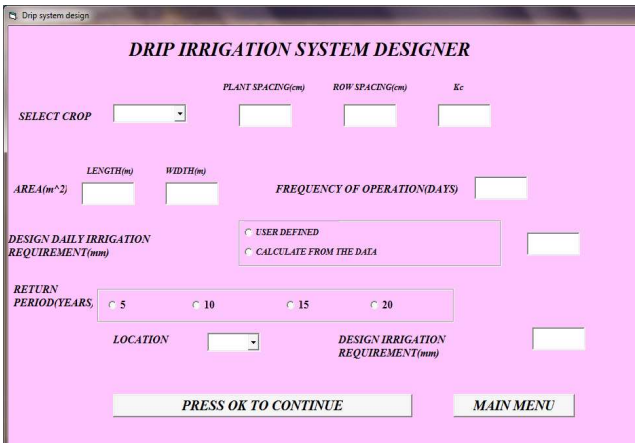

Fig. 2. Drip irrigation system design

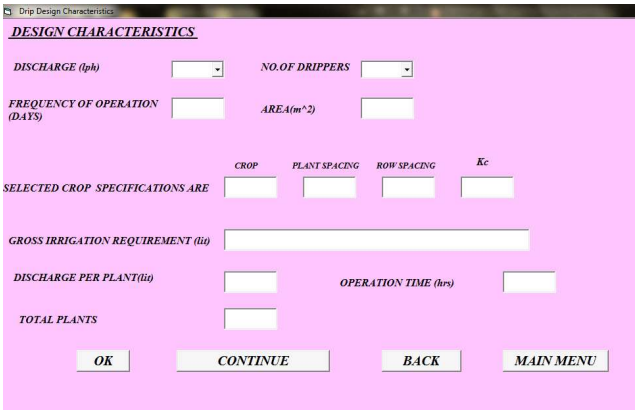

Fig. 3. Drip design characteristics

requirement value can be calculated same as in the form of drip design. The user has to define the values of operation time, spacing, suction head, delivery head in the respective text boxes and the values of operating pressure, slope, pump efficiency, motor efficiency are selected from the corresponding combo boxes. The design characteristics of sprinkler as shown in Fig. 6 and 7. The designed parameters like area, volume of water to be irrigated, no. of nozzles lengthwise and width wise, total no. of nozzles, total discharge, discharge through each nozzle, length wise discharge and width wise discharge, total head, losses, total gross head, BHP were calculated according to the formulae discussed in methodology. The final layout of sprinkler irrigation system was shown in Fig. 8 with all detailed dimensions of designed sprinkler irrigation system. The user can select the different types of surface irrigation methods from the pop-up window was shown in Fig. 9. The information regarding border irrigation was shown in Fig. 10 and the user has to enter the values of root zone depth and border width. The required type of soil can be selected from the combo box. The infiltration rate, inflow rate and slope data were displayed according the soil type. Average depth, border length and irrigation time were calculated on clicking the ok command button. The information regarding basin irrigation was shown in Fig. 11. The user has to give the values of length and width of the border, stream discharge, field capacity, average soil moisture content, apparent specific gravity, root zone depth. On clicking the ok command button, net irrigation requirement, volume of water required and time of operation were displayed. The

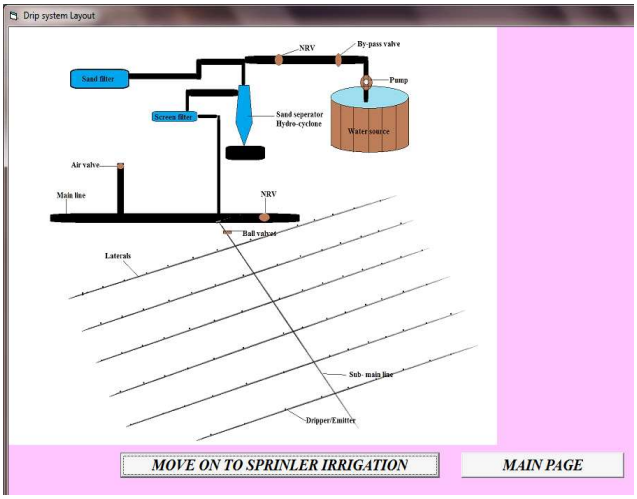

Fig. 4. Layout of drip irrigation system layout

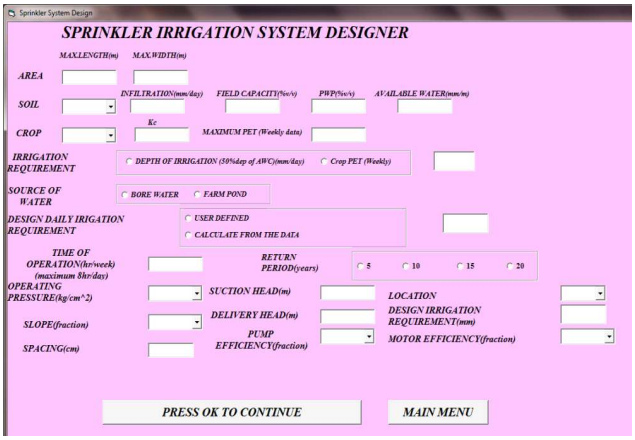

Fig. 5. Sprinkler system design

Fig. 6. Sprinkler design characteristics I

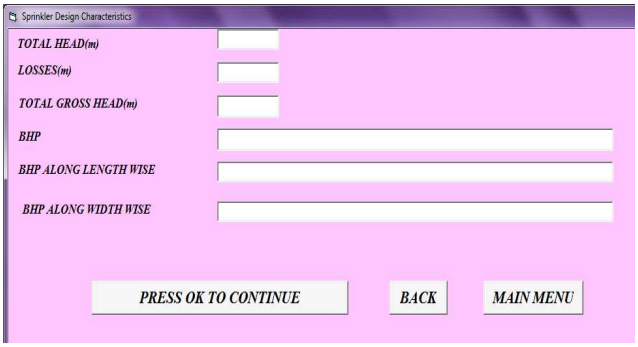

Fig. 7. Sprinkler design characteristics II

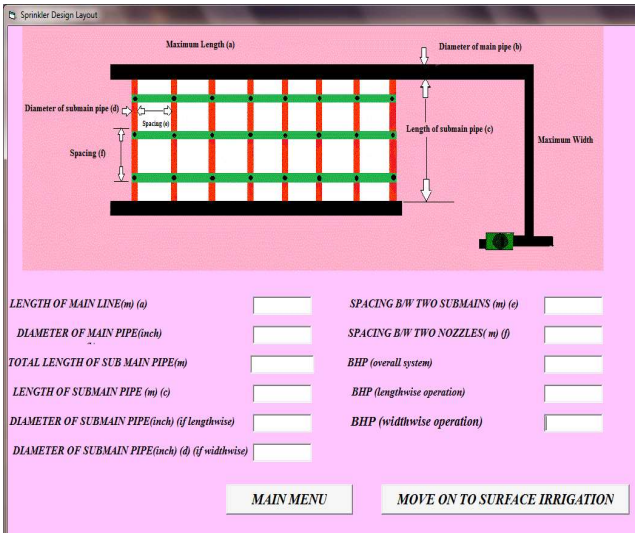

Fig. 8. Layout of sprinkler irrigation system layout

information regarding furrow Irrigation was shown in Fig. 12. The user has to enter the values of furrow length, furrow spacing, initial discharge, initial time, final discharge, final time. On clicking the ok command the values of initial average depth,final average depth, total average depth will display.

The information regarding irrigation efficiency was shown in Fig. 13. Soil type and irrigation method can be selected from the given combo box. The irrigation efficiency was calculated with available formula.

Fig. 9. Types of surface irrigation

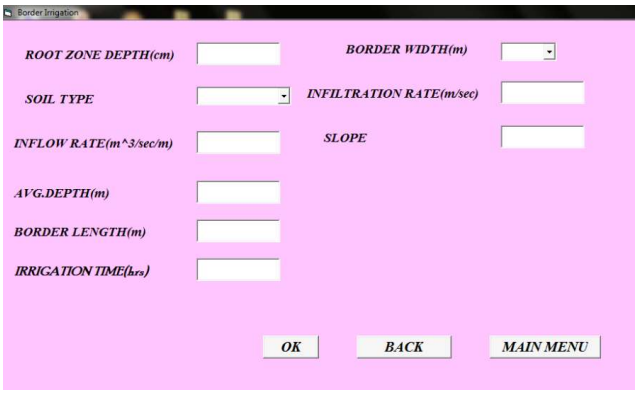

Fig. 10. Border irrigation

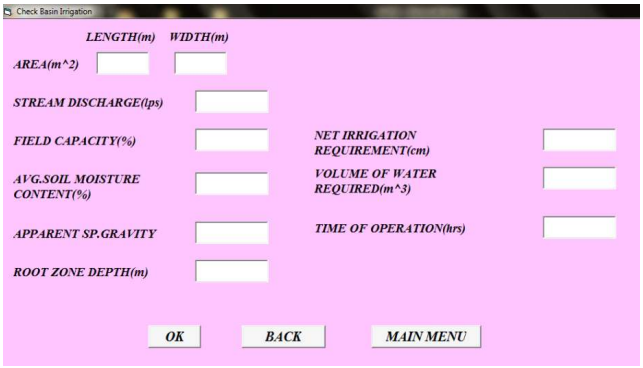

Fig. 11. Check basin irrigation

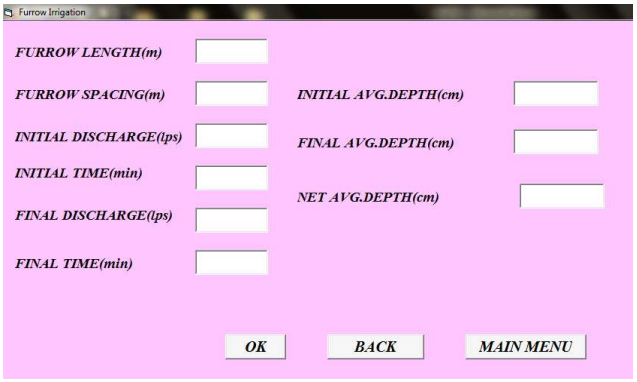

Fig. 12. Furrow irrigation

Fig. 13. Irrigation efficiency

CONCLUSIONS

A computer based software package using Visual Basic 6 programming language was developed for the development of different surface and pressurized irrigation systems. An interactive program is developed for the design of irrigation systems which consists of two parts: crop water requirements and hydraulic calculations of lateral, sub main, main line and pump. It allows the user in an interactive way to take into account all necessary soil, crop, climatic data and the basic parameters for hydraulic calculations. It offers a convenient way for design of small scale irrigation systems. Here it is worth to mention that the problems solved by the traditional method are very cumbersome and time consuming. However, this problem can be overcome using developed tool. It is concluded that developed irrigation systems calculator can be used as a teaching and design tool. It may be also useful for practicing irrigation engineers.

REFERENCES

Albaji Md, Mona G, Saeed BN and Farzad NZ 2015. Investigation of surface, sprinkler and dripirrigation methods based on the parametric evaluation approach in Jaizan Plain. *Journal of the Saudi Society of Agricultural Sciences* **14**: 1-10.

Bautista E, Clemmens AJ, Strelkoff TS and Niblack M 2009. Analysis of surface irrigation systems with Win SRFR-example application. *Agricultural Water Management* **96**: 1162-1169.

Boonstra J and Jurriens M 1988. *BASCAD. Amathematical model for level basin irrigation.* ILRI Publication 43. International Institute for Land Reclamation and Improvement, Wageningen, The Netherlands.1-30.

Brouwer C, Goffeau A and Heibloem M 1985. *Irrigation water management: training manual No. 1 - Introduction to irrigation.* Food and Agriculture Organization of the United Nations, Italy.

Cesar GC and Bibiana M 2012. Comparative analysis of design methods of pressurized irrigation networks. *Irrigation and Drainage* **61**: 1-9.

Clemmens AJ, Dedrick AR and Strand RJ 1995 .BASIN: *A computer programme for the design of level-basin irrigation systems (version 2.0).*USDA/ARS, US Water Conservation Laboratory, Phoenix, Arizona.1-58.

Hargreaves and Samani 1985. Reference Crop Evapotranspiration From Temperature. *American Society of Agricultural Engineers*1-13.

Jurriens M, Zerihun, Boonstra J and Feyen J 2001.*SURDEV: Surface irrigation software*. ILRI Publication 59.

Magayane M, Makarius M and Bruce L 2004. *Irrigation efficiency and productivity manual*. RIPARWIN Project.1-54.

Maheshwari BL and McMahon TA 1991. BICADM: A software package for border irrigation computer aided design and management. Department of Civil and Agricultural Engineering, University of Melbourne, Australia. 1- 32.

Modi PN 2014. *Irrigation Water Resources and Water Power Engineering*. Standard Book House. India.

Sirisha A, Raghuwanshi NS and Ashok M 2014. Development of surface irrigation systems design and evaluation software (SIDES).*Computers and Electronics in Agriculture* **100**: 100-109.

Suresh K, Balaguravaiah, D, Ramulu V and Sujani Rao Ch 2013. Comparative efficiency of sprinkler irrigation over check basin irrigation in groundnut at different irrigation schedules. *International Journal of Plant, Animal and Environmental Sciences* **3**(2): 9-13.

Strelkoff TS, Clemmens AJ and Schmidt BV 1998. Computer programme for simulating flow in surface irrigation: Furrows-Basins-Borders. US Water Conservation Lab, USDA-ARS, 4331E. Broadway.

Teshome Y, Biazin B, Wolka K and Burka A 2018. Evaluating performance of traditional surface irrigation techniques in Cheleleka watershed in Central Rift Valley, Ethiopia. *Applied Water Science* **8**(219): 1-14.

Zerihun D and Feyen J 1992. FISDEV: *A software package for design and evaluation of furrow irrigation systems.* Centre for Irrigation Engineering, Katholieke University, Lueven, Belgium.

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Delineation of Groundwater Potential Zone: Remote Sensing and GIS Approach in Doon Valley, Dehradun, Uttarakhand

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Abstract: Integration of various themes with remote sensing and GIS based weighted overlay technique is becoming common and cost-effective approach to delineate groundwater potential zones in groundwater studies. To understand the groundwater potential of study region, various raster themes such as geomorphology, lithology, lineament density, drainage density, Land use & Landcover, soil map, topographic position index (TPI) and slope has been prepared. The thematic content has been produced from different sources viz. Survey of India (SOI) toposheets (1:50,000), Advanced Space born Thermal Emission and Reflection Radiometer (ASTER) Global Digital Elevation model, Linear Imaging self-Scanning Sensor (LISS)-III and LANDSAT 8 imageries and processed in software's Arc Map and ERDAS Imagine. Ranking and weightages has been assigned to each class of thematic raster and thematic map was produced. Based on the obtained output entire study area has been categorized into five groundwater potential zones namely as good, moderate, poor, very poor, and extremely Poor which covers 29.92, 41.24, 11.04, 12.46 and 5.34 percent of total area respectively. The result was validated with field data, which overlaid over groundwater potential map and shows its availability. The result depicts that study area has a considerable groundwater potential and high groundwater recharging capacity.

Keywords: Groundwater potential zone, Groundwater hydrology, Weighted overlay technique, Remote sensing and GIS

Groundwater resource is one of the largest sources of freshwater on the planet excluding Glaciers and ice-caps. It constitutes a component of the earth's water circulatory system which covers 0.6 % of the world fresh water (2.8%) resource and stored in aquifers. These aquifers get recharged during atmospheric precipitation / stormy rainfall event. Globally, around 36, 42 and 27% of the total groundwater withdrawal are used for domestic, agricultural and industrial purposes (Doll et al 2012). It is an important source of water supply in both urban and rural areas of any country (Todd and Mays 2005). In Dun valley area, groundwater is regionally controlled by many factors such as Geology, Geomorphology, Drainage type (coarse/fine drainage) and Land use/Landcover of the city. Groundwater carrying capacity of rocks depends on compactness of rocks. Compactness of rocks depends upon presence of pore spaces where groundwater occupies and fundamentally important to the study of groundwater because they serve as water conduits. Groundwater movement within the rock body is controlled by permeability and secondary enhanced by presence of geological lineaments such as fracture, joints, fault and shear zone. Factors such as geology, climatic factor, geomorphic features, soil texture, terrain slope, land use/land cover, and density of drainage has a major impact on subsurface water system (Sener et al 2005, Rajaveni et al 2015, Ganesh et al 2018). Groundwater plays a supporting role in maintaining fundamental ecological balance, human well-being and economic development. Excess exploitation of subsurface water increasing with population booms leads over consumption of groundwater and causes the adverse impact on ecological system such as groundwater quality, water pollution and drawdown.

Subsurface water is a hidden precious natural resource and hence cannot be directly detected. Besides drilling test and stratigraphic investigations which is very cost effective and time-consuming process, there are certain sets of Remote Sensing and GIS method helpful in identification and delineation of groundwater regime in any region (Machiwal et al 2011).

MATERIAL AND METHODS

Study area: The study area Doon valley is extending between latitude 29.94/30.54, and longitude 78.31/77.56 which is covered by Lesser Himalayan rocks from the North and Siwalik hills in the south. Doon valley is composed of gravels which occupies the central and major part of valley and covers an area of 1904 km^2. The study area comes under survey of India survey of India (SOI) toposheet No.53F11, 53F14, 53F15, 53F16, 53J03, 53J04, 53J07, 53J08 and 53K01. Topographic relief of study area confined between

267 to 2589 m amsl, where northern facing site has higher elevated land mass, and their lengths range from North-west to North-East. Most of the valley area is flat with gentle undulations except residual hill rocks in the valley. Flat areas are mainly covered by a sedimentary formation Doon gravels. The annual average temperature of the study area is 21.8°c (Fig. 1).

Data used: In the process of generating the main output-groundwater potential map, the following thematic raster needs to be generated using different datasets. Survey of India (SOI) toposheets number 53F11, 53F14, 53F15, 53F16, 53J03, 53J04, 53J07, 53J08 and 53K01 at a scale of 1:50,000 was used to generate the base map. LANDSAT 8 OLI/TIRS, LISS-III: LANDSAT 8 and Linear Imaging Self Scanning (LISS)-III imageries was used in geomorphological feature extraction using digital image interpretation. LANDSAT-8 imagery has been used in preparation of Land use and Landcover map using supervised classification technique. Doon valley Geological Database has been created using maps from collateral source and it shows different categories of the Lithological Distribution of Garhwal – Kumaun Himalaya (modified from the Thakur and Rawat map 1992) (Table 1). *Advanced Spaceborne Thermal Emission and Reflection Radiometer (ASTER) Digital Elevation Model (DEM):* DEM at a 30 m spatial resolution was released by NASA and Japan's Ministry of Economy, Trade and industry (METI) to the worldwide public on June 29, 2009. This data was used in the preparation of Slope map, Hillshade, Lineament and Topographic Position Index (TPI) map.Thematic layers have been prepared in Arc GIS and ERDAS IMAGINE Software's. By using GIS Knowledge based Weighted Overlay techniques, appropriate weight and Rank assigned for individual thematic raster and its class based on suitability and potentiality towards water resource.

Methodology: In this research eight parameters geomorphology, lithology, landuse and landcover, drainage, lineament, soil, slope and TPI were used to generate the potential map. Each thematic raster having different categories or class has been assigned rank and weightage based on the role and effects of that respective theme over an area. Based on the expert's viewpoints and literature study, several researchers give weightage and consider more to the Lithology, slope, geomorphology and LULC for groundwater resource. The details of different raster themes mentioned in the methodology flowchart (Fig. 2).

Lithology: Study area bounds under three lithological Himalayan units, northern part covered by Lesser Himalayan rock, whereas central part consists of Doon Gravels namely as Doon valley and Siwalik hills covers its southern part. Chandpur, Nagthat, Tal, Krol and Ramgarh formation make up the Lesser Himalayan rise of study area, whereas the rocks of Siwalik group are overlain by the Doon Gravels. The Doon gravels, comprising of poorly consolidated gravel, sand and boulder with clay bands and fills up the large part of Doon valley (Ranjan 2005). The major alluvial Fans Dunga, Dehradun and Bhogpur extending from west to east and deposited by streams coming out of the Lesser Himalayas with the major relief provided due to the MBT and the associated faults (Fig. 3).

Geomorphology: The study region is carved out by a combination of fluvial, denudation and structural processes. The area has been categorized into three distinct geomorphic land units such as alluvium, piedmont fan deposits and structural hills (Residual and Denudational hills) (Fig. 4).

Lineament: Doon valley is situated in the foothills of Lesser Himalaya, consists of series of ridges from the north and centrally lying valleys with rising Siwalik Hills in the south. Geological linear features such as fracture, Joints and fault are very common in such topographic terrain and can be map very easily using the satellite imageries visual image interpretation. Lineaments play an important role in the

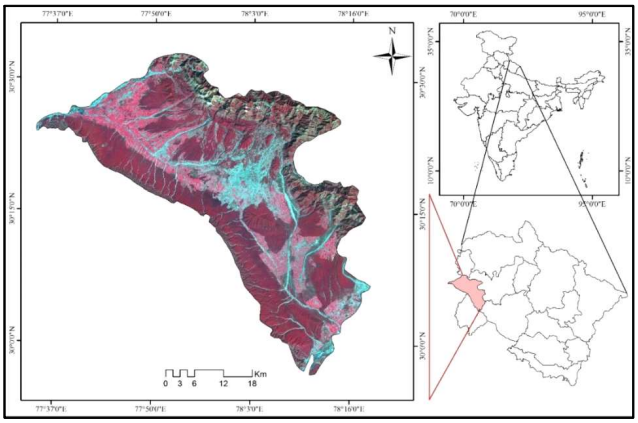


Fig. 1. Location map of Study area

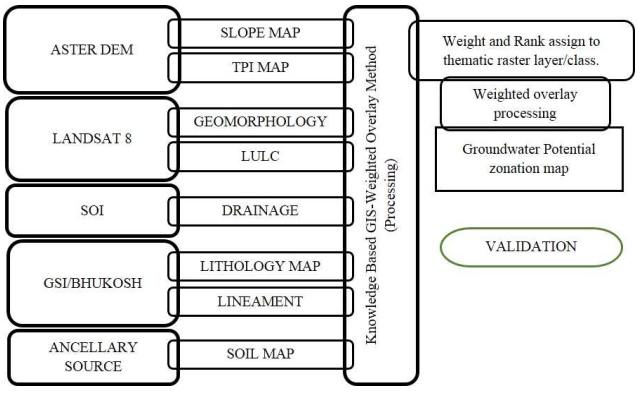


Fig. 2. Methodology flow chart

identification and mapping of groundwater regime and in other applications. These topographic hidden crustal structures are associated with high infiltration rate and serve as pathway along which the subsurface water moves and rises onto the surface (Fig. 5).

Drainage: Drainage pattern of the area is dendritic in the northern hills, which slope towards south and trellis (parallel to sub parallel) in the Siwaliks region. In the recent alluvium the pattern is parallel and sinuous. Asan, Song river and their tributaries Tons, Suwarna constitute the entire drainage network to the river system in the valley. The Ganga river enters and drains the eastern part of Dun valley and meandering south-east whereas the Yamuna river enters the district in Jaunsar and flows southwards. Besides the major Ganga and Yamuna, the other rivers that flow in the district are Asan, Suswa, Tons, Rispana, Bindal and Amalava. The drainage density map was prepared in Arc GIS using special analyst- line density tool. It reflects the area having high density with less recharge potential and less density, the higher potential toward groundwater aspect (Fig. 6).

Drainage density (Dd) = Total length of streams (km)/Basin area (km^2)

Slope: Study area landscape is characterized as steep slope hills from north and gently sloping Doon valley towards south and the gently rising Siwalik Hills to south. Elevation profile shows the trend of slope in X-Y direction Figure 7. The slope theme of the study area was developed from the ASTER GLOBAL DEM-30*30m resolution).

Soil map: Properties of soil such as type, structure, porosity and texture etc. help to determines the groundwater potential (Gintamo 2017). The soil map can be grouped into seven classes (Fig. 8).

Landuse and landcover: Landuse and Landcover of an area plays vital role in development and presence of water resources in any region. Transformation in physical landscape leads to direct profound impacts on environment components, especially on land and water resource system. Extreme urbanization and sprawling urban areas affect the local hydrological system. In such urbanized areas more than one-half of rainwater runs off and only a fraction of it goes for deep infiltration (Jr and Gibbons 2007). The LULC is an important part for water quality (Griffith et al 2002). In present study, the supervised classification with the maximum likelihood algorithm was used to classify the Land use and landcover from landsat 8 OLI images. Seven classes Crop land, forest, built-up, barren land, degraded forest, river, dry river-bed has been classified. The priority of weight and ranks given for layer and each class based on the relevancy towards groundwater potentiality. In the classified imagery Built-up area is covering around half 48.93% of the total area. Furthermore, the degraded forest area came out as a second class with coverage of 22.66% of the total area followed by only 9.84% under built-up, 7.23% under crop land, 5.11% as the dry river bed, 4.66% as barren land and 1.53% came out as a water-bodies- river class (Fig. 9).

TPI: Topographic position index generally calculates the landforms distribution and Landscape TPI values with respect to the topographic ruggedness or slope position on the area. It determines which areas are a valley, a ridge, or flat and can be applied to an area using the elevation for each cell and subtracting the average elevation of the cell's neighbours. TPI provides the additional functions to standardized and classify cell size, and to generate cell size and neighbourhood statistics (Fig. 10).

Validation: The resulted map was coinciding with field data observed during the field visit. Location L1 (near Bhauwala), L2 (near Bhaktarpur) and L3 (Chandrabadni) was visited and marked in Figure 12. In the field, it is observed that groundwater flowing out in the form of spring on to the earth surface. Generally, the natural springs forms when the pressure in an aquifer causes some of the water to flow out onto the surface of the earth. The formation of springs is controlled by the geological and structural setting and it gives an indication of the hydrological conditions, deposition of aquifers and aquitards and their stratigraphic distribution over an area. In previous studies Observation well data has been used to validate GWP map. (Abdalla 2012, Shekhar and Pandey 2014, Agrwal and Garg 2015, Patra et al 2017).

RESULTS AND DISCUSSION

In order to delineate the groundwater potential zone all thematic raster layers viz. Lithology, Geomorphology, Drainage density (D_d), Lineament density (L_d), Land use & Landcover (LULC), Soil map, Topographic Position Index (TPI) and Slope layer have been generated for area information and analysis. Prospect map was done by performing RS and GIS based approach weighted overlay for all eight thematic layers. (Geomorphology + Lithology + LULC + D_d + L_d + TPI + Soil + Slope = Groundwater Potential map). Knowledge based weight and rank examined and assigned for each layers and class for integration in weighted overlay analysis process which reflect its availability and potential towards Groundwater (Table 1). The higher weight value shows the influence of thematic layer and significance towards potential whereas, rank shows the recharge availability and development of groundwater in that class. Based on the output entire study area characterized into five groundwater potential zones ranging from good to extreme poor classes (Table 2). Good potential zone covers 29.92 % of total study area and comes under plain area, supports

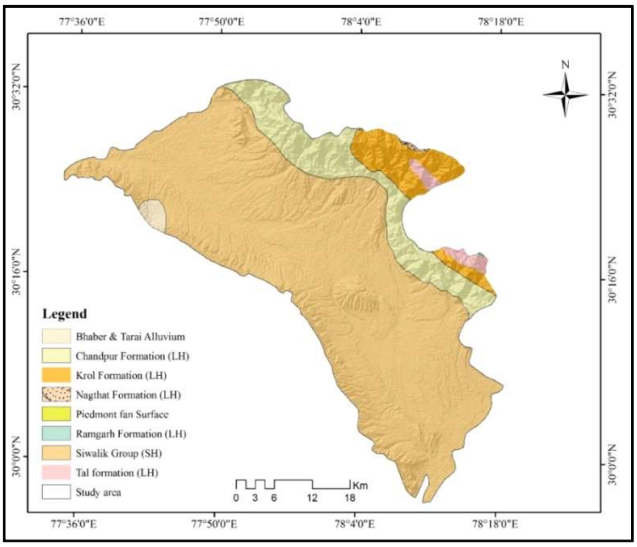


Fig. 3. Lithological map of study area

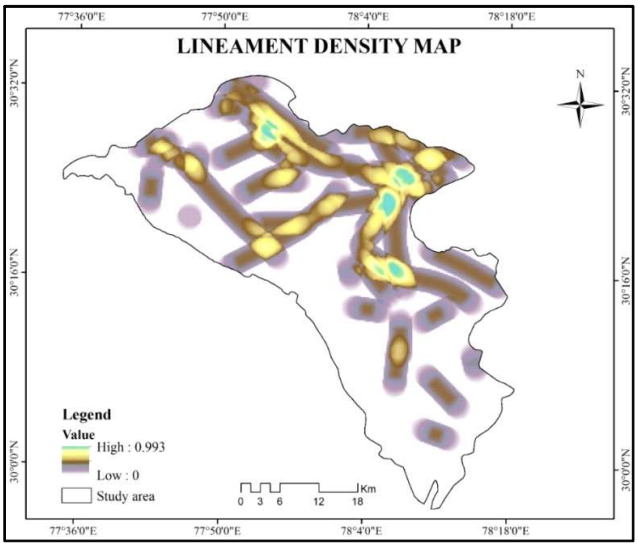


Fig. 5. Lineament density map of study area

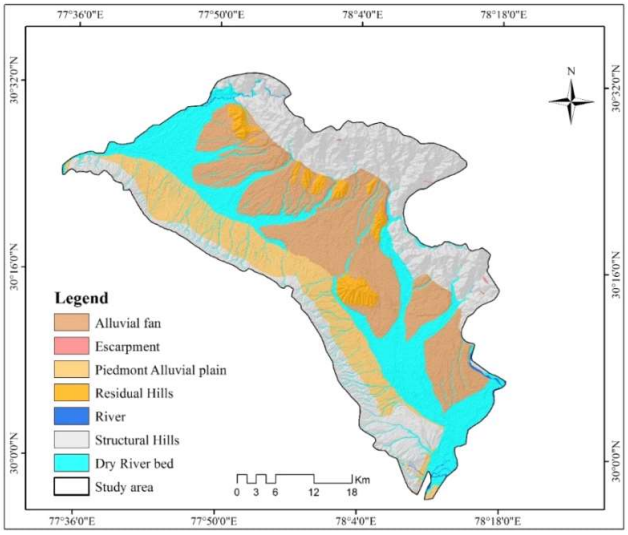


Fig. 4. Geomorphological map of study area

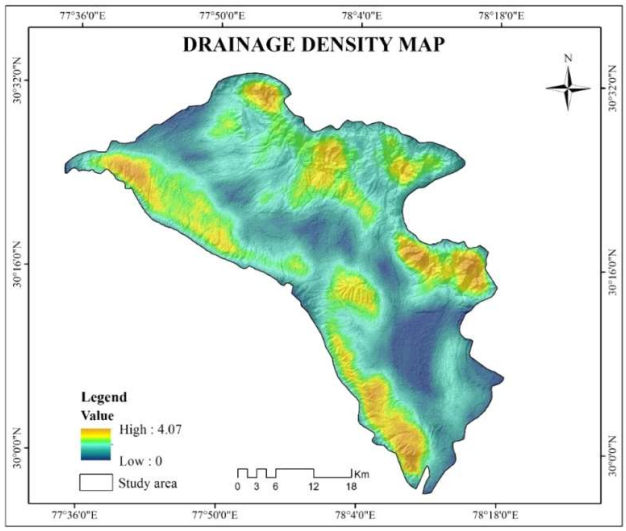


Fig. 6. Drainage density map of study area

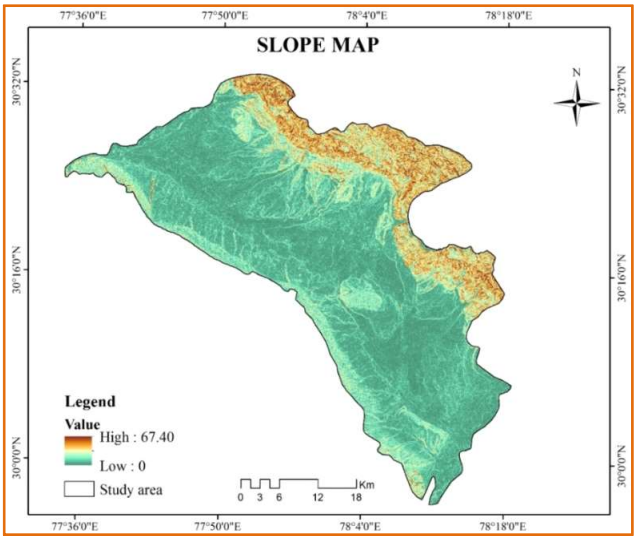


Fig. 7. Slope map of study area

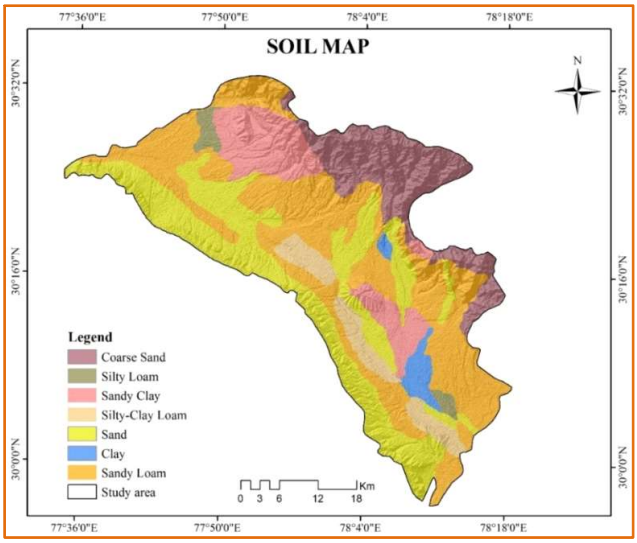


Fig. 8. Soil map of study area

Table 1. Dataset source

Thematic raster	Data sites
Base Raster	*http://soinakshe.uk.gov.in/.*
Geomorphology Raster	*https://bhuvan.nrsc.gov.in/https://earthexplorer.usgs.gov/.*
Lithological Raster	*http://bhukosh.gsi.gov.in/ http://doi.org/10.1007/978-981-10-8243-6.*
Land use and Land cover Raster	*https://earthexplorer.usgs.gov/*
Slope Raster	*https://earthexplorer.usgs.gov/*
Drainage Raster	*http://soinakshe.uk.gov.in/*
Lineament Raster	*http://bhukosh.gsi.gov.in/https://bhuvan.nrsc.gov.in/*
Soil Raster	*https://shodhganga.inflibnet.ac.in.*
Topographic Position Index (TPI) Raster	*https://earthexplorer.usgs.gov/*

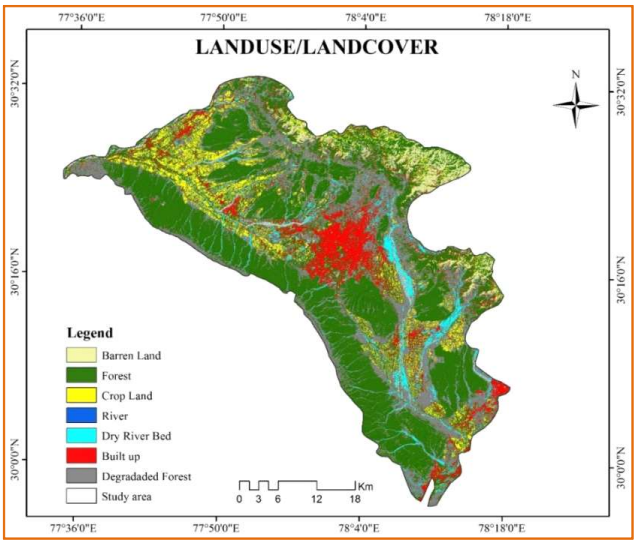
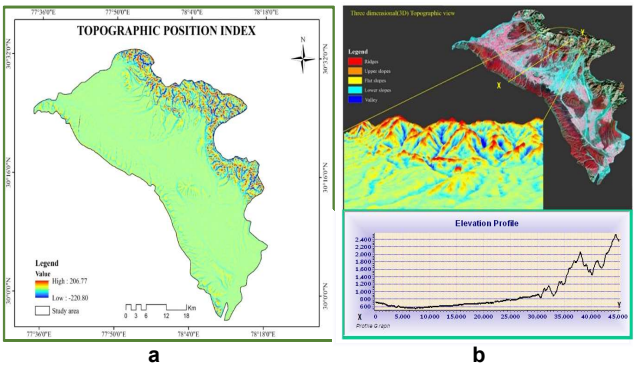


Fig. 9. Landuse & Landcover map of study area



a b

Fig. 10. (a) Topographic position index map. (b) 3-Dimensional view

favourable condition for groundwater infiltration and accumulation due to its geomorphic, geologic/tectonic setting of the area. The maximum area 41.24% characterized as moderate GWP zone, poor zone occupy 11.04% of total area, very poor covers 12.45% and 5.33 % area occupies extreme poor zone, due to the mountain in the northern part it is less prospectively towards groundwater.

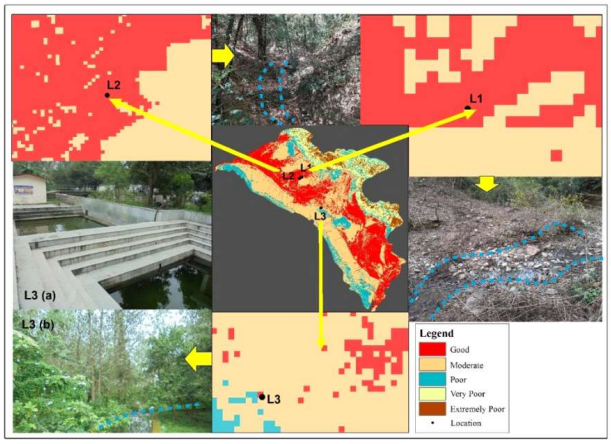


Fig. 11. Field validation with GWPZ map

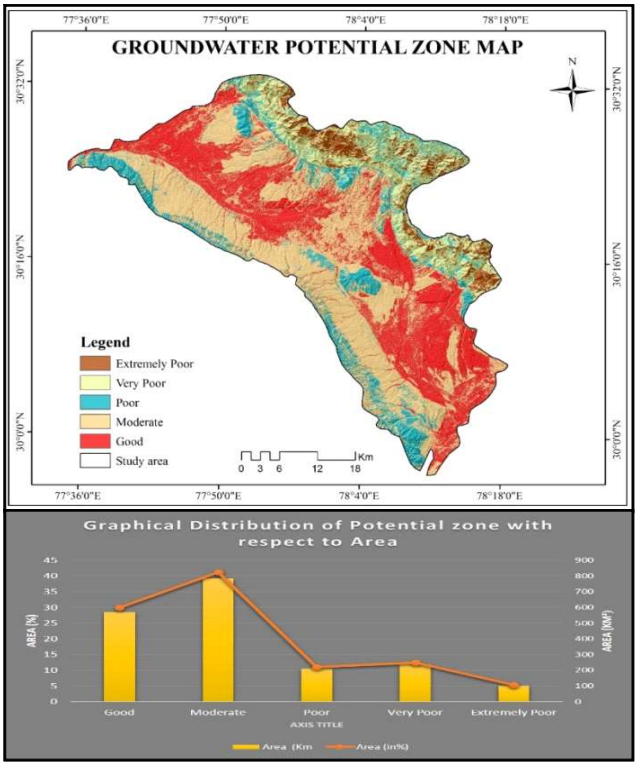


Fig. 12. Groundwater potential zone map with its distribution over an area

Table 2. Weighted and rank distribution of all thematic raster

Thematic Raster	Feature class	Weightage (%)	Rank
Lithology	Bhabar & Tarai Alluvium	16	6
	Siwalik Group (SH)		8
	Krol Formation (LH)		5
	Ramgarh Formation (LH)		2
	Tal Formation (LH)		3
	Nagthat Formation (LH)		4
	Chandpur Formation (LH)		1
Geomorphology	Alluvial Fan	15	7
	Escarpment		4
	Piedmont Alluvial Plain		5
	Residual Hills		3
	River		7
	Structural Hills		3
	Dry River bed		8
LULC	Barren Land	15	1
	Forest		6
	Crop Land		8
	River		9
	Dry River bed		7
	Built-up		1
	Degradaded Forest		4
Lineament density	0 – 0.14	13	3
	0.14 – 0.28		4
	0.28 – 0.42		5
	0.42 – 0.56		6
	0.56 – 0.70		7
	0.70 – 0.85		8
	0.85 – 0.99		9
Drainage density	0 – 0.58	10	9
	0.58 – 1.16		8
	1.16 – 1.74		6
	1.74 – 2.32		4
	2.32 – 2.90		3
	2.90 – 3.48		2
	3.48 – 4.07		1
Slope	0 – 09.62	14	7
	09.62 – 19.25		6
	19.25 – 28.88		4
	28.88 – 38.51		3
	38.51 – 48.14		2
	48.14 – 57.77		1
	57.77 – 67.40		1
Soil	Coarse Sand	10	2
	Silty-Loam		2
	Sandy Clay		4
	Silty-Clay Loam		6
	Sand		7
	Clay		5
	Sandy Loam		8
TPI	(-220.80)–(-159.72)	7	1
	(-159.72)–(-98.63)		4
	(-98.63)–(-37.55)		5
	(-37.55) – (23.52)		8
	(23.52) – (84.60)		3
	(84.60) – (145.69)		2
	(145.69 – (206.77)		1

Table 3. Rank for various parameter of groundwater potential zone

Rank	Grade remark
1	Extremely poor
2	Very poor
3	Poor
4	Moderate
5	Moderately good
6	Good
7	Very good
8	Extremely good
9	Excellent

CONCLUSION

The present study is an attempt to map groundwater potential zones in Doon valley. Five zones has been categorized in terms of good, moderate, poor, very poor and extreme poor for the sustainable development of the groundwater resources. Multidisciplinary data analysis using inverse distance weight (IDW) interpolation approaches have been used in this regard. The results generated using the technique indicates about 569.97 km^2 (29.92% of the study area) categorized as “Good”, 785.73 km^2 (41.24% of the study area) as “moderate”, 210.33 km^2 (11.04% of the study area) falls in “poor” category zone. 237.22 km^2 (12.46% of study area) covers as “very poor” and 5.34% falls in category zone “extremely poor” and it covers 101.63 km^2 of study area. Landscape with flat topographic slope and low lineament density found as most groundwater potential zone.The higher drainage density indicates more surface runoff of water during precipitation and caused the area less potential towards groundwater. The result depicts that weighted overlay is an appropriate and cost-effective technique to use in delineation and mapping of groundwater resources. The study can help to policy makers conceptualize planning and decision making for groundwater resources and their effective utilization in the development of sustainable water resource management in this region.

REFERENCES

Abdalla F 2012. Mapping of groundwater prospective zones using remote sensing and GIS techniques: A case study from the Central Eastern Desert. *Journal of African Earth Sciences* **70**: 8-17.

Agarwal R and Garg PK 2015. Remote sensing and GIS based groundwater potential recharge zones mapping using multi-criteria decision-making technique. *Water Resources Management* **30**(1): 243-260.

Doll P, Hoffmann-Dobrev H, Portmann FT, Siebert S, Eicker A, Rodell M, Strassberg G and Scanlon BR 2012. Impact of Water Withdrawals from Groundwater and Surface Water on Continental Water Storage Variations. *Journal of Geodynamics* **59-60**: 143-156.

Ganesh KM, Jagannadha Rao M, Jai Sankar G, Sai Vadapalli VKSK 2018. Integration of geology, hydrogeology and geomorphology for groundwater occurrence in a hard rock region from parts of Nalgonda District, Telangana State, India, using remote sensing and G. I. S. techniques. *International Journal of Engineering and Technology* **7**: 240-248.

Gintamo TT 2014. Ground water potential evaluation based on integrated GIS and remote ground water potential evaluation based on integrated GIS and remote sensing techniques, in Bilate River Catchment: South Rift Valley of Ethiopia. *American Scientific Research Journal for Engineering, Technology, and Sciences. (ASRJETS)* **10**(1): 85-120.

Griffith JA, Martinko EA, Whistler JL and Price KP 2002. Interrelationships among landscapes, NDVI, and stream water quality in the US Central plains. *Ecological Applications* **12**(6): 1702-1718.

Chester L Arnold Jr and James Gibbons C 2007. Impervious surface coverage: The emergence of a key environmental. *Journal of the American Planning Association* **62**(2): 243-258.

Machiwal D, Jha MK and Mal BC 2011. Assessment of groundwater potential in a semi-arid region of India using remote sensing, GIS and MCDM techniques. *Water Resources Management* **25**(5): 1359-1386.

Patra S, Mishra P and Mahapatra SC 2018. Delineation of groundwater potential zone for sustainable development: A case study from Ganga Alluvial Plain covering Hooghly district of India using remote sensing, geographic information system and analytic hierarchy process. *Journal of Cleaner Production* **172**: 2485-2502.

Rajaveni SP, Brindha K and Elango L 2015. Geological and geomorphological controls on groundwater occurrence in a hard rock region. *Applied Water Science* **7**: 1377-1389.

Ranjan Rajiv 2005. *Seismic Response Analysis of Dehradun*. M.Sc. Dissertation, International Institute for Geo-information Science and Earth Observation,Enschede, The Netherland & Indian Institute of Remote Sensing, Dehradun, Uttarakhand, India.

Sener, Erhan., Aysen Davraz and Mehmet Ozcelik 2005. An integration of GIS and remote sensing in groundwater investigations : A case study in Burdur, Turkey. *Hydrogeology Journal* **13**(5): 826-834.

Shekhar Shashank and Arvind Chandra Pandey 2014. Delineation of groundwater potential zone in hard rock terrain of India using remote sensing, Geographical Information System (GIS) and Analytic Hierarchy Process (AHP) techniques. *Geocarto International* **30**(4): 402-421.

Todd and Mays 2005. *Ground Water Hydrology (3rd ed.)*. John Wiley& sons, Inc., United States of America.

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Physicochemical Properties and Heavy Metal Analysis of Avalahalli Lake, Bengaluru, Karnataka, India

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Abstract: The present research was to determine physicochemical properties and heavy metal analysis of Avalahalli lake. Study was conducted on November 2017 to March 2018. Avalahalli lake is highly contaminated with domestic sewage, solid wastes and highly toxic compounds generated from cement factory. Water samples were collected studied for physicochemical properties and heavy metal analysis. The samples were analyzed for pH, Total Dissolved Solids, Electrical Conductivity, Turbidity, Alkalinity, Hardness, Calcium, Magnesium, Nitrate, Phosphate, Fluoride, Sulphide, Chloride, Sulphate, Sodium, Potassium, Total Suspended Solids, Boron and heavy metals like Chromium, Lead, Copper, Iron, Nickel and Zinc by comparing the standards or reference range. The quality of water was extremely polluted and conservation strategies are most required.

Keywords: Avalahalli lake, Physicochemical, Heavy metals, Domestic sewage, Solid waste

The deteriorating quality of water seriously delimits the use for human consumption and aquatic life, of which dumping of solid waste has also added to the chaos. Therefore, the periodical analysis of water quality testing is necessary to take preventive measures. Due to lack of awareness of the people living around water bodies, the ponds and lakes are getting contaminated day by day. Untreated water effluents from various industries, agricultural, sewage and residential wastewater, human and animal feces are disposed directly in the nearby water bodies causing serious environmental problems. Heavy metals are introduced into the water bodies from various sources such as effluent discharges and human contamination (Paul et al 2012). Aquatic ecosystems usually fail to eliminate heavy metals from waste discharge using their own natural processes. Some heavy metals like mercury, cadmium, copper and arsenic accumulates in sediments, from which they seep out through a process of remobilization into water (Paul et al 2012). They then move upto the highest rank of the food chain in different forms eventually effecting humans by causing serious acute and chronic ailments. Heavy metals can enter into human, animals, plants through air inhalation, diet and manual handling. The heavy metals can prevent Deoxyribose Nucleic Acid (DNA) replication and subsequent cell division leading to further health damage (Sharma et al 2014). Accumulation of heavy metals even in low concentration has invariably resulted in stress leading to irreversible physiological conditions (Jaishasnkar et al 2014). The aim of the study was to analyze the presence of various physicochemical properties and heavy metals like chromium, lead, copper, iron, nickel and zinc.

MATERIAL AND METHODS

Avalahalli lake water samples were collected and analysis done from November, 2017 to March, 2018. The present research encompassed collection of data for various aspects like physiochemical parameters and heavy metal detection.

Study area and topography: The study carried out in eastern part of Bengaluru, Karnataka, India. Bengaluru is the capital of Karnataka in the Southern part of India. It lies in the Deccan plateau at 2953 feet above sea level. Bengaluru covers an area of 741 sq km. The latitude and longitude are 12.97°N and 77.56°E respectively. In the study, the Eastern Bengaluru was selected which is popularly known as Avalahalli lake with the latitude and longitude are 12.865°N and 77.566°E respectively. The main pollutant in Avalahalli lake is inorganic waste deposits from chemical factory around it and also domestic activities like fecal discharge and dumping of solid wastes are the reason of major concern in that area.

Climate: Bengaluru has a tropical Savanna climate with distinct wet and dry season. It has a moderate climate throughout the year, the coolest month being January (15.1°C) and the hottest month April (35° C). The highest ever recorded temperature is 39.2°C (2016) and the lowest is 7.8°C (1884). The annual rainfall is 859 mm. The primary rainy season is from June to September and the secondary

rainy season is from November to December. The heaviest rainfall ever recorded lasted for 24 hours and was 179 mm.

Field studies

Water sample collection: Water samples were collected on particular dates of every month from the various lakes considered for the study. Water from the surface was collected using clean and sanitized Biological Oxygen Demand (BOD) bottles and filled up to its neck. Collection was done from the Avalahalli lake, Bengaluru city during morning at around 9-11 am for the months of November 2017 to March 2018.

Study of physicochemical parameters: Temperature of the water samples was recorded at the sampling point. Analytical Grade (AR) grade chemicals and glass distilled water was used for the preparation of the reagents. Electrical conductivity and pH was determined using Systronics - Conductometer and Digital Systronics pH – meter respectively. The water quality parameters like mean pH, Total Dissolved Solids, Electrical Conductivity, Turbidity, Alkalinity, Hardness, Calcium, Magnesium, Nitrate, Phosphate, Fluoride, Sulphide, Chloride, Sulphate, Sodium, Potassium and TSS were studied using standard procedures (APHA, 2012).

Atomic absorption spectrometry (AAS): The elements like Chromium, Iron, Copper, Lead, Nickel and Zinc were analyzed by using AAS technique. AAS is a quantitative method of metal analysis suitable for the determination of approximately 70 elements. This method measures the concentration of the element by passing light in specific wave length emitted by a radiation source of a particular element through cloud of atoms from a sample. Atoms will absorb light from an energy source known as hollow cathode lamp (HCL). The reduction in the amount of light intensity reaching the detector is seen as a measure for the concentration of particular element in the original sample.

A typical AA spectrometer consists of energy (light) source, sample compartment (atomizer). The radiation source is usually a hollow cathode lamp (HCL) or electrodeless discharge lamp (EDL), while different atomizers are used in various AAS techniques such as flame, a graphite furnace, or a quartz tube. The Monochromator is eliminating scattered light of other wavelengths by a number of lenses and mirrors to focus the radiation and the detector is typically a photomultiplier tube that converts the light signal to an electrical signal proportional to the light intensity (Beaty and Kerber 1993).

RESULTS AND DISCUSSION

The quality of the water samples were analyzed by collecting samples from the Avalahalli lake of Eastern Bengaluru from November 2017 to March 2018. The results obtained by the analysis of the water samples are listed as physicochemical parameters and heavy metal analysis during the experimental studies.

Study of physicochemical parameters and heavy metal analysis of Avalahalli lake: The sampling was done for 5 months and covered two seasons (post winter and pre summer). Sampling and analysis was carried out on the selected lake water for eight times in the whole study period. Physicochemical parameters analyzed were pH, total dissolved solids, electric conductivity, turbidity, alkalinity, hardness, calcium, magnesium, nitrate, phosphate, fluoride, sulphide, sulphate, chloride, sodium, potassium, tss, boron, chromium, lead, copper, iron, nickel and zinc (Table 1 and 2).

pH: Variation of pH was seen between 7.23 and 8.08 in Avalahalli lake in post monsoon months of 2017. But in most of the samples, pH was maintained at an average of 7.5. On an average, the pH was high in winter and pre monsoon (Table 1). Most of the studies reported higher pH was usually observed in post monsoon and winter in the first sampling period and in winter and pre monsoon in the second sampling period in most of the samples (Satyanarayana and Krishna 2017).

Total dissolved solids: TDS varied from 202ppm to 542ppm; in Avalahalli lake lowest in winter 2017 and highest in early summer of 2018 (Table 1). TDS was high in pre monsoon and monsoon and low in post monsoon and winter. Increase in monsoon was due to run off from the surrounding catchment, which was increased agricultural activities (Manohar et al 2017). Higher values were due to the decrease of water level and disturbances by various activities. Similar opinion was expressed by Veena et al (2020) on river Umschyripi at Shillong and by Kumar et al (2017) on surface water of Dehradun.

Electrical conductivity: The variation was observed between 500µs/cm and 1277µs/cm; lowest in Avalahalli lake in late winter 2017 and highest in early summer 2018 (Table 1). EC was low in first sampling year and high in second sampling year in monsoon season, due high variation in rainfall in these two sampling year. The water level of these lakes was very low in monsoon and gradually increased in post monsoon. The presence of ionic solids and minerals in water increases conductivity. EC of water is proportional to the amount of dissolved solids. Presence of dissolved salts due to poor irrigation system, leaching of salts or nutrients, agriculture runoff containing more chlorine, phosphate and nitrate, anthropogenic discharges and minerals from rain water may enhance conductivity (Manohar et al 2017). EC is affected by calcium, magnesium, ferrous or by anions and by the presence of inorganic dissolved solids like nitrate,

phosphate, sulphate and chlorine (Kumar et al 2017).

Turbidity: Turbidity varied from 0.2 to 4.8 NTU lowest in Avalahalli lake in early winter and it is highest in early summer. The turbidity was higher in post monsoon and winter in the first sampling period and in monsoon and pre monsoon in the second sampling period. Deforestation, poor agriculture practice and soil erosion contribute to increased turbidity (Table 1). Change in variation in the sampling year was seen because of drastic decrease in rainfall in the second sampling year (Ojok et al 2017). The oxidation of ferrous in its lower oxidation state was responsible for high turbidity (Khadse et al 2015). The presence of organic and inorganic particles like mud, clay, silt and aquatic organisms cause turbidity (Kjelland et al 2015).

Alkalinity: It is the sum of carbonates, bicarbonates, calcium, magnesium, hydroxides and other compounds in water and it make the water resistant to changes in pH. The values varied between 160 mg l^{-1} and 262 mg l^{-1} lowest was present in early winter and highest in early summer (Table 1). Similar observations were made by Satyanarayana and Krishna (2017). In pre monsoon, alkalinity increases with increased decomposition of human and animal excreta and indicate severity of pollution (Singh 2015, Ojok et al 2017). Increase in utilization of bicarbonates by phytoplankton and macrophytes decreases alkalinity (Naik et al 2015).

Hardness: Total hardness varied between 183.6 mg l^{-1} and 244.8 mg l^{-1}, fluctuation is observed in both the season due to various activities near by the lake. Hardness was high in pre monsoon and monsoon and low in winter and post monsoon (Table 1). The increase in hardness in summer was due high photosynthetic activity, utilization of free carbon and conversion of bicarbonates to carbonate which precipitate as Ca salts (Riddhi et al 2011). The overall range of hardness in sampling period was 108 mg l^{-1} to 635 mg l^{-1}. Hardness was usually higher in monsoon followed by pre monsoon in both the sampling year (Ojok et al 2017). Temporary hardness is due to carbonates and bicarbonates and permanent hardness is due to bivalent cations of sulphate and chlorides and it indicates the regional variation of hydrosphere (Naik et al 2015).

Calcium: Amount of calcium (Ca) in the sampling period varied from 106.08 to 199.92 mg l^{-1}; lowest in Avalahalli lake early summer of 2018 and highest in early winter of 2017 (Table 1). Similar observations were made by Saad et al (2017). Ca increases due to decomposition of organic matter, hydro-chemical process, dissolution of sedimentary rocks will increase and by anthropogenic activities and its utilization by aquatic organisms will decrease calcium content (Satyanarayana and Krishna 2017).

Magnesium: The value of magnesium (Mg) in the sampling period varied from 44.88 mg l^{-1} to 81.6 mg l^{-1} with fluctuation in all the season (Table 1). Many investigators have the opinion that calcium concentration is usually higher than magnesium (Kumar et al 2017). According to Bureau of Indian Standard (BIS) 30 mg l^{-1} to 100 mg l^{-1} is the acceptable limit and any excess in these indicate contamination and pollution (Satyanarayana and Krishna 2017).

Nitrate: Nitrate content varied from 0.135 mg l^{-1} to 0.175 mg l^{-1}, the nitrate content was high in pre monsoon and also summer season during study (Table 1). The nitrate concentration was below 10 mg l^{-1} and it is below permissible limit as per BIS (2012) in all the samples. Nitrate is also an essential nutrient for plants and plankton, which converts it into cell protein, but higher concentration, may be harmful (Divahar et al 2019). The concentration of nitrate was high during winter and pre monsoon in the first sampling period and the increase in dry seasons were attributed to domestic pollution (Ojok et al 2017). It was high in monsoon and pre monsoon in the second sampling period. Nitrate was below detectable level in post monsoon 2017 and in early summer 2018 throughout the second sampling period. Decrease in rainfall was one of the reasons behind the low concentrations of nitrate in different samples (Manohar et al 2017).

Phosphate: Phosphate content of water varied between 0.08 mg l^{-1} and 0.811 mg l^{-1} and found highly fluctuations in all the seasons (Table 1). Higher concentration of phosphate in monsoon season was due to inflow of rainwater (Vajravelu et al 2018). The aquatic systems whose terrains are made of agriculture and residential areas usually contain more phosphate in rain water runoff in the form of phosphate fertilizers, detergents, animal waste, septic tank effluent and industrial discharge (Manohar et al 2017). Increase in phytoplankton population shows more utilization of more phosphate and thus its concentration decreases. Phosphorus concentration of 0.03 mg l^{-1} is sufficient to cause algal bloom (Sheela et al 2011).

Fluoride: The natural sources of fluoride in water are apatite, fluorite, rock phosphate and topaz. It was found almost constant throughout the sampling period in almost all the samples and the value was around 0.907 mg l^{-1} to 1.061 mg l^{-1} and observed highest in the both the season (Table 1). Its concentration increases by the entry of industrial effluent and hazardous contaminants (Vinothkanna et al 2019). Fluoride content was comparatively higher in post monsoon and winter in the first sampling year. Fluoride is ubiquitous and is present in rocks, soil, water, plants and even air (Dehabandi et al 2017, Vinothkanna et al 2019).

Sulphide & Sulphate: The values of sulphide and sulphate varied between 0.325 mg l^{-1} to 0.71 mg l^{-1} and 0.042 mg l^{-1} to 0.341 mg l^{-1}; Sulphide content lowest was observed

Avalahalli lake in post monsoon and highest in pre monsoon 2018 and sulphate is fluctuation in both the seasons (Table 1). Sulphate was low in pre monsoon season. Increase in monsoon can be attributed to the surface runoff which contains organic fertilizers. Concentration of sulphate was higher in post monsoon and winter; lowest in monsoon during the first sampling period. Low concentrations sulphate in monsoon and high in winter season was recorded by Pawar (2010) which correlate with the present studies.

Chloride: Chloride (CL) content varied from 109.97 mg l^{-1} to 337.89 mg l^{-1} observed fluctuation in all the seasons (Table 1). This was due to the entry of surface runoff containing organic waste of animal origin and pesticides used for the horticulture plants (Manohar et al 2017). Indian Council of Medical Research (ICMR) and BIS have suggested 250 mg l^{-1} as the maximum permissible value. Similar findings by Singh (2015) have justified this study. Cl concentration mainly depends on climatic variations, domestic wastes, run off during monsoon, humidity and evaporation. Increased temperature and evaporation of water bodies may increase Cl content (Mohemed et al 2017).

Sodium: The sodium (Na) content varied from 18 mg l^{-1} to 26 mg l^{-1} (Table 1). The sodium values of Madivala and Begur lake at input and output are 303, 202 mg l^{-1} and 205, mg l^{-1} respectively (Balachandran et al 2012). Measure of chloride content helps in detecting sewage contamination. It occurs in natural water in different forms like sodium chloride, potassium chloride, magnesium chloride and calcium chloride (Nandal et al 2020).

Potassium: The potassium (K) content varied from 20 mg l^{-1} to 31 mg l^{-1} and observed fluctuation in all the seasons (Table 1). Potassium deficiency in plants causes abnormal plant growth. Based on the results of potassium water can be categorized under class "E". Presence of potassium in water is essential for plant nutrition in lower concentration. For good plant development it must be maintained in proper balance with other mineral requirement such as phosphorus. The potassium values of Madivala and Begur lake at input and output are 45, 59 mg l^{-1} and 52, 48.2 mg l^{-1} respectively (Balachandran et al 2012).

Total suspended solids: The wide variation between total suspended solids (TSS) concentrations for sampling site could be due to the presence of organic floatables observed during collection of the samples. The presence of these clumps of matter could significantly increase the TSS value for a sample in comparison to a similar sample without clumps. The overall range of TSS in sampling period was 0.12 mg l^{-1} to 1.2 mg l^{-1} and was high when compare to the permissible limit (Table 1). Nandal (2020), solids refer to the matter that is suspended or dissolved in the water or waste

Table 1. Physicochemical status of Avalahalli lake, Eastern Bengaluru, Karnataka, India

Months & Year	Physicochemical parameters																	
	Ph	TDS (ppm)	Conductivity (µs cm^{-1})	Turbidity (NTU)	Alkalinity (mg l^{-1})	Hardness (mg l^{-1})	Ca (mg l^{-1})	Mg (mg l^{-1})	Nit (mg l^{-1})	K (mg l^{-1})	F (mg l^{-1})	S^{2-} (mg l^{-1})	Cl- (mg l^{-1})	SO_4^{2-} (mg l^{-1})	Na (mg l^{-1})	P (mg l^{-1})	TSS (mg l^{-1})	B (mg l^{-1})
November 2017	7.72	202	500	0.2	160	191.76	138.72	53.04	0.159	0.08	1.046	0.5	109.97	0.042	20	31	0.4	0.29
December 2017	8.08	220	546	0.4	184	244.8	199.92	44.88	0.15	0.811	0.907	0.325	337.89	0.255	25	27	0.12	0.258
January 2018	7.66	302	757	2	416	224.4	142.8	81.6	0.135	0.513	1.079	0.63	215.93	0.15	18	25	1.2	0.21
February 2018	7.28	502	1186	3.8	262.23	183.6	106.08	77.52	0.175	0.769	0.917	0.53	Abs	0.341	26	20	0.26	0.251
March 2018	7.23	542	1277	4.8	175	204	126.48	77.52	0.141	0.289	1.061	0.71	124.6	0.161	23	27	0.44	0.229

water. The TSS, is a portion of total solids (TS) retained by a filter while the total dissolved solids (TDS) are the in filterable solids, mostly inorganic salts and small amount of organic matter dissolved in the water.

Boron: The boron concentration range from 0.21 to 0.258 mg l^{-1}, the concentration seen in all the months of 2 seasons were fluctuation in condition (Table 1). Concentrations of boron in groundwater throughout the world range widely, from <0.3 to >100 mg/l. High concentrations of boron can be found in many parts of the world, particularly in highly mineralized, naturally carbonated ground waters. Concentrations of boron in surface waters, except in areas of particularly high natural boron, are almost entirely less than about 0.5 mg/l (Parks and Edwards 2007).

Heavy metal analysis of Avalahalli lake by Atomic Absorption Spectroscopy (AAS)

Chromium: In water, chromium (Cr) ranged 0.57 – 4.07 ppm (2.13 ppm) exceeding the drinking water standards stipulated by BIS, EPA, and irrigation standards limit by Food and Agriculture Organization (FAO). Moreover, Cr exceeded tolerance limit for water bodies subject to pollution which is 2.0 ppm ((Nithya et al 2018). In water, the range of Cr in all the lake was shown 0.036 to 0.058 ppm and observed fluctuation in all the season (Table 10). The critical level range is between 5.00 ppm – 30.0 ppm. Onchoke and Sasu (2016) put the critical range between 20 – 100 ppm. This was below the probable effect level (PEL) of 90.0 ppm and under the background value of 32.0 ppm reported by Elias et al (2018).

Lead: The study area lead (Pb) range was 0.0005 – 0.4717 ppm (Table 2). Lead's concentration is very high in Feb 2018 in all the lakes compare to other months and very lowest in winter season 2017 in all the lakes. This range exceeded the drinking water standards and effluent discharge limits prescribed by Central Pollution Control Board (CPCB). Nevertheless, Pb has been known to accumulate in aquatic macrophytes in considerable levels based on the rooted and floating species. Critical range for Pb as described by Mohanakavitha et al (2019) is 30-300 ppm. However, Pb concentration in Vartur Lake exceeded the background value for uncontaminated sediments reported by Onchoke and Sasu (2016). Pb can exist in several valences and are of critical environmental importance. In urban areas, the principal source of Pb in wetlands comes from gasoline additives, metal plating, e-waste and battery cells, electrical equipment, textile mills, dye and pigments, paper mills, chemical and fertilizer industries, and ghee manufacturing industries (Jumbe and Nandini 2009).

Copper: The study area copper (Cu) in water was ranging between 0.0001 – 0.0848 ppm. Cu was within drinking water standards stipulated by ICMR and Environmental Protection Agency (EPA), but exceeded BIS limits of 0.05 ppm. The normal range of Cu in all the lakes shown in all the seasons was in the normal range should be 4 – 15 ppm (Jumbe and Nandini 2009). However, the mean exceeded the background value of 27.0 ppm reported by Mohanakavitha et al (2019). Cu reaches the aquatic environment through wet and dry depositions, mining activities and storm water run-offs, industrial, domestic, and agricultural waste disposal. Among industrial sources include copper plating, pulp and paper mills, e-waste, sewage and other forms of waste waters.

Table 2. Heavy metal status of Avalahalli lake, Eastern Bengaluru, Karnataka, India

Months & Year	Heavy metal parameters					
	Cr (ppm)	Pb (ppm)	Cu (ppm)	Fe (mg l^{-1})	Ni (ppm)	Zn (ppm)
November 2017	0.046	0.0005	0.0106	0.5565	-0.0598	0.1074
December 2017	0.049	0.0179	0.0034	0.3402	0.0178	0.0201
January 2018	0.058	0.0197	0.0026	0.5516	0.1598	0.1308
February 2018	0.036	0.4717	0.0848	0.3395	0.1332	0.1077
March 2018	0.043	0.0344	0.0001	0.4627	0.2756	0.0008

Iron: The iron (Fe) was usually below detectable level in most of the samples and in many seasons. The overall range of Fe in sampling period was 0.3395 mg L-1 to 0.5565 mg L-1 and was high when compare to the permissible limit. It was high in pre winter and it was low in summer in study lake (month wise) (Table 2). In monsoon, the concentration of Fe was more due to the heavy runoff of water into lakes. Similar variation of parameter was also observed by Mallampati and Osman (2015). Decomposition process is the source in dry seasons (Manohar et al 2017).

Nickel: The study area water, nickel (Ni) range was -0.0598 to 0. 2756 ppm and was highest in early summer months of 2018 in studied lake compare to winter season (Table 2). This was above drinking water standards stipulated for Ni. But the mean was within the tolerance limit for water bodies subjected to pollution discharge. Similarly, Ni has been found in a variety of plants and ranges up to 340 ppm have been recorded non-edible wild plants. The overall mean for Ni in macrophytes of Vartur lake was 47.91 ppm. The range was 26.0 – 65.32 ppm. This is in critical category of Ni contents in plants as described by Jumbe and Nandini (2009) which is between 10 – 50 ppm.

Zinc: The zinc (Zn) concentration in water ranged 0.0008 – 0.1308 ppm with mean Zn of 0.07336 ppm. This was within the stipulated drinking water standards by BIS, ICMR, EPA

and irrigation limits by FAO. This fluctuated range of Zn was seen in all the months of 2 seasons during the study (Table 2). Zn in urban lake water is caused by a variety of industrial effluents including phosphates fertilizers, ghee manufacturing, metal processing units, zinc plating ndustries, silver plating industries, distillery units, landfill leachates, urban storm water, fly ashes of coal powered plants, poultry sewage and compost (Elias et al 2018). In Bangalore lakes, the range for Zn was 42.93 ppm which was below the PEL limit reported by Jumbe and Nandini (2009).

CONCLUSIONS

The major source of pollution in the sampling lakes was the sewage and waste water from the village that entered the lakes without any prior treatment, agricultural runoff, washing and cleaning activities of people. The experimental data indicate that the lake is moderately polluted and certain precautionary and constructive steps may avoid further eutrophication of lakes. Some of the measures like maintaining grass buffer strip around the lake, remediation of sewage domestic waste and sedimentation of agricultural runoff to reduce the particulate matter before entering lake may reduce rate of pollution. The entry of pesticide containers, thinners, lubricants and direct flow of drainage from livestock facilities into lake should be restricted to reduce pollution. People should be educated regarding method of domestic water treatment, type of toilet facility and human waste disposal. This may contribute to decrease in the water pollution.

REFERENCES

American Public Health Association (APHA) 2012. American Water Works Association – Awwa; Water Pollution Control Federation - Wpcf. *Standard methods for the examination of water and waste water*. 22th ed. Washington DC.

Balachandran C, Dinakaran S, Alkananda B, Boominathan M and Ramachandra T 2012. Monitoring aquatic macroinvertebrates as indicators for assessing the health of lakes in Bangalore, Karnataka. *International Journal of Advanced Life Sciences* **5**(1): 19-33.

Beaty RD and Kerber JD 1993. *Concepts Instrumentation and Techniques in Atomic Absorption Spectrophotometry*. USA, Perkin Elmer Shelton CT, pp. 8-12.

Dehbandi R, Moore F, Keshavarzi B and Abbasnejad A 2017. Fluoride hydrogeochemistry and bioavailability in groundwater and soil of an endemic fluorosis belt, central Iran. *Environmental Earth Sciences* **76**: 177.

Divahar R, Aravind Raj PS, Sangeetha SP and Mohanakavitha T 2019. Impact of industrial wastewater disposal on surface water bodies in Kalingarayan canal, Erode district. *Indian Journal of Ecology* **46**(4): 823-827.

Elias MS, Ibrahim S, Samuding K, Rahman SA and Wo YM 2018. Assessment of toxic elements in sediments of Linggi River using NAA and ICP-MS techniques. *Methods X*. **5**: 454-465.

Jaishankar M, Tseten T, Anbalagan N, Mathew BB and Beeregowd KN 2014. Toxicity, mechanism and health effects of some heavy metals. *Interdisciplinary Toxicology* **7**: 60-72.

Jumbe AS and Nandini N 2009. Impact assessment of heavy metals pollution of Vartur lake, Bangalore. *Journal of Applied and Natural Science* **1**(1): 53-61.

Khadse GK, Patni PM and Labhasetwar PK 2015. Removal of iron and manganese from drinking water supply. *Sustainable Water Resources Management* **1**: 157-165.

Kjelland ME, Woodley CM, Swannack TM and Smith DL 2015. A review of the potential effects of suspended sediment on fishes: potential dredging-related physiological, behavioral, and transgenerational implications. *Environment Systems and Decisions* **35**: 334-350.

Kumar R, Chauhan A and Rawat L 2017. Physico-chemical analysis of surface and ground water in selected sites of Dehradun, Uttarakhand, India. *Journal of Environmental and Analytical Toxicology* **7**: 1-6.

Mallampati P and Osman MK 2015. CCME water quality index and assessment of physico-chemical parameters of lake Hawassa, Ethiopia. *International Journal of Recent Scientific Research* **6**: 7891-7894.

Manohar S, Mangoka JM, Ndunda E and Gathuru G 2017. Assessment of Yatta canal water quality for irrigation, Machakoscounty, Kenya. *Journal of Environmental and Analytical Toxicology* **7**: 2-6.

Mohamed A, Leducb C, Marlinc C, Waguéd O and Cheik MS 2017. Impacts of climate change and anthropization on groundwater resources in the Nouakchott urban area (coastal Mauritania). *Comptes Rendus Geoscience* **349(**6–7): 280-289.

Mohanakavitha T, Divahar R, Meenambal T and Siraj KT 2019. Assessment of water quality of surface water in Kalingarayan canal for heavy metal pollution, Tamil Nadu. *Indian Journal of Ecology* **46**(1): 49-54.

Naik G, Rashid M and Balkhi MH 2015. Changes in physico-chemical parameters at different sites of Manasbal lake of Kashmir, India. *Fishery and Aquaculture Journal* **6**: 1-4.

Nandal A, Kaushik N, Yadav SS, Rao AS, Singh N and Gulia SS 2020. Water quality assessment of pond water of Kalanaur Block, Rohtak, Haryana. *Indian Journal of Ecology* **47**(1): 1-6.

Nithya SE, Mohamed AS and Viji R 2018. Removal of chromium (VI) from aqueous solution using *Azolla caroliniana* as adsorbent. *Indian Journal of Ecology* **45**(2): 388-392.

Onchoke KK and Sasu SA 2016. Determination of hexavalent chromium (Cr(VI)) concentrations via ion chromatography and UV-Vis spectrophotometry in samples collected from nacogdoches wastewater treatment plant, East Texas (USA). *Advances in Environmental Chemistry* **2016:** Article ID 3468635.

Parks JL and Edwards M 2005. Boron in the environment. *Critical Reviews in Environmental Science and Technology* **35**(2): 81-114.

Paul BT, Clement GY, Patlolla AK and Sutton DJ 2012. Heavy metals toxicity and the environment. *Esperentia Supplementum* **101**: 133-164.

Pawar AL 2010. Seasonal variations in physico-chemical quality of Lonar Lake water. *Journal of Chemical and Pharmaceutical Research* **2**: 225-231.

Riddhi S, Vipul S, Madhu Sudan S, Kumar VB, Rachana M and Singh GK 2011. Studies on limnological characteristic, planktonic diversity and fishes (species) in lake Pichhola, Udaipur, Rajasthan (India). *University Journal of Environmental Research and Technology* **1**: 274-285.

Saad AS, Massoud MA, Amer RA and Ghorab MA 2017. Assessment of the physico-chemical characteristics and water quality analysis of Mariout lake, southern of Alexandria, Egypt. *Journal of Environmental and Analytical Toxicology* **7**: 1-19.

Satyanarayana JE and Krishna PV 2017. Assessment of water quality in terms of physico - chemical parameters of east Godavari mangrove ecosystem (Coringa wildlife sanctuary), East Godavari, Andhra Pradesh, India. *International Journal of*

Advanced Research **5**: 782-788.

Sharma B, Singh S and Siddiqi NJ 2014. Biomedical implications of heavy metals induced imbalances in redox systems. BioMed Research International **2014:** Article ID 640754, 26 pages.

Sheela AM, Letha J and Joseph S 2011. Environmental status of a tropical lake system. *Environmental and Monitoring Assessment* **180**: 427-449.

Vajravelu M, Martin Y, Ayyappan S and Mayakrishnan M 2018. Seasonal influence of physico-chemical parameters on phytoplankton diversity, community structure and abundance at Parangipettai coastal waters, Bay of Bengal, South East Coast of India. *Oceanologia* **60**(2): 114-127.

Veena DV, Jayalatha NA and Adi VK 2020. Water quality index of Bangalore's Bhattrahalli lake 2020. *World Journal of Pharmacy and Pharmaceutical Sciences* **5**(2): 491-506.

Vinothkanna S, Rajee R and Senthilraja K. Assessing fluoride intensity of ground water in Dindigul district, Tamil Nadu. *Indian Journal of Ecology* **46**(2): 277-282.

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Pre-Impoundment Study of Diatom and Benthic Macroinvertebrate Community in a Lesser Himalayan River, The Tons

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Abstract: A pre-impoundment study was designed in lesser Himalayan river. The taxonomic composition and abundance of diatom and benthic macroinvertebrate community was determined at three locations; S1 (upstream of proposed dam site), S2 (proposed dam site) and S3 (downstream of proposed dam site). The study was conducted between April to June 2014. The density of diatom community decreased from S1 to S2 and increased at S3, however, benthic invertebrate density increased from S1 to S2 but decreased at S3. The abundance of diatom taxa varied at S1 (*Diatoma mesodon - Achnanthidium biasolettianum* var. *biasolettianum*, *Diatoma vulgare* var. *producta*), S2 (*Achnanthidium biasolettianum* var. *biasolettianum*, *Diatoma mesodon*, *Achnanthidium minutissimum* var. *minutissimum*, *Encyonema minutum*) and S3 (*Diatoma mesodon*, *Cocconeis placentula*, *Diatoma vulgare* var. *producta*, *Achnanthidium minutissimum* var. *minutissimum*). Among the benthic macroinvertebrate community, may fly (Ephemeroptera) was highest taxon rich order followed by the caddis fly (Trichoptera), two wing fly (Diptera) and stone fly (Plecoptera). Total 10 families were recorded and Hydropsychidae was most abundant among all of them. The higher abundance and presence of mainly pollution intolerant taxa suggest that the river is unpolluted and healthy at present.

Keywords: Benthic macroinvertebrate, *Diatoma mesodon,* Himalaya, Hydropsychidae, Hydroelectric project, Ecosystem health

The streams transport various ions, sediments and organic debris to the larger rivers. Stream regulation by damming of rivers and ensuing impoundment are one of the most frequent causes of depletion in the biological diversity of aquatic ecosystems resulting in interference with the natural process of dispersal. The physical and chemical characteristics of streams state the quality and diversity of aquatic communities. Among aquatic communities, diatom and benthic macroinvertebrate have great ecological significance as the farmer is known for primary producer while later as primary consumer. They are also evident as best biological indicator for river ecosystem health and management (Jiang et al 2011, Mishra and Nautiyal 2013a, Mishra and Nautiyal 2017).

There was a sharp increase in the hydro-electricity generation activity on Himalayan rivers in India during the 1980s, which continues to the present, because these rivers constitute a vast hydrological estate with great potential for power generation. It is therefore extremely important to conduct detailed analyses of the physical and chemical characteristics along with biotic communities of a river prior to impoundment. However, in Indian waters, few scientific studies are available on the aquatic biodiversity information of some rivers before impoundment or stream regulation (Bhatt et al 2005). In view of this, a pre –impoundment study was performed in a Himalayan river, the Tons, which has proposed a capacity of 72 MW Hydroelectric Project. The density, taxonomic composition and abundance of diatom flora (producer) and benthic macroinvertebrate fauna (primary consumer) will be determined to assess river health before impoundment. Since these communities are widely used for river bio-monitoring and ecosystem health assessment, therefore the present study will be a reference for future during river ecosystem health assessment after the impoundment.

Study Area

The river Tons is a glacier fed largest tributary of the Yamuna and flows through Garhwal region in Uttarakhand, touching Himachal Pradesh. The Tons rivers flows in the valley named as Tons valley which lies in Jaunsar Bawar region, as it emerges from the Himalayas with Dehradun on its eastern bank. The cantonment town of Chakrata is situated between, the Tons and Yamuna rivers. It is one of the most major perennial Indian Himalayan glacier fed river, arises from Bandarpunch mountain at an elevation of 6,315 m asl height and drain in to the Yamuna river below Kalsi near Dehradun, Uttarakhand. The Uttarakhand Project Development and Construction Corporation Ltd. (UPDCC) has proposed a capacity of 72 MW Hydroelectric Project at Tiuni -Plasu on river Tons, district Dehradun (Fig. 1).

Station 1 (S1): It was located on the Tons river 500 m U/S (up stream) from the confluence with Pabbar river. The

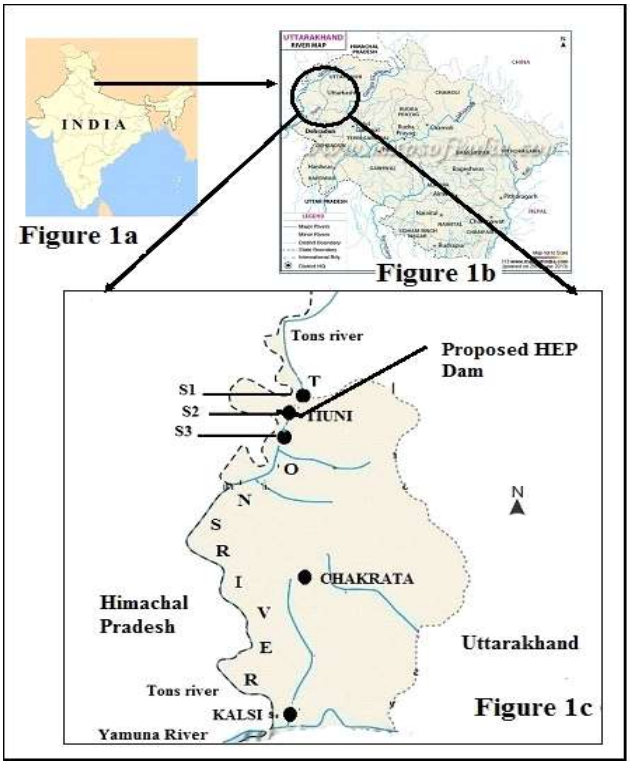

Fig. 1. a-c Geographical location of Uttarakhand state in the India and Tons river in the Uttarakhand. The sampling locations on the river Tons with respect to dam site S1, S2, & S3

agriculture as well as horticulture practices were present at both banks of the river along with forest. Rapids were major habitat present inside the river along with few short riffle and runs. Predominance of rock was found inside and outside of the river water channel and the substrate composition; rock - boulder-cobble -gravel.

Station 2 (S2): This station was proposed Dam site and located on main stream just after 500 m D/S (down stream) from the confluence with Pabbar river. Dense forest with overhanging vegetation was present at both banks of the river. Rapids were major habitat present inside the river. The dominant substratum was rock inside and outside of the river water channel and the substrate composition; rock– boulder - cobble -gravel.

Station 3 (S3): This was Power House location. Both sides of the river banks were invaded with forest along with human habitation villages. Rapid and riffle were major habitat present inside the river. Predominance of rock was found inside and outside of the river and the substrate composition; Rock -Boulder –cobble –gravel –sand.

Sampling

The physico-chemical and biological samples (diatom and benthic macroinvertebrate) were collected during April 2014 to June 2014 (every month). The sampling and analysis of physical and chemical characteristics were carried out according to standard methods for the examination of water and wastewater (APHA 1992). The water temperature (WT; Mextech, multi meter), current velocity (CV - EMCON current meter), pH (Hanna portable digital meters) and conductivity (LABTRONICS model – LT23) were determined with standard digital instruments. However, transparency was calculated by Secchi disk. The chemical parameters like dissolved oxygen, total alkalinity, total hardness, chloride and phosphate were determined by titration methods.

The diatom community was sampled by scraping 3 x 3 cm surface area of submerged cobble/rock/boulder/ plant/algal substrate. The acid–peroxide treated samples were used to prepare permanent diatom mounts in Naphrax that were later examined under brightfield using a BX-40 Trinocular Olympus microscope (×10 and ×15 wide field eyepiece) fitted with a PLANAPO ×100 oil immersion objective used to enumerate diatom valves using standard literatures (Krammer 2003). The benthic macroinvertebrate samples were collected by lifting of small boulders, cobbles and pebbles from the marked area (1 ft^2) and washing in a bucket full of water by dipping number of times to dislodge the attached fauna. The soft substratum in the form of clay -silt was sampled with Ekmann dredge and was sieved to obtain the fauna. The samples were preserved in 5% formalin for laboratory analysis. Standard literatures were used to identify benthic macroinvertebrate fauna (Mishra and Nautiyal 2017).

RESULTS AND DISCUSSION

The water temperature (WT) ranged between 14.0 ^{O}C to 18.0 ^{O}C in the Tons river. W T regime was increased by 4^{o}C during sampling period. The current velocity (CV) ranged between 1.6 to 1.9 ms^{-1}, while dissolved oxygen (DO) ranged from 9.6 to10.8 mgl^{-1}. The other parameters like transparency, (0.2-0.5 m), pH (7.31-7.68), conductivity (95-120µC), hardness (48-55 mgl^{-1}), alkalinity (41-49 mgl^{-1}), chloride (30-32 mgl^{-1}) and phosphate (0.001-0.002 mgl^{-1}) also varied among the stations (Table 1). The WT increased and DO decreased from S1 to S3. Generally, the Himalayan rivers start flooding since the end of April of every year. The snow melting affects river characteristics by decreasing the transparency and increasing alkalinity, hardness and current velocity. These helps in the hydrolysis of dissolved solids, salts of bicarbonates and carbonates, and develop hydroxyl ions, resulting increase of pH.

Diatom community: The total density decreased downstream from S1 to S2 (S1 456 cells mm^{-2} to S2 345 cells mm^{-2}) and increased to S3 (512 cells mm^{-2}) in the Tons river. Nautiyal (2001) also observed low density in the glacier fed

streams (<1000 cellsmm^{-2}) compared with spring fed (1000–3000 cells mm^{-2}). Total 28 diatom taxa were reported from the river Tons. Longitudinal distribution of taxa indicated that 21 diatom taxa were common among all the stations, while four taxa (*Cymbella tumida, Encyonopsis leei, Gomphonema clevei, Gomphonema minutum*) were restricted at S2 and S3 and two taxa (*Fragilaria arcus* var. *recta, Planothidium lanceolatum var. lanceolatum*) at S1 and S2. *Diatoma vulgare* var. *producta* was only taxa restricted at S1 and S3 (Table 2). *Diatoma mesodon* (DM), *Achnanthidium biasolettianum* var. *biasolettianum* (ABB) and *Diatoma vulgare* var. *producta* (DVP) were abundant taxa at S1, while ABB, DM, *Achnanthidium minutissimum* var. *minutissimum* ((AMM) and *Encyonema minutum* (EM) were abundant at S2. The taxa like DM, *Cocconeis placentula* (CP), DVP and AMM were abundant taxa at S3 (Table 3). The abundance of these species indicated that the water quality of the river is good (unpolluted). The abundance of ABB, AMM and EM gradually decreased from S1 to S3 with the decline of DO, CV and WT (Fig. 2). However, the abundance of DVP and CP increased from S2 to S3 with increase of pH, conductivity, hardness and alkalinity (Fig. 3). Bhatt et al (2005) also indicated that *A. minutissima*, *A. minutissima* var. *cryptocephala*, *A. microcephala*, *C. cymbiformis* and *C. microcephala* are the clean water species. Nautiyal (2005) reported that the species-rich genera differ in the upper mountain zone (*Navicula – Achnanthidium*), lower mountain zone (*Cymbella – Navicula*) and plain zone (*Navicula-Cymbella – Nitzschia*) compared with *Achnanthidium – Cymbella* in Alaknanda.

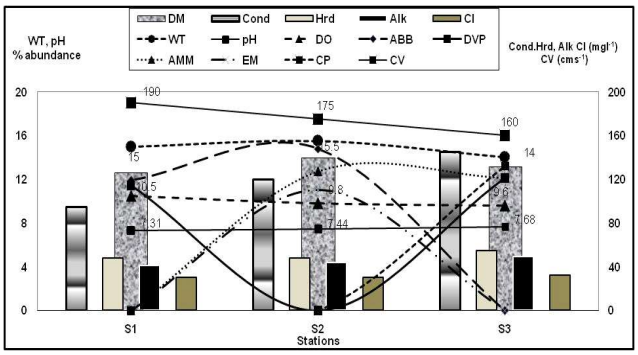

Fig. 2. Relation between abundant Diatom community with physico-chemical characteristics. Acronyms: ABB-*Achnanthidium biasolettianum* var. *biasolettianum,* AMM-*Achnanthidium minutissimum* var. *minutissimum,* DM-*Diatoma mesodon,* DVP- *Diatoma vulgare* var. *producta,* CP- *Cocconeis placentula*, EM-*Encyonema minutum,* Cond.- Conductivity, Hrd-Hardness, WT- Water Temperature, Cl- Chloride, Alk-Alkalinity, DO- Dissolved oxygen, CV-Current velocity

Table 1. Geographical position and physico-chemical characteristics of the river Tons at various stations on the river Tons

Parameters	S1 (500 m U/S from Pabbar R. confluence)	S2 (Dam Site: 500 m D/s Pabbar R. confluence)	S3 (Power House Site)
Latitude (°N)	30°57'06.16"	30°57'15.60"	30°56'17.23"
Longitude (E)	77°51'15.61"	77°51'16.64"	77°50'44.83"
Altitude (m)	945	937	902
Landuse	Forest along with Agriculture patch	Forest Canopy	Village
Habitat type	Rapids, Runs	Rapids	Rapid, Riffle
Substrate composition (%)	Rock – Boulder-cobble-gravel: 60-20-10-10	Rock – Boulder-cobble-gravel:50-25-15-10	Rock -Boulder -cobble-gravel-sand:55-15-10-10-10
RD (m)	60 (approx.)	50 (approx.)	60 (approx.)
WT (°C)	14.0	15.5	15.0
CV(ms^{-1})	1.90	1.75	1.60
pH	7.31	7.44	7.68
DO (mg l^{-1})	10.5	9.8	9.6
Cond. (µC)	95	120	145
T (m)	0.2	0.5	0.5
Hrd. (mg l^{-1})	48	48	55
Alk (mg l^{-1})	41	44	49
Cl (mg l^{-1})	30	30	32
P (mg l^{-1})	0.001	0.001	0.002

Acronyms: Alk- Alkalinity, Cond.- Conductivity, Cl- Chloride, CV- Current Velocity, DO- Dissolved oxygen, Hrd.- Hardness, P Phosphate, RD- River Depth, T-Transparency, WT- Water Temperature

Table 2. Distribution of diatom and benthic macroinvertebrate taxa various stations in the Tons river

Taxa	S1	S2	S3
Diatom			
Achnanthidium biasolettianum var. biasolettianum	+	+	+
A. minutissimum var. minutissimum	+	+	+
Cocconeis placentula	+	+	+
Cymbella kolbei	+	+	+
C. levis	+	+	+
C. tumida		+	+
Diatoma mesodon	+	+	+
Diatoma vulgare var. producta	+		+
Encyonema silesiacum	+	+	+
E. minutum	+	+	+
Encyonopsis leei		+	+
Fragilaria arcus	+	+	+
F. capucina	+	+	+
F. rumpens	+	+	+
F. arcus var. *recta*	+	+	
Gesslaria decussis	+	+	+
Gomphonema parvulum	+	+	+
G. clevei		+	+
G. minutum		+	+
Luticola mutica	+	+	+
Navicula caterva	+	+	+
N. cryptocephala	+	+	+
N. radiosafallax	+	+	+
Nitzschia capitellata	+	+	+
N. palea	+	+	+
Planothidium lanceolatum	+	+	
Reimeria sinuata	+	+	+
Synedra ulna	+	+	+
Benthic Macroinvertebrate			
Baetidae	+		+
Heptageniidae	+	+	+
Siphlonuridae	+	+	
Hydropsychidae	+	+	+
Limnephilidae	+		
Chironomidae	+		+
Caenidae	+		
Psephenidae	+		
Perlidae	+	+	
Brachycentridae		+	

Table 3. Diatom and benthic macroinvertebrate abundance (>10%) at various stations in the Tons rivers

Taxa	S1	S2	S3
Diatom			
Achnanthidium biasolettianum var. biasolettianum	11.9	14.8	0
A. minutissimum var. minutissimum	0	12.7	12.1
Diatoma vulgare	11.4	0	12.1
Cocconeis placentula	0	0	13.2
Diatoma mesodon	12.6	14	13.2
Encyonema minutum	0	11	0
Benthic Macroinvertebrate			
Baetidae	3	0	27
Heptageniidae	7	33	23
Siphlonuridae	7	17	0
Hydropsychidae	30	33	36
Limnephilidae	13	0	0
Chironomidae	23	0	14

Benthic macroinvertebrate community: The benthic macroinvertebrate density increased from S1 to S2 and decreased at S3 (Table 1). The density declined at S3 was attributed to anthropogenic presence of village landuse and activities as agriculture and bathing. The impact of anthropogenic activities on benthic macroinvertebrate community was also evident in central Indian rivers (Mishra and Nautiyal, 2013b). Total 10 families of benthic macroinvertebrate belonging to phylum Arthropods, class Insect and 5 orders; Ephemeroptera (4), Trichoptera (3), Diptera (1), Plecoptera (1) and Coleoptera (1) were recorded. Among these, Ephemeroptera was higher taxonomic rich order followed by Trichoptera. Nautiyal *et al* (2015) observed Trichoptera as highest taxonomic rich order in the streams of Mandakini basin. Similarly, Trichoptera was also dominant order in the headwater zone of a central highlands river Paisuni (Mishra and Nautiyal,(2011). However, in the Ganga river, twenty families were reported between Devprayag (9 families) to Rishikesh (17 families) belonging 8 orders (Joshi, 2005).

Longitudinally, Heptageniidae and Hydropsychidae were common at all the stations, while Caenidae, Limnephilidae and Psephenidae were restricted at S1 only. The taxa Siphlonuridae and Perlidae were common at stations S1 and S2, while Baetidae and Chironomidae at S1 and S3 only. The Brachycentridae was only taxon restricted at S2 (Table 2). Hydropsychidae was most abundant taxon at S1 (30%) and S3 (36%) while Heptageniidae and Hydropsychidae were equally abundant taxa (33%) at S2 (Table 3). The assemblage forming taxa varied at S1 (Hydropsychidae - Chironomidae - Limnephilidae), S2

(Hydropsychidae - Heptageniidae) and S3 (Hydropsychidae – Baetidae - Heptageniidae - Chironomidae) in the Tons river. The abundance of Baetidae and Hydropsychidae declined relation increase of water temperature, dissolved oxygen and current velocity from. However, slight increase in pH, conductivity, alkalinity and hardness supported increase in the abundance of Heptageniidae, Chironomidae and Siphlonuridae (Fig. 3). The pollution intolerant taxa such as stone fly (Perlidae), caddis fly (Hydropsychidae, Brachycentridae and Limnephilidae) and may fly (Baetidae, Heptageniidae, Caenidae, Siphlonuridae) constitute about 69% of the total density of benthic macroinvertebrate community. The pollution tolerant taxon Chironomidae represented 23% share of the total density of benthic macroinvertebrate at S1. However, at S2 only pollution intolerant taxa were found, because of canopy cover of forest landuse stop the entry of pollutant in the river water. Sudden increase from 0 to 14% of Chironomidae indicated the presence of village land use at S3, which was responsible to increase of the pollution tolerant macroinvertebrate. Bhatt *et al.,* (2005) indicated that pollution tolerant macroinvertebrate taxa was found both in unpolluted and polluted waters of major Himalayan rivers.

Analysis of various physical, chemical and biological parameters indicated that Tons river is a non-polluted and have healthy freshwater ecosystem. However, the proposed river regulation is likely to bring about changes in the physical and chemical characteristics of water, which would consequently affect the composition, density and diversity of diatom and benthic macroinvertebrate communities. In the Tons river, more than 4 km stretch downstream of the proposed dam site, may affect diatom and benthic macroinvertebrate communities adversely. The dryness of downstream stretch of dam site will lead to minimize the river depth and in this stretch temperature may increase, if it happens the level of dissolved oxygen decline to less than 6 mg l^{-1}. The level of dissolved oxygen affect to aquatic biotic communities (Banerjee *et al.,* 2018). These adverse effects can be prevented by providing minimum discharge to maintain environmental flow in the river especially in the lean season. In the upstream at proposed dam site, the various kinds of human activities along the river continuum will increase the nutrients level in the reservoir and may cause eutrophication. Bhatt *et al.,* (2005) stated that the process of eutrophication disturb the ratio of carbonate-bicarbonate and also concentration of CO_2. It would result in decline of the mean pH values of the water, consequently affect the density and diversity of the benthic communities. The stringent measures should be implemented so that solid and/or liquid waste flow into the reservoir is checked.

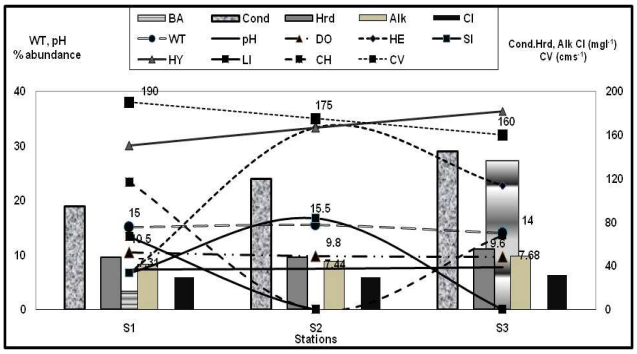

Fig. 3. Relation between abundant benthic macroinvertebrate taxa with physico-chemical characteristics. Acronyms: BA-Baetidae, CH- Chironomidae, HE-Heptageniidae, HY- Hydropsychidae, LI-Limnephilidae, SI- Siphlonuridae. Rest acronyms are similar as Figure 2

CONCLUSION

In the present study, the abundance of intolerant taxa indicated about good quality of river health. However, during and after the construction of Hydroelectric dam, the water quality of the river will change as reservoir develop in upstream of the dam. Therefore, it is necessary to prepare artificial circulation applied to eutrophic impoundment for improving the water quality of the reservoir and tail water and it will help to maintain river health.

REFERENCES

APHA (American Public Health Association) 1992. *Standard Methods for the Examination of Water and Wastewater.* New York: APHA, Water Work Association, Water environmental Federation, Washington, DC, p 1504.

Bhatt J P, Bhaskar A and Pandit M K 2005. Biotic communities of Kishanganga river: A pre-impoundment case study of a Himalayan river. *Aquatic Ecosystem Health and Management* **8**(3): 259-265

Banerjeea A, Chakrabartyb M, Rakshita N, Bhowmickc AR and Ray S 2018. Environmental factors as indicators of dissolved oxygen concentration and zooplankton abundance: Deep learning versus traditional regression approach. *Ecological Indicators* https://doi.org/10.1016/j.ecolind.2018.09.051

Krammer K 2003. Diatom of Europe. Lange-Bertalot H (Ed.), Diatom of European inland waters and comparable habitats, the genus *Cymbopleura, Delicata, Navicymbula, Gomphocymbellopsis* and *Afrocymbella*, 164 pl. Vol. 3, 530p. A R G Gantner, Verlag K G, FAL94191 Ruggell Distributed by Koeltz Scientific Books, Koenigstein.

Jiang X, Xiong J, Xie Z and Chen Y 2011. Longitudinal patterns of macroinvertebratefunctional feeding groups in a Chinese river system: A test for river continuum concept (RCC). *Quaternary International* **244**: 289-295

Joshi BD 2005. Studies on the ecobiology of tributaries of river Ganga between Devprayag and Rishikesh,pp 19–35. In: P Nautiyal, JP, Bhatt, OP Gusain, AK Dobriyal (Eds), *Biological Diversity in Freshwater Environments*. Transmedia, Srinagar-Garhwal.

Mishra AS and Nautiyal P 2011. Factors governing longitudinal

variation in benthic macroinvertebrate fauna of a small Vindhyan River in central highlands Eco region (central India). *Tropical Ecology* **52**(1): 103–112.

Mishra AS and Nautiyal P 2013a. Functional composition of benthic macroinvertebrate fauna in the plateau rivers, Bundelkhand, central India. *Journal of Threatened Taxa* **5**(13): 4752-4758.

Mishra AS and Nautiyal P 2013b**.** Longitudinal distribution of benthic macroinvertebrate assemblages in a central highlands river, the Tons (central India). *Proceedings of National Academy of Science, India, Section B Biological Science* **83**(1): 47–51.

Mishra AS and Nautiyal P 2017. Canonical correspondence analysis for determining distributional patterns of benthic macroinvertebrate fauna in the lotic ecosystem. *Indian Journal of Ecology* **44**(4): 697-705.

Nautiyal P 2001. Ecology of mountain streams and rivers in Garhwal Himalaya, pp 393-417. **In:** A. Kumar (Ed.), *Ecology and conservation of lakes, reservoirs and rivers*. A.B.D. Publishers Jaipur.

Nautiyal R 2005. Altitudinal variations in the community structure of benthic diatoms in a mountain river the Alaknanda, pp. 224–241. **In:** P Nautiyal, J P Bhatt, O P Gusain, AK Dobriyal (eds), *Biological diversity of freshwater environments as proceedings of the national symposium on aquatic biodiversity and emerging trend in freshwater biology*, Transmedia, Srinagar-Garhwal.

Nautiyal P Mishra AS and Semwal VP 2015. Spatial distribution of benthic macroinvertebrate fauna in mountain streams of Uttarakhand**,** India, pp. 31–51. **In:** M Rawat, Dookia S, C. Sivaperuman (Eds.), *Aquatic Ecosystem: Biodiversity, Ecology and Conservation*, Springer. https://doi.org/10.1007/978-81-322-2178- 4_4

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Microplastics Distribution in Freshwater Lake and Drinking Water Treatment Plant: A Case Study

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Abstract:At present freshwater bodies including lakes are highly polluted with various pollutants. A study was conducted to investigate the presence of microplastics in a fresh water lake which is the drinking water source for Chennai city, Tamil Nadu India. Water samples were collected during the pre-monsoon period (October 2019) from the lake (Puzhal Lake), the inlet and outlet of the drinking water treatment plant and analysed for the presence of microplastics (MPs). The surface water collected from the lake harbored 3 to 4 microplastics litre^{-1} of water. The samples collected from inlet and outlet of the treatment plant also had 3 to 4 microplastics/liter of water. Most of the MPs were in the form of fibers (76%) and the MPs detected were red, green, black, blue and white in colour.

Keywords: Microplastics, Freshwater lake, Inlet and outlet, Drinking water treatment plant

Microplastics are synthetic pollutants having the specific characteristics such as solid polymer particles and insoluble in water. Based on the size of the particles they are grouped into microplastics (≤5mm) and nanoparticles(<1µm) (Koelmans et al 2015). The source of microplastics in the environment is attributed to the direct introduction with runoff and breakdown of meso and macroplastics due to weathering (Andrady 2015). Further the micro and nanoplastics used in the manufacture of consumer products especially used as exfoliants (Fendall and Sewell 2009) in cosmetic formulations are introduced into the lakes through runoff (Maynard 2006).

Now a days so many studies have been conducted to establish the presence of microplastics in air, water and soil (Wright and Kelly 2017, Schymanski et al 2018, Long et al 2019). Globally, limited studies have been conducted to investigate the presence of microplastics in freshwater systems (Cable et al 2017) such as North Americn Seine River in Europe (Dris et al 2015), Thames River (Horton et al 2017) and Italian lakes (Fischer et al 2016). The outcome of few studies revealed the presence of microplastics in freshwater and drinking water treatment plants (Novotna et al 2019). Annual plastic waste produced by India is 5.6 million tons (Toxics link, 2014) and disposed into landfills and environment. The plastics in soil undergo physical, chemical and biological actions such as weathering and erosion (Gewert et al 2015), oxidative degradation under ultraviolet irradiation (Ivar do Sul and Costa, 2014), crop cultivation (Rilling et al 2017) and decomposition by insects and microorganisms and converted into smaller particles. Further the plastic accumulated in the soil through littering is ending into the nearby water bodies such as lakes, rivers and oceans by surface runoff (Blasing and Amelung 2018). The drinking water source for most of the city dwellers is lakes and from there the water is being treated in drinking water treatment plants prior supply to the individuals. Microplstics were detected in raw water samples collected from selected drinking water treatment plants (Pivokonsky et al 2018). Further, it was investigated that >4000 items were present in a litre of water collected from a drinking water treatment plant. MPs are present abundantly in lakes, rivers and dams' water worldwide (Triebskorn et al 2019). In India a study conducted in Vembanad estuary revealed the presence of microplastics in water and sediment samples (Sruthy and Ramasamy 2016). The study was carried out to investigate the occurrence of microplastics in water samples in water treatment plants before and after treatment and in the water collected from households.

MATERIALS AND METHODS

Collection of water samples: Initially water samples were collected from Puzhal lake, located 23kilometers from centre of Chennai city, India (13°11'1.596"N, 80°11'26.22"E). This lake is one of the two rain-fed (17mm) reservoirs from which water is being withdrawn to satisfy the need of the dwellers of Chennai city. The samples were collected from Puzhal Lake during October, 2019. About 20 litres os surface water samples were collected from 2 sites of the lake at one hour interval using Neuston net. Likewise, samples were collected from the inlet and outlet of the water treatment plant where

the water is being treated. The samples were collected in glass bottles, labeled and stored at 4°C for further analysis.

Extraction of microplastics from water sample: The extraction of microplastics from the collected samples was done as per the method of National Oceanic and Atmospheric Administration (NOAA) protocol (Masura et al 2015). The water was passed through a sieve stacked arrangement of 5.6mm and 0. 3mm stainless steel mesh sieve to isolate the solid materials. After that the sieved materials were dried and subjected to wet peroxide oxidation (WPO) in the presence of Fe (II) to digest the labile organic matter. In order to isolate the microplastics the unaltered plastic debris were added with 5M NaCl (d = 1.3 g ml^{-1}) (Galgani et al 2015) through floatation. The floating solids (plastic debris) were separated using 0. 3mm filter, air dried.

Visualization and characterization: The plastic was transferred carefully to a glass slide using fine – tip tweezers and observed under Stereo microscope (40 x) (Accu Scope, Thomas Scientfic Inc.).

RESULTS AND DISCUSSION

Microplastics in Puzhal Lake: The number of MPs detected was 4 $litre^{-1}$ of water. Since the sampling was done at the surface during pre - monsoon season the possibility of distribution of microplastics in the surface was less and it might be settled down. However study indicate that the clear surface water also harbored microplastics and leading to the conclusion that the microplastics are distributed in Puzhal Lake. The microplastics detected in the water samples collected from the inlet of the treatment plant ranged from 3 to 4 particles $litre^{-1}$ of water (Table 1). The samples collected inlet and the outlet of the treatment plant were having the MPs in red, green, blue, black and white colours (Fig. 1 and 2). In these samples also fibres (76%) were predominant and pellets and beads were found to be in less number (Table 2).

The reason behind the accumulation of microplastics in the aquatic environments such as lakes, rivers, estuaries and marine is the huge usage of the plastic products and poor waste disposal (Li et al 2018). In Tamil Nadu, Chembarambakkam Lake harbored 9 microplastic $particles litre^{-1}$(Monisha et al 2019). The major source of the MPs in water bodies are littering and dumping of household and industrial wastes (Sathish et al 2019). The MPs in freshwater systems are in the range of 10 to 4000 particles $litre^{-1}$ of water (Mintering et al 2019). The huge difference in microplastics content is attributed to the spatial variation and

Table 1. Microplastics distribution in the water samples collected from the inlet of Water treatment plant

Sample identification	Plastics classification based on colour					Plastic classification based on forms		
	Red	Green	Blue	Black	White	Fibre	Pellet	Bead
1		1	3		2	4		2
2	1		2	1	1	3		2
3			1	1	1	3		
4	2	1		2	1	4	1	1
5				2		2		
6	1	2		2		4		1
7	1		1			2		
8	2		1	1		3		1

The colour of the MPs identified was in red, green, blue, black and white and most of the MPs were in the form of threads and others were in the form of beads and pellets

Table 2. Microplastics distribution from the outlet sample of water treatment plant

Sample identification	Plastics classification based on colour					Plastic classification based on forms		
	Red	Green	Blue	Black	White	Fibre	Pellet	Bead
1		1	1		1	3		
2		1			3	1		3
3		2	1	2	1	5		1
4	1	1		2		2	1	1
5				2		2		
6	1					1		
7	1			2		3		
8	1			1		2		

sampling location, the dissimilarities in sampling and analytical methods followed (Silva et al 2018).

Further, MPs were detected in samples collected from inlet and outlet of the drinking water treatment plant. There is no legislative limit for MPs contents in drinking water so far and no treatment method is targeted to remove the MPs in the drinking water treatment plants (Pivokonsky et al 2018). However, a part of MPs are removed by conventional treatment methods in the treatment plants (Novotna et al 2019). The reason might be due to the lack of knowledge about the properties of microplastics in water (Ogonowski et al 2018).Further, no technological improvements or modifications in water treatment plants are done until to reduce the micro and nano plastic particles from water (Shen et al 2020). The MPs in the form of fibers were detected in the analyzed water samples. The Stereo Micrograph of the MPs extracted from the samples is shown in Figure 3.

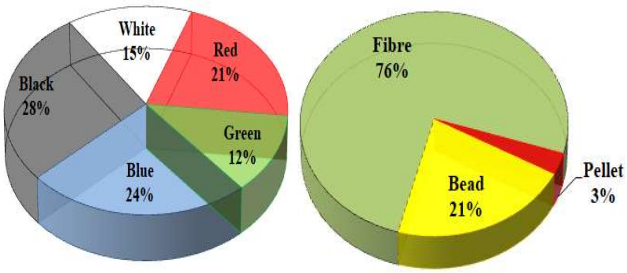

Fig. 1. Percent distribution of various forms and colours of plastic debries in water samples collected from inlet

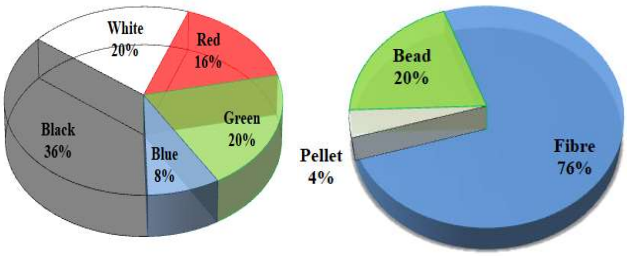

Fig. 2. Percent distribution of various forms and colours of plastic debries in water samples collected from outlet

Fig. 3. Photomicrograph of Microplastics (Fibres) in freshwater samples

The surface water was mainly contaminated with MPs disintegrated from products made of Polyethylene (PE) and Polypropylene (PP) (Triebskorn et al 2019). The distribution of these materials is due to the wide application of these materials in manufacturing products namely food and cosmetic packaging, house ware, toys and food and agricultural films (Plastics Europe, 2019).

CONCLUSIONS

Microplastics were observed in water samples collected from PuzhalLake and inlet and outlet of water treatment plant. Most of the microplastics detected were in the form of fibres. The colur of the microplastics detected were red, green, blue, black and white. Since, the MPs were detected in samples collected from the outlet; more attention is needed to improve the treatment technology to remove them. When the water with MPs is consumed, it will cause health effects. Hence, more research is needed to identify, characterize, quantify and remove MPs from water.

REFERENCES

Andrady AL 2015. Persistence of plastic litter in the oceans.In: Bergmann, M. Gutow, L. Klages M (eds.). *Marine Anthropogenic Litter*, Springer, Cham, P. 456.

Blasing M and Amelung W 2018. Plastics in soil: Analytical methods and possible sources. *Science of the Total Environment* **612**: 422-435.

Cable R N Beletsky D, Beletsky R, Wigginton K, Locke B H and Duhaime M B 2017. Distribution and modeled transport of plastic pollution in the Great Lakes, the world's largest freshwater resource. *Frontiers in Environmental Science* **5**(45) https://doi.org/10.3389/fenvs.2017.00045.

Dris R, Gasperi J, Rocher V, Saad M, Renault N and Tassin B 2015. Microplastic contamination in an urban area: A case study in Greater Paris. *Environmental Chemistry* **12**(5): 592-599.

Fendall LS and Sewell MA 2009. Contributing to marine pollution by washing your face: Microplastics in facial cleansers. *Marine pollution Bulletin* **58**(8):1225-1228.

Fischer EK, Paglialonga L, Czech E and Tamminga M 2016. Microplastic pollution in lakes and Lake Shoreline sediments: A case study on Lake Bolsena and Lake Chiusi (Central Italy). *Environmental Pollution* **213**: 648-657.

Galgani F, Hanke G and Maes T 2015. Global distribution, composition and abundance of marine litter. In: Bergmann, M.,

Gutow, L., Klages, M. (Eds.), *Marine Anthropogenic Litter*. Springer International Publishing, pp. 29-56.

Gewert B, Plassmann M M and Mac Leod M 2015. Pathways for degradation of plastic polymers floating in the marine environment. *Environmental Science Processes Impacts* **17**: 1513-1521.

Ivar do Sul JA, Costa MF and Fillmann G 2014. Microplastics in the pelagic environment around oceanic islands of the Western Tropical Atlantic Ocean. *Water Air Soil Pollution* **225**: 2004.

Koelmans AA, Besseling and Shim WJ 2015. In: Bergmann, M. Gutow, L. Klages M (eds.). *Marine Anthropogenic Litter*, Springer, Cham. pp 325-340.

Li J, Green C, Reynolds A, Shi H and Rotchell JM 2018. Microplastics in mussels sampled from coastal waters and supermarkets in the United Kingdom. *Environmental Pollution* **241**: 35-44.

Long Z, Pan Z, Wang W, Ren J, Yu X, Lin L and Jin X. 2019. Microplastic abundance, characteristics, and removal in wastewater treatment plants in a coastal city of China. *Water Research* **155**: 255-265.

Maynard A 2006. *Nanotechnology: A Research Strategy for Addressing Risk.* Woodrow Wilson International Center for Scholars Project on Emerging Nanotechnologies. Available at: (Meenakumari). http://www.nanotechproject. org/file_ download/files/PEN3_Risk.pdf.

Masura J, Baker J, Foster G, Arthur C and Herring C 2015. Laboratory methods for the analysis of microplastics in the marine environment: recommendations for quantifying synthetic particles in waters and sediments. *NOAA Technical Memorandum* NOS-OR&R-48.

Mintenig SM, Loder MGJ, Primpke S and Gerdts G 2019. Low numbers of microplastics detected in drinking water from groundwater sources. *Science of the Total Environment* **648**: 631-635.

Monisha G, Nallathambi G and Srinivasalu S 2019. Fate and Transport of microplastics from water sources. *Current Science* **117**(11): 1879-1885.

Novotna K, Cermakova L, Pivokonska L, Cajthaml T and Pivokonsky M 2019. Microplastics in drinking water treatment: Current knowledge and research needs, *Science of the total Environment* **652**: 602-610.

Received 22 July, 2020; Accepted 10 November, 2020

Ogonowski M, Gerdes Z and Gorokhova E 2019. Whatwe know and what we think about microplastic effects: A critical perspective. *Current Opinion in Environmental Health* **1**: 41-46.

Pivokonsky M, Naceradska J, Kopecka I, Baresova M, Jefferson B, Li X Henderson RK 2016. The impact of algogenic organic matter on water treatment plant operation and water quality: A review. *Critical Reviews in Environmental Science and Technology* **46**(4): 291-335.

Pivokonsky M, Cermakova L, Novotna K, Peer P, Cajthaml T and Janda V 2018. Occurrence of microplastics in raw and treated drinking water. *Science of the Total Environment* **643**: 1644-1651.

Plastic Europe 2019. *Plactics: The facts*. An analysis of European plastics production. Demand and Waste Data www.plasticseurope.org.

Rillig MC, Ingraffia R and Machado A 2017. Microplastic incorporation into soil in agrosystems, *Frontiers in Plant Science* **18**: https://doi.org/10.3389/fpls.2017.01805**.**

Sathish N, Jeyasanta KI and Patterson J 2019. Abundance, characteristics and surface degradation features of microplastics in beach sediments of five coastal areas in Tamil Nadu, India. *Marine Pollution Bulletin* **142**: 112-118.

Schymanski D, Goldbeck C, Humpf H and Furst P 2018. Analysis of microplastics in water by micro-Raman spectroscopy: Release of plastic particles from different packaging into mineral water, *Water Research* **129**: 154-162.

Shen M, Song B, Zhu Y, Zeng G, Zhang Y, Yang Y, Wen X Huan MC 2020. Removal of microplastics via drinking water treatment: Current knowledge and future directions. *Chemosphere* **251**: 126612.

Silva AB, Bastos AS, Justino CIL, da Costa JP, Duarte AC and Rocha-Santos TAP 2018. Microplastics in the environment: Challenges in analytical chemistry: A review. *Analytica Chimica Acta* **1017**: 1-17.

Sruthy S and Ramasamy EV 2016. Microplastic pollution in Vembanad Lake, Kerala, India: The first report of microplastics in lake and estuarine sediments in India. *Environmental Pollution* **222**: 315-322.

Triebskorn R, Braunbeck T and Grummt T et al 2019. Relevance of nano- and microplastics for freshwater ecosystems: Acritical review. *Trends in Analytical Chemistry* **110**: 375-392.

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Analysis of Groundwater Level Fluctuation using GIS Technique in Blocks of Ranchi District, Jharkhand

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Abstract: Mechanism of groundwater level fluctuations in different blocks of Ranchi district, Jharkhand was explored in the present paper. The spatial and temporal pattern of groundwater level fluctuation was interpolated by the Kriging interpolation method with the use of Arc-GIS. The analysis revealed that the deeper aquifer of Ranchi urban area is having a declining trend of water level. Few places in different blocks were found to have a groundwater fluctuation of less than 2m and places such as Kurgi (Nagri), Taimara (Bundu), Chuttupal (Ormanjhi), and Silli showed the higher groundwater level fluctuation as more than 8m and hold great potential of groundwater. In Kanke block, the stage of groundwater development is observed to be 122.44%. The area is under intensive domestic and industrial draft. The spatial output will aid policy planners and decision-makers for efficient management of the groundwater resources.

Keywords: Groundwater fluctuation, Interpolation, Kriging method, GIS Technique

Groundwater represents the second-most abundantly available freshwater resources and constitutes about 30% of freshwater resources of the globe and is easy to extract and it remains well protected from the hazards of pollution. However overexploitations of groundwater resources are not uncommon and due to the rapid growth of population, industrialization, and urbanization, the available water resource is unable to meet the agriculture, industrial, and domestic needs. Groundwater overexploitation has reached the near-crisis level in the states dominated by electric tube-wells and cheap or free power – the nine states which account for 85% of India's groundwater blocks that are in critical condition. If current trends of declining groundwater tables continue, 60% of all aquifers in India will be in critical condition by 2025 (Government of India 2015b). Many studies on groundwater exploitation have confirmed the unregulated and unsustainable withdrawal of groundwater is leading to large scale depletion of groundwater reserve (Manjunatha et al 2015, Nema et al 2017, Sinha et al 2018). With the advent of remote sensing and GIS technology, the application of spatial technique is important in studying the groundwater variability, a spatial-temporal trend of rainfall and groundwater level, and exploring the suitability of groundwater recharge zone (Kumari and Krishna 2013). A variety of approaches can be used to assess the impact of LU/LC changes on subsurface hydrology. The most direct approach is relating to LU/LC changes to water-table fluctuations. The significance of terrain parameters such as lithology, landforms, soil, slope, and rainfall (climate) in affecting the groundwater movement (Radhakrishnan and Elango 2011, Basavarajappa et al 2015). Kriging technique has been very popular and has found numerous applications in groundwater interpolation (Moslemzadeh et al 2011, Uyan and Cay et al 2013, Nayak et al 2015). Kumari et al (2014) explored the groundwater recharge possibilities by constructing well recharging unit. They observed rise in water table by 14.87 % when compared to control well. Krishna et al (2015) applied the integrated approach with GIS and the DRASTIC model to derive a groundwater vulnerability to pollution in Ranchi district, Jharkhand, India. Aquifer vulnerability maps generated in this study were quite useful aid in environmental planning and groundwater management. Sharma et al (2020) studied the impact of groundwater abstraction on the flow-regimes in the Gomti River Basin (GRB) in Uttar Pradesh, India. They observed that during the lean flow periods, the groundwater usage was highest in the basin, and base flow reduced due to which rivers were not able to meet the minimum flows requirements. The study recommended groundwater recharge through water bodies to maintain sufficient ecological flows in the river.

The Ranchi district in the Jharkhand state of India has been facing the complexity of groundwater availability in recent times due to rapid urbanization and the presence of hard rock strata. The major problem is the declining trend of deeper aquifers in the urban area of Ranchi city. The detailed study on groundwater fluctuation with respect to space and time is not carried out in this region. It is necessary to have

thorough knowledge about water level fluctuations and rainfall occurrences for evolving a system to manage the water resources effectively. Thus the present work was attempted to illustrate the spatial and temporal variation of groundwater levels using remote sensing and GIS techniques within a block of Ranchi district.

MATERIAL AND METHODS

Study area: Ranchi district has a total geographical area of 5097 km^2 and is located between 22°52'-23 °45' North latitude to 84°45'-85°50' East longitude. The average elevation of the city is 651 m from the mean sea level and receives an average annual rainfall of 1394 mm. The major water divides in the district which is run from north to south direction through the Lodhma and Ratu. The area in the western part of the divide is drained by South Koel and Karo and the eastern part of the water divide is drained by Subarnrekha. The main river basins are the Subarnrekha, the South Koel, the Karkari, and the Damodar. The Raru and Kanchi are the tributaries of river Subarnrekha. The South Koel initiates from Piska near Ranchi. The Karkare river drains the south-eastern division of the district (Fig. 1).

Land use and cropping pattern: The total geographical area of Ranchi district is about 5,09,700 ha, in which forest area is 20.97%, infertile land is 4.2%, land put to non-agricultural use is 5.6%, current fallow is 16.35%, land other than current fallow is 8.7%. Net area sown is 33.64%, the cultivable wasteland is 3.4% and area sown more than once is 2.21% (CGWB, 2013). There are commonly three types of cropping patterns such as Kharif, Rabi, and summer crops in which 89% of Kharif crops are unirrigated and 4% of Kharif crops are irrigated. Only 3% of Rabi crops are irrigated and 2% of Rabi crops are unirrigated. In the general elevation of the area varies from 500m to 700m above mean sea level. There are a lot of hillocks through the district having altitude 700m above mean sea level. In the greater part of the district, the formation of a lateritic type of soils from the rocks of Archean metamorphic complex due to high temperature and high rainfall. The districts have been classified into four classes in terms of the texture of the soils such as alluvial soils, laterite soils, red and yellow soils, and stony and gravelly soils

Groundwater scenario: The Ranchi district has diverse hydrogeological characteristics due to which groundwater potential fluctuates from one region to another region. In a three-fourth fraction of the area is underlain by Chotanagpur granite gneiss of pre-Cambrian age (CGWB 2013). Two types of aquifers systems have found such as fractured aquifers and Weathered aquifer. The thickness of weathered aquifers varies from 30-60m in lateritic terrain and 10-25 m in granite terrain. In weathered aquifer, groundwater arises in unconfined condition whereas in fractured aquifer groundwater takes place in semi-confined to confined conditions.

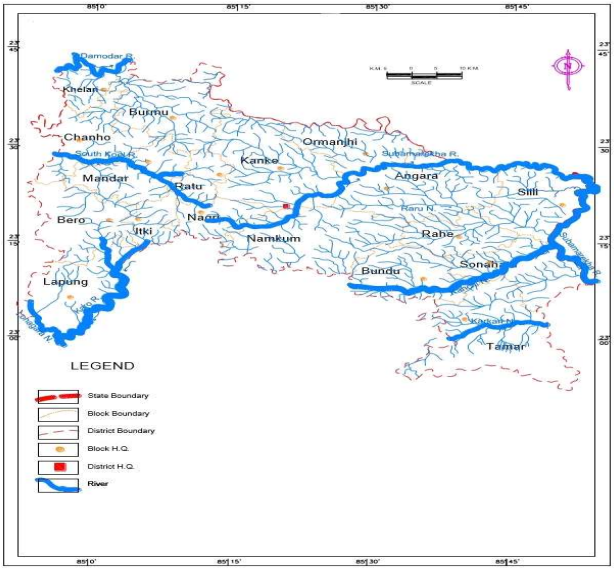

Fig. 1. Drainage map of Ranchi district (CGWB 2013)

Pre-processing of groundwater data: Groundwater data for Ranchi district was collected from Groundwater Investigation Division Ranchi (Water Resources Department, Govt. of Jharkhand) covering the period 2013-2019. The data includes the measurements two times in a year (May and October) and cover the entire period. There are 18 blocks are present and each block has a minimum of three to four observations well except some blocks have one observation well. Each observation well has latitude and longitude coordinate data. In this present study Block wise Annual Maximum Groundwater Fluctuation was considered (Table 1). The dataset for pre and post-monsoon periods was merged for analysis of the Spatio-temporal trends.

Groundwater level data analysis: After cleaning the dataset, pre- and post-monsoon data from 2013 to 2019, data were analyzed with the help of a trend analysis tool in ArcGIS. Ordinary Kriging method was applied for this study and the data was exported into the ArcGIS System for mapping the spatial distribution of groundwater fluctuation. Groundwater level maps for each year were prepared using a raster calculator tool in ArcGIS to recognize the spatio-temporal trends of Groundwater level deviation.

RESULTS AND DISCUSSION

Blockwise annual maximum groundwater fluctuation: The maximum groundwater fluctuation (GWF) in Ratu block increased from 2013 to 2017 (Fig. 2). Similar plottings were

made for other blocks also but not presented here. In Angara, Silli, Bundu, Chanho, Burmu, and Rahe block, maximum GWF was in 2016. Surprisingly, in Kanke block, maximum GWF was as 7.20 m in 2019, and previously 7.10, water table was in 2015. Mandar block recorded maximum fluctuation in the water table in 2013 and then up to 2019, varied from 3.50 to 4.15. Maximum fluctuations were observed in Tamar, Namkum, and Ormanjhi block in 2019. The Bero block recorded maximum fluctuation in 2018. In Nagri block, water table fluctuations varied from 11.30 m in 2016 to 13.20 m in 2019. In Ranchi districts, the entire area is covered by hard rock terrain i.e. Granite Gneiss Complex and the specific yield of the formation is 0.015%. Therefore the quantities of water that can be extracted from these areas was very small and largely depend on the rainfall for its recharge. The availability of water resources is not uniformly distributed over time. This resource depletes often in summer which causes a reduction of bore well's yield. Further, in parts of Ranchi district, high dependency on groundwater for Industrial and Domestic as well as irrigation purposes need to be addressed in time. Deeper aquifers of Ranchi urban area is showing a declining trend of water levels. In Kanke block, the stage of groundwater development 122.44%. The area is under intensive domestic and industrial draft and very important to make it mandatory for even existing households to make a recharge pit.

Spatio-temporal patterns of maximum GWL fluctuation: The year-wise spatio-temporal pattern of max GWL fluctuation for 2013-2019 of the Ranchi district are presented in (Fig. 3). The positive values represent an increase in GWL and vice versa. The larger value of groundwater level fluctuation indicates the good recharge of groundwater. For 2013, the average maximum GW fluctuation was 3.50m. Out of 18 blocks, as 11 blocks have not sufficient data of pre and post-monsoon water level and post-monsoon water level, only seven blocks were considered such as Angara, Bundu, Chanho, Kanke, Mandar, Ratu, and Silli (Fig. 3a). Similarly, during 2014, only ten blocks were considered such as Angara, Bundu, Chanho, Kanke, Mandar, Namkum, Ormanjhi, Ratu, Silli, and Tamar and the average max GW fluctuation was as 4.85m. For 2015, only 11 blocks out of 18 were included with average maximum GW fluctuation of 3.16m. The maximum GW fluctuation of Ormanjhi block has

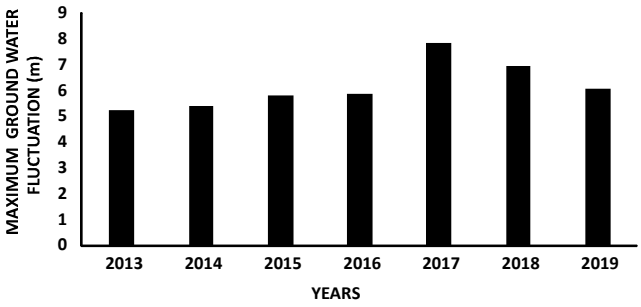

Fig. 2. Maximum groundwater fluctuation (m) in Ratu block, Ranchi

Table 1. Block wise annual maximum groundwater fluctuation in Ranchi district

Block name	Annually maximum groundwater fluctuation (m)						
	2013	2014	2015	2016	2017	2018	2019
Angara	2.75	5.04	1.80	6.45	5.30	5.90	5.95
Bero	N.A	N.A	N.A	4.75	4.70	6.80	3.80
Bundu	3.70	7.05	5.40	10.50	9.90	9.10	7.35
Burmu	N.A	4.50	3.03	5.40	4.85	4.45	4.90
Chanho	3.28	3.95	2.72	5.30	3.90	3.80	3.80
Itki	N.A	N.A	N.A	NA	3.55	5.90	N.A
Kanke	3.14	N.A	7.10	0.65	6.59	4.80	7.20
Mandar	5.33	4.15	3.30	3.62	3.32	3.72	3.82
Nagri	N.A	N.A	N.A	11.30	12.70	11.50	13.20
Namkum	N.A	6.20	0.90	4.70	5.60	6.30	6.95
Ormanjhi	N.A	4.55	-0.15	5.50	4.43	5.02	8.50
Rahe	N.A	N.A	N.A	3.40	2.85	3.35	3.25
Ratu	5.28	5.40	5.87	5.90	7.85	6.95	6.10
Silli	1.04	3.80	2.03	8.80	7.15	6.80	8.25
Sonahatu	N.A	N.A	N.A	2.70	1.80	8.40	8.40
Tamar	N.A	3.85	2.80	5.40	4.5	5.60	5.80

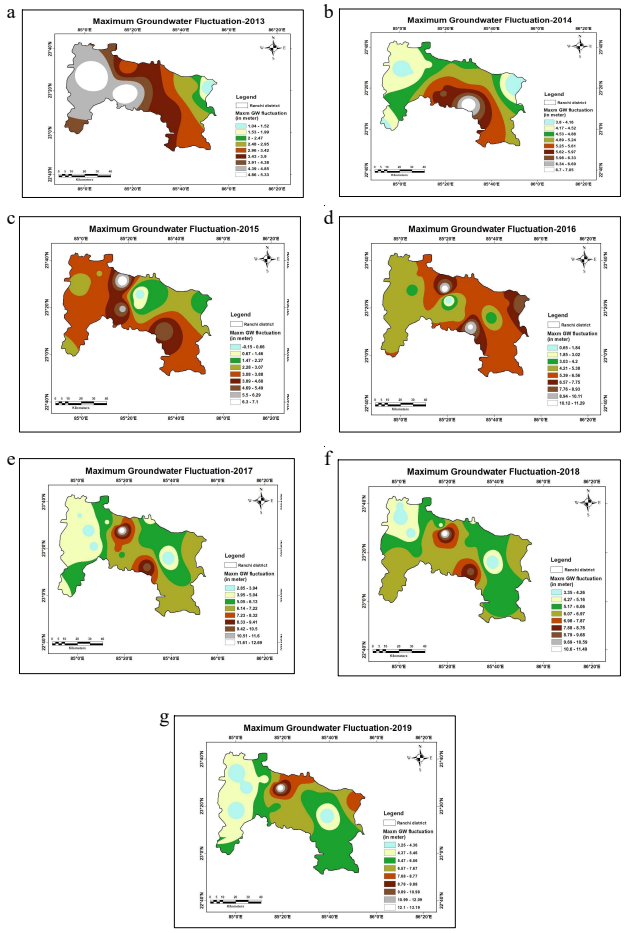

Fig. 3. Maximum Ground water Fluctuation Ranchi, 2013-2019

the negative value (-0.15m) which shows that groundwater was not recharged on that year (Fig. 3c). This is a serious issue and effort must be made to make provisions for surface storage structure which helps in recharging the groundwater. The Ormanjhi is near to Ranchi also and many institutions and house building projects are in line. Watershed management approach may be adopted and the most affected area within the block is to be identified. For 2016, only 14 blocks out of 18 were considered for analysis and the average maximum GW fluctuation was recorded as 5.83m. Blocks such as Bundu and Nagri showed the maximum GWF as 10.5m and 11.3m, respectively which shows that the water recharge capacity of that region is extremely high (Fig. 3d). New urban settlement can be planned in these blocks keeping in view the good availability of groundwater for use. Fifteen blocks were analyzed for maximum average groundwater fluctuations in 2017 and blocks such as Bundu and Nagri showed the maximum GWF as 9.9m and 12.7m, respectively.

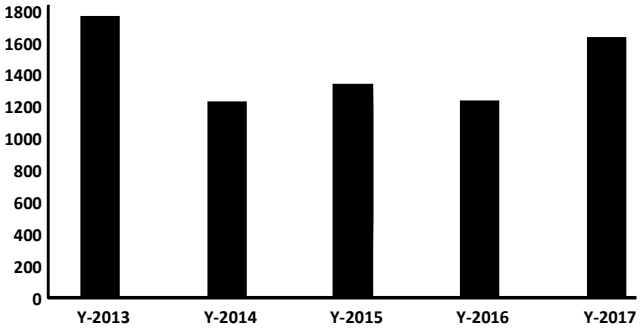

Fig. 4. Annual average of rainfall of Ranchi district

Rahe block had the lowest GWF value as 2.85m. The average maximum GW fluctuation was 5.98m in the year 2018. In 2019, only 14 blocks out of 18 were considered and the average maximum GW fluctuation was 6.35m. This was observed that the water recharge capacity of the Bundu region is constantly decreasing in comparison to the preceding years. In 2018, the Jharkhand government had declared 129 blocks in 18 districts as drought-affected and released 6.6 million USD for immediate relief. Jharkhand received 72 percent average rainfall in 2018. However, in some places, it was less than 50 percent. The worst affected areas were Pakur and Koderma. The average rainfall in the state is 1,027.7 mm, but in 2018 it received only 741.9 mm. There are lots of spatial variations among the different blocks of Ranchi districts (Fig. 4).

CONCLUSIONS

The effort was made to understand the mechanism of groundwater level fluctuations in different blocks of Ranchi district, Jharkhand. Spatial and temporal patterns, in terms of groundwater level fluctuation as well as pre and post-monsoon depth to water level by Kriging interpolation method with the use of Arc-GIS, were analyzed. The deeper aquifer of Ranchi urban area is having a declining trend of water level. Increasing population, industrialization, and rapid urbanization seem to be the primary driver for the decline in groundwater level. Places such as Bizupara more (Chanho block), Sons (Chanho), Hesalong (Burmu), Kanke (Kanke), Bariatu (Kanke) and Malghosa (Ormanjhi) were found to have the groundwater fluctuation of less than 2m and places such as Kurgi (Nagri), Taimara (Bundu), Chuttupal (Ormanjhi) and Silli showed the higher groundwater level fluctuation as more than 8m and hold great potential of groundwater. It is further noticed that the recharge rate is moderate to poor in calcareous and black cotton soils, respectively. The spatial output will aid policy planners and decision-makers for efficient management of the groundwater resources.

REFERENCES

Basavarajappa HT, Pushpavathi KN and Manjunatha MC 2015. Climate Change and its impact on Groundwater Table Fluctuation in Precambrian rocks of Chamarajanagara district, Karnataka, India using Geomatics technique. *International journal of Geomatics and Geosciences* **5**(4): 510-524.

CGWB 2013. *Groundwater Information Booklet*. Central Groundwater Board (CGWB), Government of India, Ranchi, Jharkhand.

Government of India 2015b. *Energy statistics 2015*. New Delhi: Central Statistics Office, Ministry of Statistics and Programme Implementation, Government of India.

Krishna R, Iqbal J, Gorai AK, Pathak G, Tuluri F and Tchounwou PB 2015. Groundwater vulnerability to pollution mapping of Ranchi district using GIS. *Applied Water Science* **5**: 345–358.

Kumari N and Krishna AP 2013. Geospatial techniques based assessment of groundwater recharge site suitability. *International Journal of Advanced Remote Sensing and GIS* **2**(1): 96-109.

Kumari R, Sharma B, Singh R and Singh RM 2014 Estimation of groundwater recharge using well recharging unit in Parasai-Sindh watershed of sat region of India. *Indian Journal of Ecology* **41**(2): 252-256.

Manjunatha MC, Basavarajappa HT and Jeevan L 2015. Climate change and its impact on groundwater table fluctuation in Precambrian terrain of Chitradurga district, Karnataka, India using Geomatics application. *International Journal of Civil Engineering and Technology* **6**(3): 83-96.

Moslemzadeh M, Salarizazi M and Soleymani S 2011. Application and assessment of Kriging and Cokriging methods on groundwater level estimation. *Journal of American Science* **7**(7): 34-39.

Nayak TR, Gupta SK and Galkate R 2015. GIS based mapping of groundwater fluctuations in Bina basin. *Aquatic Procedia* **4**: 1469-1476.

Nema S, Awasthi MK and Nema RK 2017. Spatial and temporal ground water responses to seasonal rainfall replenishment in an alluvial aquifer. *Biosc. Biotech. Res. Comm* **10**(3): 431-437.

Radhakrishnan N and Elango L 2011. Study of influence of terrain and climatic factors on groundwater-level fluctuation in a minor river basin using GIS. *Geo-spatial Information Science* **14**(3): 190.

Sharma U, Adeeba and Dutta V 2020. Impact of declining groundwater levels on river flows in the Ganga Alluvial Plain: A case study of Gomti River, India. *Indian Journal of Ecology* **47**(1): 40-48.

Sinha R, Gupta S and Nepal S 2018. Groundwater dynamics in North Bihar plains. *Current Science* **114**(12): 2482.

Uyan M and Cay T 2013. Spatial analyses of groundwater level differences using geostatistical modeling. *Environmental and Ecological Statistics* **20**(4): 633-646.

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Estimation of Land Use and Crop Economics of Parasai-Sindh Watershed in Semi Arid Tropics of Central India

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Abstract: The watershed geographical area is 12.46 km^2 and the dominant soil class was red followed by black. The crop cultivation area was major in watershed and occupied 88.73% of total area. During *Kharif* season, the groundnut grown 93% area followed by sesame whereas, wheat was major crop during *Rabi* season of total cultivable area. The maximum crop productivity was observed in maize and wheat during *Kharif* and *Rabi* season, respectively. The highest return per rupees investment was recorded in gram crop followed by groundnut (1.67). The total human days involved in agriculture was recorded148643 in the watershed and it's economic value was accounted INR 22.296 million.

Keywords: Land use, Soil type, Crop economics, Employment generation, Parasai-Sindh Watershed

Watershed characteristics, such as land use/land cover, slope, and soil attributes, affect hydrologic and water quality processes and hence regulate sediment and chemical concentration (Basnyat et al 2000). However, most studies do not quantify contributions of change for individual land use and land cover (LULC) to different hydrological responses. Without accurate quantification, the impacts of changes for some LULC classes on hydrologic components may be exaggerated or understated, or even misinterpreted. LULC change is probably the most visible response of the agricultural community to these external factors. Farmers adapt to changing conditions by utilizing their land in a manner which yields the greatest return on their investment of time, energy and money. Soil and water are the two most vital natural resources for agriculture and the agricultural productivity depends on efficient use of these resources. Under the present scenario, India's land resources are under immense pressure. These share only 2 per cent of the world's geographical area, but support around 18 per cent of global population and over 15 per cent of the world livestock number (Kumari et al 2014). In India, approximate, 66% of the total cultivated area comes under dry land agriculture and it produces nearly half of the total agricultural output (Kumari et al 2018). In India, 48% food crops are grown in rainfed areas, where more than 90% of millets and 75% of pulses are grown. The production potential of dry land system has continued to be low as a result of frequent drought due to high variability in rainfall (amount and distribution) during the growing season, low soil fertility, low plant nutrient use efficiency, small size of farm holding and poor socio-economic condition of the farmers (Sharma et al 2015). Therefore, dry land areas are important for the economy of the country and also need to continue in the future and attempts are made for sustainable use of natural resources through watershed management under Integrated Watershed Management Programme (IWMP) for better eco-system services. Presently, numerous watershed projects under IWMP schemes are being implemented in Bundelkhand region. Therefore, this research is concerned with land use and land cover of watershed and this will based to be assessed the impact of project.

MATERIAL AND METHODS

Study was carried out at Parasai-Sindh watershed, which is located at 78º 20' - 78º 22' E and 25º 23' -25º 27' N, and about 270-315 m above mean sea level in Jhansi district of Uttar Pradesh. It's covering three villages *viz*. Parasai, Chhatpur and Bachhauni. It comes under agro-climatic zone of Central Plateau Hill Region. The agro-climate of the watershed is characterized by dry and hot summer, warm and moist rainy season and cool winter with occasional rain showers. Rainfall is highly erratic, both in terms of total amount and its distribution over time. The annual average rainfall in study region is 877 mm, out of this 90% is received during South-West monsoon period from June to September (Singh et al 2014, Kumari et al 2015). The mean potential

evapotranspiration varies from 1329 to 1532 mm for Budelkhand region. Mean annual temperature ranges from 24 to 25 °C. The mean summer (April-June) temperature is 34 °C which may rise to a maximum of 46 to 49 °C during the month of May and June. The mean winter temperature (December-February) is 16 °C which may drop to 3-5 °C in December and January.

Data collection and analysis: The map of the study area was analyzed, for characterization of various land forms and its geomorphology with the help of GIS software Arc GIS 10. The land use layer was digitized in GIS environment using Survey of India (SOI) Top sheet 54K/7 of 1:50000. The digitized area was classified in various land uses as agricultural land, scrub land, forest, drainage network, road and habitation. Different soil type of watershed was identified and classified under different slope class. Slope classes of watershed was prepared by using satellite imagery of ASTER 30m digital elevation model. Different slope classes were digitized as per guidelines suggested by IMSD (1995).

Crop economic: The economics of all the crops grown during *Kharif* (June to October), 2012 and *Rabi* (November to March), 2012-13 were worked out.All the fields were digitized in the GIS environment and the coverage of different crops in both the seasons were marked on a map and estimated using ArcGIS ver. 10. Primary data for crops, which were grown in watershed, collection involves randomly selected seventy-five households form watershed. For the primary data collection plot wise Input/ Output details questionnaires were used. Income from different crops was worked out on the basis of current procurement price (CACP 2013). The net return and cost benefit ratio was worked out.

RESULTS AND DISCUSSION

Land use and soil of watershed: The land use of the watershed was digitized in GIS environment. The geological area of watershed is 12.46 km^2. Land use of watershed comprised in six groups. Out of total area, crop cultivable area is 88.73% followed by scrub land, drainage network, habitat, road and very small area covered by forest (Table 1).The soils of the watershed can be conveniently grouped into two soil groups, viz., (i) red soils and (ii) black soils. In watershed, red soil dominated and it's covered 10.26 km^2, whereas rest area covered by black soil (Fig. 1). The red soils are coarse grained upland and middle land soils while black soils are heavy soils and distributed in low lying area of the watershed. It's containing higher clay content and very high water holding capacity. They also swell when wet and develop crack when dry. The soils of watershed also classified on the basis of land slope, it's covered. Maximum area under red soil was estimated 4.61 km^2 under 5-10 per cent slope. Maximum area under black soil was 1.10 km^2 under 5-10 per cent slope whereas minimum area obtained under 0-0.5 per cent slope (Table 2).

Cropping structure of watershed: The cropping structure of watershed was collected through visited in watershed, conducted meetings with farmers and had elaborated discussions followed by field visits to collect the primary information on field crops grown in particular field. The groundnut was the predominate *Kharif* (June to October) and wheat was dominant *Rabi* (November to march) crops. Kumari et al (2015) was also found similar finding. Other *Kharif* season crops are sesame, black gram and maize and gram and mustard are *Rabi* crops (Table 3). Out of total agricultural area, the fallow area of watershed was recorded 4.30 and 6.34% during *Kharif* and *Rabi* season, respectively.

Economical behavior of *kharif* season crop: The productivity of groundnut, sesame, black gram and maize were observed 0.96, 0.38, 0.44 and 1.00 MT ha^{-1}, respectively. The production of groundnut, sesame, black gram and maize were 987.92, 7.93, 3.09 and 0.66 MT ha^{-1}, respectively (Table 4). The average cost of cultivation of groundnut, sesame, black gram and maize were recorded

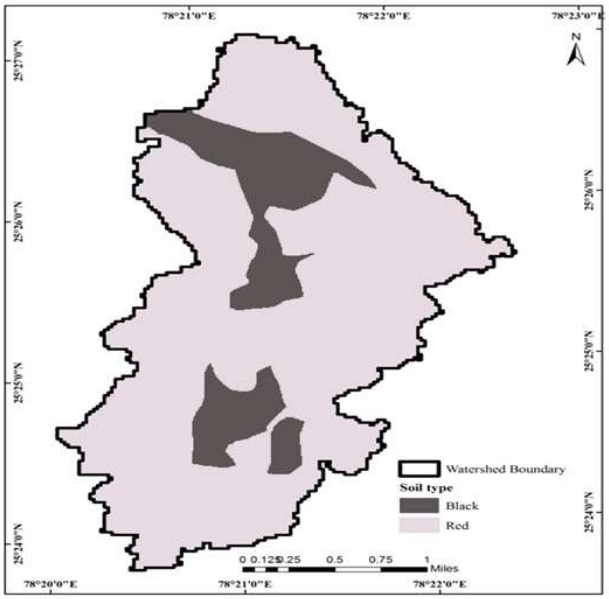

Fig. 1. Soil map of Parasai-Sindh watershed

Table 1. Landuse of Parasai-Sindh watershed

Land use/cover	Area (%)
Agricultural	88.73
Scrub land	5.30
Drainage	3.48
Forest	0.45
Other	2.04

INR 26650, 14453, 14229 and 13744 ha^{-1}, respectively. The total cost of cultivation of watershed was INR 27.840 million. The gross return of watershed was obtained INR 46.214 million, out of this 98.97% recorded under groundnut followed by sesame. The maximum and minimum net gain were recorded INR 18.313 and 0.001 million of groundnut and maize, respectively. The maximum B:C ratio of watershed was calculated under groundnut crop (1.67), with average B:C ratio 1.29 during *Kharif* season.

Economical behavior of *rabi* season crop: The grain productivity of wheat, gram and mustard were recorded 1.95, 1.25 and 1.00 MT ha^{-1}, respectively (Table 5). The production of wheat, gram and mustard were 1905.54, 30.02 and 34.16 MT, respectively. The average cost of cultivation of INR 24577, 18244 and 16363 ha^{-1} for the wheat, gram and mustard, respectively, were recorded in watershed. The total cost of cultivation of watershed was INR 25.014 million. The gross return of watershed during the *Rabi* season was calculated INR 28.526 million, out of this, 94.06% recorded under wheat. The highest net return was estimated INR 28.15 million of wheat followed by gram. The highest and lowest B:C ratio were obtained 1.92 and 1.12, respectively, of gram and wheat, with average B:C ratio 1.52 in *Rabi* season. Similar studies conducted in the Parasai-chhatpur watershed proved the economic viability of watershed development projects (Kumari et al 2014).

Employment generation: Highest employment generation was recorded in wheat followed by groundnut and maize. Total employment generation in watershed was for 148643 human days (Table 6). The economic value of human days was accounted INR. 22.296 million in the watershed. It is expected that after watershed interventions, labour requirement for crop cultivation will increase because of improve crop area which comes under fallow as well as adoption of high value crops.

Table 2. Area under red and black soil under different slope categories

Slope categories (%)	Red soil area (km^2)	Red soil area (%)	Black soil area (km^2)	Black soil area (%)
0-0.5	0.000	0.00	0.001	0.04
0.5-1.0	0.174	1.69	0.038	1.70
1.0-2.0	0.618	6.02	0.101	4.57
2.0-3.0	1.028	10.02	0.194	8.83
3.0-5.0	2.468	24.06	0.469	21.33
5.0-10.0	4.607	44.90	1.104	50.18
10.0-15.0	1.195	11.64	0.264	12.01
> 15.0	0.172	1.67	0.030	1.34
Total	10.260	100.00	2.200	100.00

Table 3. Distribution of agricultural area of watershed in different crops growing *Kharif* and *Rabi* season

Kharif season crop	Area (%)	*Rabi* season crop	Area (%)
Groundnut	93.09	Wheat	88.39
Sesame	1.91	Mustard	3.09
Black gram	0.64	Chickpea	2.17
Maize	0.06	Fallow	6.34
Fallow	4.30		

Table 4. Crops economic of *Kharif* season crops of Parasai- Sindh watershed

Crop	Productivity (MT ha^{-1})		Production (MT)		Cost of cultivation (*INR ha^{-1})	Total cost (**INR in million)	Gross return (INR in million)			Net return (INR in million)	B:C ratio
	Grain	Fodder	Grain	Fodder			Grain	Fodder	Total		
Groundnut	0.96	1.50	987.92	1543.62	26650.00	27.425	44.456	1.281	45.738	18.313	1.67
Sesame	0.38	0.00	7.93	0.00	14453.00	0.306	0.333	0.000	0.333	0.027	1.09
Black Gram	0.44	0.00	3.09	0.00	14229.00	0.100	0.133	0.000	0.133	0.033	1.32
Maize	1.00	3.00	0.66	1.98	13744.00	0.009	0.008	0.002	0.010	0.001	1.07

* INR ha^{-1} = Indian rupees per hectare, ** INR in million = Indian rupees in million

Table 5. Crops economic of *Rabi* season crops of Parasai- Sindh watershed

Crop	Productivity (MT ha^{-1})		Production (MT)		Cost of cultivation (*INR ha^{-1})	Total cost (**INR in million)	Gross return (INR in million)			Net return (INR in million)	B:C ratio
	Grain	Fodder	Grain	Fodder			Grain	Fodder	Total		
Wheat	1.95	2.40	1905.54	2345.28	24577.00	24.017	24.486	2.345	26.831	2.815	1.12
Gram	1.25	0.00	30.02	0.00	18244.00	0.438	0.841	0.000	0.841	0.402	1.92
Mustard	1.00	0.00	34.16	0.00	16363.00	0.559	0.854	0.000	0.854	0.295	1.53

* INR ha^{-1} = Indian rupees per hectare, ** INR in million = Indian rupees in million

Table 6. Employment generation through crop cultivation in watershed

Crop	Area (ha)	Employment generation (No.ha^{-1})	Total employment in watershed (No.)	Economic value employment (INR In million)*
Wheat	977.2	77	75244	11.287
Gram	24.0	48.5	1081	0.162
Mustard	34.2	45	1657	0.249
Groundnut	1029.1	67.5	69463	10.419
Sesame	21.1	43.75	925	0.139
Black Gram	7.1	33.75	238	0.036
Maize	0.7	53.75	35	0.005
Total	2093.3		148643	22.296

*The prevaling wage rate @ INR 150/day

CONCLUSION

The crop productivity of watershed was very low due to maximum area under red soil being 5-10% slope class. In *Kharif* season, Groundnut, sesame, black gram and maize are grown, while wheat, gram and mustard grown during *Rabi* season in this watershed. The highest B:C ratio was for groundnut during *Kharif* season while during *Rabi* season, in gram because of less cost of cultivation as well as higher rate of produce. The B: C ratio of crop cultivation was1.29 and 1.52 during *Kharif* and *Rabi* seasons, respectively. The employment generation was highest in wheat, followed by groundnut and maize.

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REFERENCES

Basnyat P, Teeter L, Lockaby BG and Flynn KM 2000. Land use characteristics and water quality: a methodology for valuing of forested buffers. *Environmental Management* **26**: 153-161.

CACP 2013. *Report on Price Policy.* Commission for Agricultural Costs and Prices (CACP), Ministry of Agriculture, Government of India. Available at online http://cacpdacnetnicin/msppdf

IMSD 1995. I*ntegrated Mission for Sustainable Development (IMSD)*, Technical Guidelines, National Remote Sensing Agency, Balanagar, Hyderabad, India.

Kumari R, Kumari P, Sharma B, Singh R and Singh RM 2018. Cost-effectiveness and water use efficiency of groundnut and wheat under SAT region of Central India. *International Journal of Plant and Soil Science* **21**(1): 1-9

Kumari R, Sharma B, Kushwah A, Singh R, Singh RM, Tewari RK and Dhyani SK 2014. Construction of rainwater harvesting structures and economics of crops in Parasai-Chhatpur watershed in Bundelkhand region of Central India. *Agricultural Economics Research Review* **27**(2): 327-333.

Kumari R, Sharma B and Singh R 2015. comparative assessment of yield and water use efficiency of different groundnut varieties (*Arachis hypogaea*) of semi-arid Bundelkhand region.*Indian Journal of Ecology* **42**(1): 27-30.

Sharma B, Kumari R, Kumari P, Meena SK and Singh RM 2015. Effect of planting pattern on productivity and water use efficiency of pearl millet in the Indian Semi-Arid Region. *Journal of the Indian Society of Soil Science* **63**(3): 259-265.

Singh R, Garg KK, Wani SP, Tewari RK and Dhyani SK 2014. Impact of water management interventions on hydrology and ecosystem services in Garhkundar-Dabar watershed of Bundelkhand region, Central India.*Journal of Hydrology* **509**: 132-149.

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Short-Term Flood Forecasting using Ensemble Learning

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Abstract: Flood Forecasting at Narmada River basin, Madhya Pradesh, India is carried out using an ensemble technique. The presented model has been compared with the individual models such as Support Vector Machine (SVM-EPS & SVM-NU), Random Forest, Multiple Linear Regression, Gradient Boosting, Extreme Gradient Boosting, and various performance measures has been used in order to evaluate and compare the performances of individual models with the stacked model. The evaluation results shows that the stacked model surpass all the individual models and shows improvement in the prediction of peak flows when compared to the individual models with minimal error.

Keywords: Flood forecasting, Rainfall, Runoff modelling, Stacking

Among the entire disasters flood is a common and natural disaster which is getting more acute day by day due to the increase in the level of precipitation. Few factors that cause damage due to floods are population growth and fiscal restraints etc. Hence forecasting of flood plays a vital role in protecting human lives as well as economic losses. In order to forecast, understanding the relationship between the rainfall and runoff process, modelling of rainfall-runoff process is necessary. Modelling of Rainfall-Runoff process helps in making effective decision. Many of the models have been developed for flood forecasting till date which can be broadly classified as Theory-Driven and Data-Driven. Data-driven Modelling is a Black – Box based model which works on the analysis of the system's input and output variables rather than having knowledge about the physical behavior of the system. Data-driven model focuses on machine learning methods that is used to build models based on the system's input and output variables thereby replacing the physical based models which were employed in many of the forecasting literatures (Sudheer et al 2002, Ghalkhani et al 2013, Kasiviswanathan et al 2016). The growth of the forecasting models has resulted in so many successful models such as support vector machine, boosted trees (extreme gradient boosting, gradient boosting), Random Forest, ANN (Gupta 2013, Gizaw and Gan 2016, Shiyamala and Ganapathy 2019). Starting with SVM, it is a popular method in machine learning due to its robustness. Dibike et al (2001) explained about the advantages of using RBF kernel when compared to the other existing kernels (Polynomial, Sigmoid and Linear), thereby RBF kernel based SVM is used for this study. Another modelling approach have been carried out using random forest (classification and regression) for flood susceptibility mapping and flood risk assessment. The use of Random Forest and Boosted trees has been demonstrated by Sunmin Lee et al (2017). However, every method exhibit some disadvantages such as over fitting, complexity in the mathematical functions etc. Each method or algorithm has its own prerequisites, characteristics, advantages and disadvantages and none of the single algorithm achieves the most accurate result, thereby introducing ensemble techniques. Was used to reduce the risk of unfortunate prediction and to improve the performance. The main objective of this study is to improve the forecasting accuracy using stacking and to capture the peak flows accurately which are fraught with errors.

MATERIAL AND METHODS

Study area: The Narmada River basin includes the northern and southern slopes of Satpuras and Vindhyas and also the streams that flows into Ganga and Yamuna situated in Madhya Pradesh is selected (Fig. 1). The whole catchment area, which constitutes an area of 93398 km^2 is considered. The Narmada basin lies between north latitude 21°20° - 23°45° and east longitude 72°32°-81°45°. For this study, daily data had been collected for 4 years (2012-2015, Fig. 1) and the first 75% of the data is considered for training and the remaining for testing

In developing a forecasting model the inputs considered here are the rainfall and discharge. The following steps are involved in framing a generalized stacked (Fig. 2).

1. Frame an input pattern using the rainfall and discharge data provided.
2. Choose the suggested models that are said to perform better in the existing literatures.
3. Divide the data for training and testing phases.
4. Train the data using different machine learning

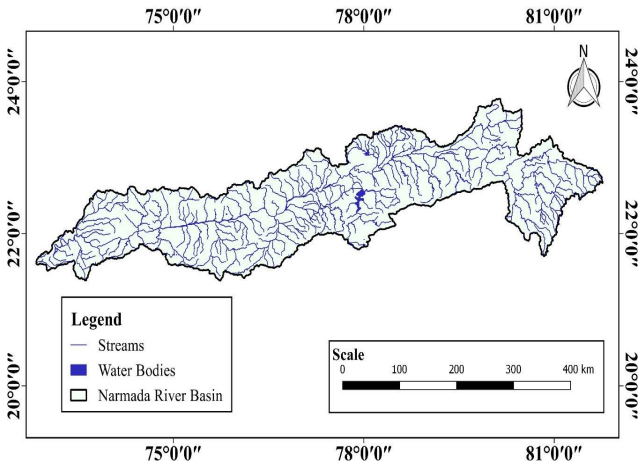

Fig. 1. Narmada river basin, India

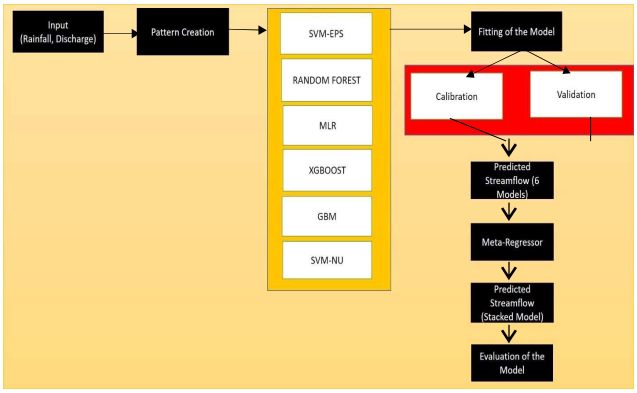

Fig. 2. Schematic representation of the Ensemble model

algorithms followed by testing phase for prediction using the previous experience gained from the training phase.

5. Combine all the predicted data of the individual models and train it again using a meta-level algorithm (followed by testing phase).
6. The performance of the individual models and the stacked models are evaluated using the statistical measures such as root mean square error, mean absolute error, nash sutcliffe error, coefficient of determination percentage bias and percentage error.
7. Finally, the individual model performance results are compared with the stacked model and the conclusions are made.

Based on the literature the individual models considered for this study are Support Vector Machine- Epsilon, SVM-NU, Random Forest, Gradient Boosting Machine, Extreme Gradient-Boost and Multiple Linear Regression.

Selection of input: The most important part of model development is selection of the input parameters and not all the input variables are informative some may be noisy and nowhere related to the output generation. Hence it is necessary to understand the relationship between the variables (Maier and Dandy 2000. When the relationship to be modeled is not understood properly, then the statistical techniques such as cross correlation, auto correlation is employed *(*Silverman and Dracup 2000, Coulibaly and Bobee 2001, Sudheer et al 2002*)*. The current study employed the method suggested by (Sudheer et al 2002) for selecting the input which input variables that are influencing the output variables during different time lags can be identified using various statistical techniques such as Cross correlation, Auto- correlation, Partial auto-correlation.

The data shows significant correlation at 1st and 2nd time lag on the flow at any time. Hence the following input variables are selected for modelling: RT-1, RT-2, DT-1, DT-2 where, RT represents rainfall and DT represents Discharge. From the total available data from 2012-2015 input patterns were created using the method suggested *by* (Sudheer et al 2002.) The 6732 patterns were identified and divided into training and testing data. Finally, the same data has been applied to all the individual models and the results are compared.

Framework

Stacking: Stacking a novel approach introduced by Wolpert in 1992 in order to combine multiple classifiers. The idea behind stacking is to learn from the output of the base level classifiers using a meta-learner. Stacking can be defined as the combination of multiple classifiers or regressors generated by different base learning algorithms I_1, I_2, ……, I_n using single dataset D, which is a feature vector can be written as ci = (ai, bi). The technique of stacking can be defined as follows:

I. Generate a set of base-level regressors R_1, R_2,… R_n Where $R_i = I_i(D)$

ii. Train a meta level regressor to combine the outputs of the base-level regressors.

Performance evaluation: The performance of the model is evaluated using statistical techniques that are used in standard and referred as “Goodness of Fit” (Nayak et al 2005). The metrics employed in this study are RMSE, MAE, NSE, R^2, PBIAS. Many studies have used some of the above-mentioned performance metrics used RMSE, NSE as one of the main measures in order to justify the effectiveness of the prediction. NSE is the measure that reproduces the closeness between the observed and the predicted values. RMSE is considered to be one of the common measure for daily, hourly and monthly flow prediction hence employed in this study. Each of these statistical measures have been widely used to measure the performances of the data driven models. (Kisi (2009) developed a study on intermittent flood

forecasting using Artificial Neural Networks and wavelet conjunction model, where RMSE and MAE had been used as the performance measures. The performance of the stacked model is evaluated using these statistical measures since they are most commonly used measures in forecasting floods and applicable to most of the data driven models. RMSE increases from zero to large positive values. A high value of R^2 and a very small RMSE indicates a very good model and R^2 is sensitive to outliers it should not be the only goodness-of-fit criteria in model simulation. Additional insight about the model can be provided by the Nash Sutcliffe efficiency (Value = 1, best fit). The percent bias (PBIAS) provides the percentage tendency of the observed and simulated data. The optimal value of the PBIAS is 0 and the low values are satisfactory, positive and negative value indicates the underestimation and overestimation (Table 3).

RESULTS AND DISCUSSION

Forecast at 1-day Lead-Time: Performance metrics were evaluated for all the individual models and compared with the stacked model at 1-day Lead-Time during Training and Testing Phases (Table 1). The NS efficiency is greater than 95% for XG-Boost and Stacked model, whereas around 50% for SVM-EPS, SVM-NU and RF, but for GBM and MLR it is less than or equal to 50% (Table 1). R^2 value is higher and the RMSE value is lower in the stacked model. Lower the RMSE, higher the accuracy of the model. Similarly, PBIAS, MAE, shows significant accuracy in the stacked model. During the testing phase, stacked model showed the highest accuracy by having NSE=0.98 when compared to the individual models. RMSE values are better in testing phase of stacked model than in the training phase which shows that the stacked model results are the combination of all the individual models. The value of R^2 (0.99), shows the best predictive ability of the ensembled model whereas it is comparatively low for all the other individual models.

The error percentage of all the models is around 90% at one day lead time (Table 2). The positive value indicates overestimation and the negative value indicate underestimation of the predicted discharge value. The highest peak estimated by the stacked model has an error percentage of less than or equal to 5% during one day lead time. The Stacked model predicts the peaks accurately than the other individual models and the predictive ability of the stacked model is higher than the individual models (Fig. 3).

Forecast at >1-day lead-time: The models are simulated for

Table 1. Comparison of model performance at 1-day lead-time during training phase

Performance measures	SVM- EPS	RF	MLR	XG- BOOST	GBM	SVM- NU	STACKING
Training Phase							
MAE	436.76	370.05	607.9	153	483.75	435.35	32.74
PBIAS	-27	-37.9	-64.8	-17.6	-44.8	-27.5	0.1
R2	0.48	0.67	0.4	0.97	0.45	0.48	0.98
RMSE	1829.42	1607.58	2201.93	723.85	1972.81	1832.23	312.53
NSE	0.43	0.56	0.18	0.91	0.34	0.43	0.98
Testing Phase							
MAE	199.75	228.33	254.9	57.58	219.6	199.39	32.74
PBIAS	-15.3	-31.9	-48.9	-13.8	-33.8	-15.7	2
R2	0.61	0.52	0.56	0.95	0.56	0.61	0.99
RMSE	679.62	757.78	870.31	212.59	752.69	682.37	72.42
NSE	0.59	0.49	0.33	0.96	0.5	0.59	0.98

Table 2. Comparison of Percentage error of all the models during 1-day lead-time

Peaks	Observed peaks (m^3/sec)	Percentage Error (%)						
		SVM- EPS	RF	MLR	XG- BOOST	GBM	SVM- NU	STACKING
P1	759.079	-73.4447	-85.2723	-74.7369	-11.7225	-84.7535	-73.1938	1.841312
P2	1486.548	-98.3282	-98.7074	-97.9902	-13.467	-98.8578	-98.2972	-2.3036 4
P3	1159.838	-99.4456	-99.0148	-99.9141	-9.02566	-99.4093	-99.3794	2.868088
P4	955.606	-85.3048	-85.1282	-81.9014	-16.7393	-89.893	-85.3007	-10.7175
P5	1157.144	-73.9964	-80.7638	-76.6368	-8.81386	-85.4796	-74.187	3.10758

2 to 5 days lead time gives the range of the performance metrics from which the performance of the models can be evaluated (Table 3). The values of the stacked model are satisfactory on every metrics. Lower the RMSE, better the model. The Stacking shows lower RMSE in testing phase when compared to training phase. The value of PBIAS ranges from ±10 where, 0 indicates perfect model. The value of PBIAS in testing phase its less than 1 which shows better accuracy than individual models. The Coefficient correlation between the observed and predicted data has been calculated and the values for all the 5 lead time show a very good fit. The value of NSE shows the perfect fit at all the lead times. It is clearly evident that from the performance statistics stacked model performs better than the individual models in all the aspects.

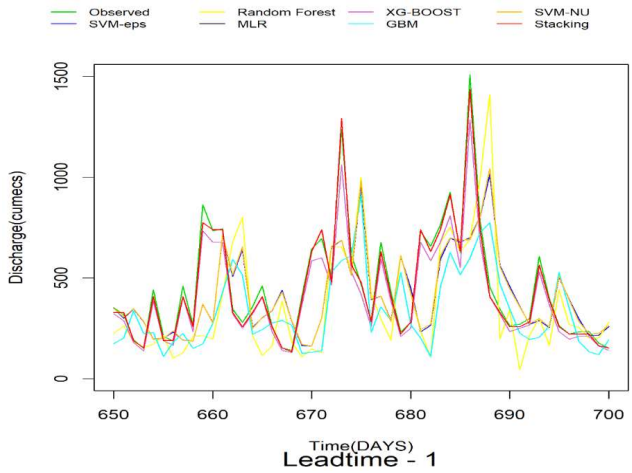

Fig. 3. Observed and simulated peak discharge of the testing phase during lead-time-1

Peak flow estimation: The performance statistics 4 gives us accurate information about the model's overall performance (Table 4). But it fails to provide information about the performance of the model at high flows. Hence other important measure called Percentage Error is considered in order to understand the model's performance at high flows in the testing phase. The value of Percentage Error can be calculated as follows:

$$\text{Percentage error} = \frac{\text{Simulated discharge-Observed discharge}}{\text{Observed discharge}} * 100$$

The positive values indicate over-estimation and the negative value indicates under- estimation of the peak flows. The five typical peak flows during the testing phase Indicate that these peak flows have been taken during different time durations and different flood event (Table 4). Stacked model can able to forecast the peak flows at higher accuracy even till 5th lead time and the error rate is less when compared to the model that is suggested by (Nayak et al 2005) for the same case study Stacking gives us the percentage error of less than 10% for 2 to 5 days lead time

Table 3. Performance evaluation of the stacked model during the testing phase

Statistical criterions	Value	Classification of performance	L2	L3	L4	L5
$MAE = \sum_{i=1}^{n} \frac{y(obs) - y(sim)}{n}$	Varies according to the data	NIL	30.99	31.15	25.17	20.73
$PBIAS = \frac{\sum_{i=1}^{n} y(obs) - y(sim)}{\sum_{i=1}^{n} y(obs)^2} * 100$	PBIAS<±10	Very good	0.8	0.8	0.7	-0.5
	±10≤PBIAS<±15	Good				
	±15≤PBIAS<±25	Satisfactory				
	PBIAS≥±25	Unsatisfactory				
$R^2 = 1 - \frac{\sum_{i=1}^{n} y(obs) - y(sim)^2}{\sum_{i=1}^{n} y(obs) - y(obs\ mean)^2}$	0 to 1, if 1	Very Good	1	1	0.99	0.99
	0.75 to 1	Good				
	≤0.5	Unsatisfactory				
$RMSE = \frac{\sum_{i=1}^{n} y(obs) - y(sim)^2}{n}$	Value below half of the Standard Deviation	Satisfactory	80.76	82.2	66.5	78.62
$NSE = 1 - \frac{\sum_{i=1}^{n} y(obs) - y(sim)^2}{\sum_{i=1}^{n} y(obs) - y(mean)^2}$	0.75<NSE≤1.0	Very Good	0.99	0.99	0.99	0.99
	0.65<NSE≤0.75	Good				
	0.50<NSE≤0.65	Satisfactory				
	0.4<NSE≤0.50	Acceptable				
	NSE≤0.4	Unsatisfactory				
	0.4≤NSE≤0.70	Acceptable				

Table 4. Comparison of percentage error of all the models during 2-5days lead-time

Lead-times (Days)	OBS (m^3/sec)	SVM- EPS (%)	RF (%)	MLR (%)	XG- Boost (%)	GBM (%)	SVM- NU (%)	STACKING (%)
2	759.079	- 86.3813	- 87.7286	-84.5809	-10.9967	-89.386	- 86.2399	-0.63813
2	1486.548	- 98.4597	- 98.8906	-98.0291	-13.485	-99.2853	-98.493	-1.53619
2	1159.838	- 98.5676	- 99.2536	-96.95	-9.04375	-99.3263	- 98.5454	3.03373
2	955.606	- 86.3728	- 87.4433	-79.9622	-16.7554	-88.4389	- 86.2422	-7.15745
2	1157.144	- 86.9939	- 87.5372	-82.4816	-8.83199	-88.454	- 86.7863	3.273608
3	759.079	- 89.3379	- 90.7544	-87.7929	-11.2304	-91.768	- 88.9392	0.540795
3	1486.548	-98.3816	-99.0056	-97.9232	-13.6843	-99.2257	-98.4259	-3.89357
3	1159.838	- 98.0325	- 98.6357	-96.6574	-9.979	-99.1667	- 98.0448	-1.00879
3	955.606	-85.109	-84.151	-75.6667	-16.828	-85.9501	-85.0715	-3.48765
3	1157.144	- 80.6814	- 81.4262	-78.7628	-9.76942	-78.1397	-80.282	-0.77832
4	759.079	- 87.7932	- 91.8084	-84.3458	-11.2452	-90.7383	- 87.3201	-3.47374
4	1486.548	- 98.1649	- 98.7723	-97.6755	-13.7119	-98.7985	- 98.2634	-0.7359
4	1159.838	- 98.3195	- 98.1842	-97.5293	-9.98373	-99.37	- 98.2115	2.595456
4	955.606	- 86.8438	- 89.4564	-77.9406	-16.8298	-89.5861	- 86.9585	-7.02057
4	1157.144	-79.2287	-77.7514	-80.052	-9.77416	-81.2399	-78.4922	2.834313
5	759.079	- 85.7754	- 91.1207	-85.1131	-11.8841	-85.1815	- 85.4676	-8.88807
5	1486.548	- 97.5598	- 97.6217	-97.9486	-17.7951	-98.0461	- 97.6868	-2.95424
5	1159.838	- 99.0649	- 99.0702	-99.1465	-9.96138	-99.4674	- 99.0736	5.267806
5	955.606	- 90.3079	- 91.6172	-90.5772	-13.6585	-91.3779	- 89.7906	0.578476
5	1157.144	- 80.9164	- 81.1235	-75.014	-9.75176	-78.2724	- 80.5214	5.512885

Table 5. Observed and simulated peaks for all 5 lead times

Observed peaks (m^3/sec)	Simulated peaks (m^3/sec)				
	L1	L2	L3	L4	L5
341.502	333.0547	350.1381	329.767	354.1042	357.3078
241.473	244.9212	240.7092	223.742	246.7151	235.0112
955.606	853.1894	887.209	922.2778	888.517	961.134
1572.517	1452.303	1566.311	1545.624	1518.187	1542.441
1260.527	1227.749	1195.024	1182.629	1300.473	1220.936
149.191	148.2729	160.1787	159.1797	159.2822	140.156

with higher accuracy (Table 5). Remaining models has the higher error percentage for all the lead time where RF has the highest error percentage, which shows the overestimation of peak flow discharges. SVM and MLR seems to perform quite better than RF where the error percentage is between 80-90. GBM at the next stage predicts at the little higher accuracy when compared to SVM and RF models. XG-Boost has quite higher prediction ability of all these models. The major peaks of the study area has been captured precisely for all the lead times (Table 5). The peak flow estimation of all the models during 2,3,4 and 5 days lead time indicate results are good still few peaks are 0ver-estimated or Under-estimated due to the uncertainty in the rainfall-runoff process (Fig. 4).

CONCLUSIONS

A stacked model for Narmada River basin, Madhya Pradesh, India has been developed in this study. Results indicates that Stacked Model gives the best performance in terms of all the statistical criteria during both the training and testing phase and the peak flow prediction shows the good predictive ability of the stacked model. The prediction of flood till 5-days lead time with the best performance metrics shows greater accuracy and the estimation of peak flow is also accurate in stacked model. Hence, the results are highly acceptable and suggest that the stacked model is viable for

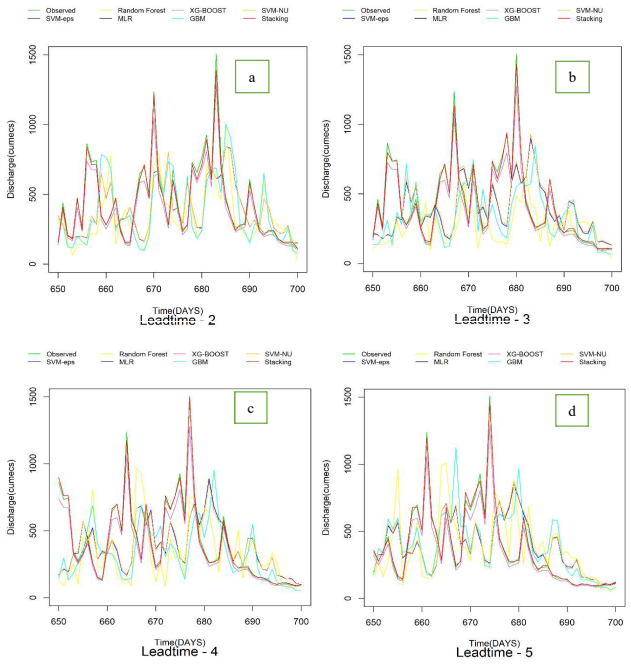

Fig. 4. Observed and simulated peak flow discharge by SVM-EPS, RF, XG-BOOST, SVM- NU, MLR, GBM, STACKING at 2-5 days lead-time [a, b, c, d]

accurate short-term flood forecasting. Future research can be focused on long term and real time forecasting and also the time to peak.

REFERENCES

Coulibaly P Anctil and Bobee B 2001. Multivariate reservoir inflow forecasting using temporal neural network. *Journal of Hydrologic Engineering* **6**(5): 367-376.

Faulkner H 1992. Simulation of summer storms of differing recurrence intervals in a semiarid environment using a kinematic routing scheme. *Hydrological Processes* **6**: 397-416.

Ghalkani H Golian S Saghafian, B Farokhnia A and Shamseldin A 2013. Application of surrogate artificial intelligent models for real-time flood routing. *Water and Environment Journal* **27**(4): 535-548.

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Kasiviswanathan KS, He J, Sudheer KP and Tay JH 2016. Potential application of wavelet neural network ensemble to forecast streamflow for flood management. *Journal of Hydrology* **536**: 161-173.

Kisi O 2009. Neural networks and wavelet conjunction model for intermittent stream flow forecasting. *Journal of Hydrologic Engineering* **14**(8): 773-782.

Maier HR and Dandy GC 2000. Neural networks for the prediction and forecasting of water resources variables: A review of modeling issues and application. *Environmental Modelling and Software* **15**: 101-124.

Mesgana Seyoum Gizaw and Thian Yew Gan 2016. Regional flood frequency analysis using support vector regression under historical and future climate. *Journal of Hydrology* **538**: 387-398.

Shiyamala Gowri G and Ganapathy GP 2019. Model-based clustering approach for regional flood frequency analysis. *Indian Journal of Ecology* **46**(3): 493-504.

Nayak PC, Sudheer KP, Rangan DM and Ramasastri KS 2005. Short-term flood forecasting with a neurofuzzy model. *Water Resources Research* **41**(4): 1-16.

Nikam V and Gupta K 2013. SVM-based model for short-term rainfall forecasts at a local scale in the Mumbai urban area, India. *Journal of Hydrologic Engineering* **19**(5): 1048-1052.

Qu,Jian and Ming J Zuo 2010. Support vector machine-based data processing algorithm for wear degree classification of slurry pump systems. *Measurement* **43**(6): 781-791.

Silverman D and Dracup JA 2000. Artificial neural networks and long-range precipitation in California. *Journal of Applied Meteorology* **31**(1): 57-66.

Singh J, Knapp HV, Arnold JG and Demissie M 2005. Hydrological Modeling of the Iroquois River Watershed Using HSPF AND SWAT1 2005. *Journal of American Water Resources Association* **41**(2): 343-360.

Sudheer KP, Gosain AK and Ramasastri KS 2002. A data-driven algorithm for constructing artificial neural network rainfall-runoff models. *Hydrological Processes* **16**: 1325-1330.

Sunmin Lee, Jeong-Cheol Kim, Hyung-Sup Jung, Moung Jin Lee and Saro Lee 2017. Spatial prediction of flood susceptibility using random-forest and boosted-tree models in Seoul metropolitan city, Korea, Geomatics. *Natural Hazards and Risk* **8**(2): 1185-1203.

Vapnik V N 1995. *The Nature of Statistical Learning Theory*. Springer-Verlag, New York, USA. 314 p.

Wolpert D 1992. Stacked generalization. *Neural Networks* **5**(2): 241-260.

Dibike YB, Slavco Velickov, Dimitri Solomatine and Abbott MB 2001. Model induction with support vector machines: Introduction and applications. *Journal of Computing in Civil Engineering* **15**: 208-216.

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Effect of Pollutants of the Tigris River Water on Activity of the Acetylcholinesterase Enzyme in Brain Tissues of *Cyprinus carpio* and *Condrostoma regium*

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Abstract: This study was conducted to record effect of lead and cadmium in the Tigris River on the activity of the acetylcholinesterase (AChE) enzyme in the brain tissue of local fish *Cyprinus carpio* and *Condrostoma regium*. The effect on physical and chemical properties was also estimated. Three sites were chosen in the study area representing the entering of the river to the city of Mosul (Wana region), the city center (after the estuary of Al-Khosar), and the south of the city (Al-Busaif area). Water samples were collected monthly for the period from June 2018 until the end of March 2019 and fish were collected from the same sites. The results showed fluctuation in water temperature, electrical conductivity, pH, total hardness, dissolved oxygen concentration, and the biochemical oxygen demand as well as the concentration of accumulated heavy metals shown by lead and cadmium, which are the most polluting heavy metals in river water. There was significant inhibition of the activity of the acetylcholinesterase (AChE) enzyme in the brain tissue of both local fish during the autumn, winter and spring seasons. This study concludes that the toxic activity of different pollutants leads to inhibit the activity of the AChE enzyme in the brain, therefore, it can be used as a guide for the impact of pollutants on aquatic organisms such as fish.

Keywords: Acetylcholinesterase, Tigris River, Heavy metals, *Cyprinus carpio*, *Condrostoma regium*

Environmental pollution of aquatic ecosystems is one of the most serious problems that cause abnormal effects on the environmental balance. The pollutants are concentrated and accumulated in aquatic organisms, especially animals, such as fish that can collect these pollutants at higher concentrations than in water and bottom sediments (Al-Sarraj 2013). The feeding of fish is also on the organic materials in the water environment, chemical fertilizers and pesticides, in addition to the effluent water that brings with it a lot of human, agricultural and industrial wastes to the water bodies. All of these are work to increase the pollution of biochemical loads, and its transition to humans through the food chain (Olaifa et al 2004). The poor infrastructure, lack of health control, and increased waste disposal directly to the Tigris River without treatment during its flow into the city, have negatively affected the water quality and to the aquatic environment in terms of their suitability for living fish and other aquatic life. Fish is one of the most important vertebral groups inhabiting in the aquatic environment and is a good indicator for assessing the ecosystem's health, as it can metabolize and store pollutants accumulatively in the tissues of their organs through the need for large quantities of water during the breathing process (Dural et al 2007). Their effect is transmitted from one organism to another by feeding through the food chain (Tiimub and Afua 2013). Fish are located at the top of the food chain in aquatic ecosystems (Rasheed 2012). The accumulation of these pollutants is also influenced by various environmental factors in the surrounding water (Van den Broek et al 2002). Several studies indicated that some organisms can be present and reproduce in polluted environments. This is useful in the process of sensitization to the presence of environmental changes, which indicates that these organisms are sensitized to specific environmental factors. Biomarkers are living organisms that can respond to limited changes as well as beings that can the pollutants accumulate within their tissues. Exposure of living animal organisms such as insects and fish to trace concentrations of heavy metals and other pollutants results in changes in biochemical metabolic pathways stimulated by enzymes, which leads to inhibit their activity. This is because pollutants can destroy the conformation enzymes that perform vital functions in the body, including neurological effects. Pollutants are specialized in their effect on the nervous system in these organisms because they inhibit the acetylcholinesterase activity. This enzyme is widely found in the animal kingdom and is evidence of the activity and vitality of living organisms, and it has an important physiological role in the kinematics mechanism. It is one of the enzymes that have a fundamental role in the transmission of nerve instructions in the locations of synapses in the brain and

motor nervous end like the muscles (Senger et al 2006). Then, the nerve instructions regulate the permeability of plasma films (Sant Anna et al 2011). The environmental pollution caused by the presence of lead contributes to physiological damage and behavior imbalance, in addition to a sudden exit of the neurotransmitters in their places such as dopamine and acetylcholine. The death of neural cells in the central nervous system when constantly exposed to low concentrations of lead (Struzynska et al 2007). Cadmium is a non-essential, highly toxic element that enters the aquatic environment through agricultural wastes containing fertilizers and industrial and household pollutants (Afshan et al 2014). Also, the low concentrations of Cadmium cause headache and nausea symptoms (Cheng and Gobas 2007). The organic phosphorous compounds have a significant inhibiting effect on the acetylcholinesterase enzyme AChE, these compounds are used as agricultural pesticides. Insecticides and bushes are considered among the most organic pollutants in river water (Al-Hamdani 2010). The Tigris River is exposed to continuous additives from estuaries that carry agricultural, industrial and human wastes. Further, Torrents and rain carry wastes and residues, agricultural fertilizers and pesticides, The objectives of this study are to know the impact of the pollutants on the behavior and activity of fish by estimating the activity of the acetylcholinesterase enzyme AChE in brain tissues of two local fish collected from three different regions along the Tigris River within the city of Mosul, during the seasons of the study.

MATERIAL AND METHODS

The current study was conducted on the water of the Tigris River within the Mosul city for the period from June 2018 until the end of March 2019.

The first site: the water of the Tigris River in the north of the Mosul city (Wana site), it considered as a control area for comparison.

The second site: the water of the Tigris River in the center of the Mosul city (after the confluence of the Tigris River with the Al-Khoser River).

The third site: the water of the Tigris River in the south of the Mosul city (near the Al-BuSaif site).

Water sampling analysis: Water samples were collected from the three sites starting from June 2018 until the end of March 2019, with one monthly sample from the water surface. Samples were collected using bottles made of polyethylene. For estimating the concentration of dissolved oxygen (DO) and biochemical oxygen demand (BOD5), samples collected by 250 ml glass bottles. Physical and chemical properties and heavy metals (Pb and Cd) tests have been performed according to (APHA 1998).

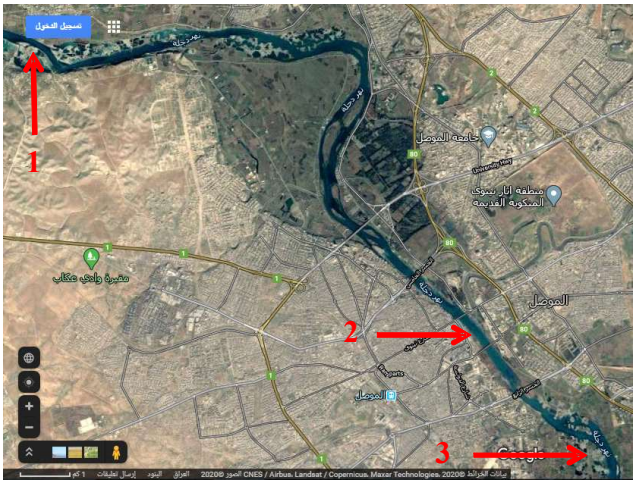

Fig. 1. The Tigris River within the Mosul city from (Google Earth)

Collecting the local fish samples: The studied fish samples were collected from the three sites on the Tigris River by one sample per month. Two types of local fish were selected, which are used by humans as food, these are *Cyprinus carpio* and *Condrosto meregiu*m with close weights between 15-20 cm and ages not exceeding one year. The ages of the fish were estimated by relying on the scales of each fish according to Lagler (1956) by 3 replicates for one species, for each site and season during the study period. The fish were transported to the laboratory and anatomized to extract the brain from two types of fish, according to Lucky (1977), to evaluate the activity of the AChE enzyme in the extracted brain.

Estimating the activity of AChE enzyme in the extracted brain: The activity of the enzyme was estimated according to the Ellman chromatographic method (Ellman et al 1961). It is one of the most important methods for estimating the activity of enzymes in the blood and tissues. The AChE enzyme stimulates the acetylthiocholine basic substance to thiocholine and acetic acid. The estimating of the activity is depended on the product reacts with the 5:5- Dithiobis 2-Nitrobenzoic Acid (DTNB) agent, producing a yellow color. The intensity of the yellow color is directly proportional to the activity of the enzyme, which indicates an increase in its activity. It was measured at the wavelength of 412 nanometers using a Spectrophotometer, as shown in the following equations:

$$\text{Acetylthiocholine} + H_2O \xrightarrow{\text{AChE}} \text{Thiocholine} + \text{acetate}$$

Thiocholine + 5:5- Dithiobis- 2-Nitrobenzoic Acid → Yellow color

The absorption intensity was measured after 1 minute and then after 3 minutes. The AChE enzyme activity was calculated according to the following law:

AChE enzyme activity (micromol / min / gm wet weight) =

$$\frac{\text{Change in absorbance} \times \text{micromol} \times \text{Volume of reaction solute (ml)}}{\text{Min.} \times 13.6 \times \text{vol. (ml)} \times \text{tissue weight (gm)}}$$

Statistical analysis: The results were statistically analyzed using Complete Randomized Design. Differences between the sites and studied fish types with the control group were determined using Duncan's Multiple Range Test for all physical and chemical properties and AChE enzyme activity at probability (P≤0.01) using the Statistical program SPSS.

RESULTS AND DISCUSSION

Physical and chemical properties of the Tigris river water: The fluctuation in the water temperature was observed at various sites and seasons of the year. High water temperature was in the second and third sites in the summer season as a result of mixing the water with estuaries that had high pollutant scontained (Table 1). This increase in temperature has an effect on the rate of chemical reactions and to the behavior of the living organisms, in addition to the amount of the dissolved oxygen in the water consumed by aquatic organisms (Saadalla et al 1997). The high values of electrical conductivity in polluted sites cause an increase in the toxicity of many pollutants such as lead, cadmium, and zinc (Harrison 2006). The high conductivity values were observed at the spring season in the second site (522 µS/cm), as a result of increased water turbidity, increased rainfall, and high water levels resulting in bulldozing large quantities of agricultural soils on both sides of the river. The pH value ranged between 6.7-8.1and decreased during the winter season at the second site as a result of mixing the water with estuaries. The pH value accelerates the processes of bio-degradation and bio-oxidation and contributes to forming a variety of compounds such as mineral carboxylic acids. The pH plays a significant role in the toxic impact because it affects many toxic substances present in the environment.

The high concentration of dissolved oxygen in water is an indicator of environmental quality. The maximum dissolved oxygen in the first site was 8.5 mg/l in the winter because the concentration of dissolved oxygen is inversely proportional to the environment temperature. The dissolved oxygen in the second site at the summer is reduced to 6.2 mg/l, due to the presence of liquid waste discharged from the estuaries that lead to reduce the concentration of dissolved oxygen. The BOD_5 values are inversely proportional to Do values, the minimum at the first site is 0.8 mg/l in the spring, and the maximum 2.4 mg/l in the second site in the winter. It is attributed to the increase in pollutants, and the rain floods discharged to the river. The maximum value of total hardness in the second site was 328 mg/l in the winter, because of the mixing of estuaries and floods with the river.

Nutrients (nitrates and phosphates) play an important role in the vitality of fish because their presence has a detrimental effect on fish. The increase in nitrate ion concentration forms a risk to the ability of the aquatic organisms to bio accumulate heavy metals in their tissues. The less nitrate concentration value at the first site during the summer was 0.2 mg/l, while at the second site the highest was 1.6 mg/l in the spring. This is due to domestic and human waste, and what the heavy rain and flooding carry to the river. Related to orthophosphate concentration, the less concentration at the first site is 0.01 mg/l in the summer, and the high concentration in the second site is 0.31 mg/l in the spring. This increase is attributed to the high level of detergent powders, agricultural fertilizers, and pesticides such as organic phosphorous compounds that flow with rainwater and floods into the Tigris river.

Table 1. Physical and chemical properties and concentration of lead and cadmium for the waters of the Tigris River for the studied sites during the seasons of the year 2018-201

Seasons	Summer			Autumn			Winter			Spring		
Sites/Variables	1	2	3	1	2	3	1	2	3	2	1	3
Temperature (°C)	24.5	25	25	22	22.6	23	12.1	13	13.4	15.5	15	16
EC_{25} (µS/cm)	354	390	401	363	431	392	430	446	450	522	501	516
pH	7.7	7.1	7.6	7.8	7.2	7.4	7.9	6.7	7.1	6.9	8.1	7.5
DO (mg/L)	7.9	6.2	7.5	7.8	6.8	7.1	5.8	7.2	7.7	7.5	8.3	7.7
BOD_5 (mg/L)	1.3	1.8	1.2	1.2	2	1.3	1	2.4	1.5	1.2	0.8	1.4
TH (mg/L)	220	235	230	232	266	257	260	328	326	320	311	324
NO_3^- (mg/L)	0.2	0.6	0.5	0.8	1.2	1	1.1	1.4	1.2	1.6	1.2	1.4
PO_4^- (mg/L)	0.01	0.09	0.07	0.08	0.12	0.09	0.21	0.3	0.28	0.31	0.23	0.26
Pb (mg/L)	0.01	0.09	0.07	0.06	0.11	0.09	0.12	0.22	0.15	0.26	0.19	0.24
Cd (mg/L)	0.002	0.006	0.004	0.003	0.007	0.005	0.011	0.019	0.014	0.023	0.012	0.019

The concentrations of lead and cadmium in the three sites, the concentrations differ from one site to another with seasonal changes in their concentration levels. Such heavy elements have harmful effects on aquatic organisms via bio-accumulate within their tissues (Gulfraz et al 2001) and the concentrations in the first site were low in the autumn, while increased in the second and third sites due to the mixing of estuaries with the human activities, agricultural wastes, and industrial wastes of civil factories in the city. Lead can affect the central nervous system and accumulate in the fish bones andis toxic element that passes by wastewater, industrial and solid waste into aquatic ecosystems. The high concentration of lead causes brain and nerve changes in fish and other aquatic organisms (Kalay et al 1999).

Correlation coefficient: The correlation coefficient showed a wide range of statistical relationships between two variables of qualitative water parameters (Table 2).

Temperature: A positive relationship between the temperature and pH, BOD_5, orthophosphate, and cadmium ion. The negative relationships were shown between temperature and electrical conductivity, dissolved oxygen, total hardness, nitrate ion and, lead.

Electrical conductivity: The positive relationships between electrical conductivity and dissolved oxygen, total hardness, nitrate ion, orthophosphate, lead and cadmium and negative to pH and BOD_5.

pH: The positive relationship between pH and dissolved oxygen was 0.203, while the relationship between pH and the other properties was negative.

Dissolved oxygen: A negative relationship was observed between dissolved oxygen with BOD_5 and cadmium ion, and positive relationship was observed with total hardness, nitrate ion, orthophosphate, and lead**.**

Biochemical oxygen demand: The relationships between BOD_5 and total hardness, nitrates, orthophosphates, lead, and cadmium were positive.

Total hardness: The relationships between total hardness and the nitrate ion, orthophosphate, lead, and cadmium are positive.

Nitrates: The results showed positive relationships between nitrates, and orthophosphates, lead, and cadmium.

Orthophosphate: Positive relationships were observed between orthophosphate, and lead and cadmium, it reached to 0.930 and 0.493 respectively.

Lead and Cadmium: Positive relationships found between the lead and cadmium elements (0.454).

Activity of AChE enzyme in brain tissues of local fish: The highest inhibition ratio in the activity of the AchE enzyme in the extracted brain tissues of the both fish, collected from the city center in the spring and autumn seasons, was 37, 32 in *Cypriuns carpio* and 24, 21 in *Condrostoma regium*, respectively, compared to the activity of the AChE enzyme in the extracted fish brain tissues collected from the first site (Wana site) which was considered to be a control group. Correspondingly, there is a significant inhibition in the activity of the AChE enzyme in the extracted brain tissues of the *Cyprinus carpio* of 31%, 21%, and 15%, and in *Condrostoma regium* is 14%, 10%, 6% in the third site at the autumn, spring, and winter respectively, (Table 3). A significant inhibition in the enzyme activity of *Condrostoma regium* in the third site is seen as a less ratio than in the *Cyprinus carpio*, The significant increase, was due to the high temperature of the water in the summer that leads to increase the kinetic energy of the enzyme and its binding with AChE enzymein the central nervous system (Nelson and Cox 2013). Inhibition is considered the main

Table 2. Correlation between physical and chemical properties and heavy metals (lead and cadmium) in the waters of the Tigris River within the Mosul city

Variables	Temperature	EC	pH	DO	BOD_5	TH	NO_3^-	PO_4^-	Pb	Cd
Temperature	1.000	-0.697	0.108	-0.009	0.044	-0.819	-0.763	0.840	-0.387	0.009
EC		1.000	-0.184	0.213	-0.102	0.871	0.840	0.859	0.938	0.187
pH			1.000	0.203	-0.788	-0.404	-0.387	-0.393	-0.399	-0.562
DO				1.000	-0.286	0.265	0.009	0.075	0.140	-0.025
BOD_5					1.000	0.174	0.154	0.118	0.121	0.670
TH						1.000	0.881	0.950	0.922	0.483
NO_3^-							1.000	0.893	0.906	0.390
PO_4^-								1.000	0.930	0.493
Pb									1.000	0.454
Cd										1.000

* Correlation is a value between the value +1 and -1. +: positive relationship. -: negative relationship

Table 3. Activity of the AChE enzyme (μ mol/min/gm wet weight) in the brain tissue of *Cypriuns carpio*

Seasons/ Locations	Summer			Autumn			Winter			Spring			Average %
	Enzyme activity	Activity %	Change %	Enzyme activity	Activity %	Change %	Enzyme activity	Activity %	Change %	Enzyme activity	Activity %	Change %	
North of the city	0.205jk	100	-	0.341a	100	-	0.261c	100	-	0.306b	100	-	0.278a
City center	0.221fg	107	+7	0.216gh	63	-37	0.200k	76	-24	0.208ij	68	-32	0.211c
South of the city	0.214hi	104	+4	0.234e	68.8	-31	0.223f	85	-15	0.243d	79	-21	0.228b

* Numbers followed by vertically different letters indicate a significant difference at the probability level (P≤0.01) according to the Duncan test

Table 4. Activity of the AChE enzyme (μ mol/min/gm wet weight) in the brain tissue of *Condrostoma regium*

Seasons/ Locations	Summer			Autumn			Winter			Spring			Average %
	Enzyme activity	Activity %	Change %	Enzyme activity	Activity %	Change %	Enzyme activity	Activity %	Change %	Enzyme activity	Activity %	Change %	
North of the city	0.217d	100	-	0.274a	100	-	0.188g	100	-	0.2203c	100	-	0.224a
City center	0.222e	107	+7	0.206f	76	-24	0.148j	79	-21	0.176h	80	-20	0.186c
South of the city	0.224c	103	+3	0.242b	90	-10	0.162i	86	-14	0.206f	94	-6	0.209b

* Numbers followed by vertically different letters indicate a significant difference at the probability level (P≤0.01) according to the Duncan test

objective of pollutants effect on the AChE enzyme activity in the extract of the two fish species collected from the studied area. Inhibition in the AChE enzyme activity in the second and third sites during the autumn, winter and spring seasons is due to the increased concentrations of pollutants present in the water of the study area, such as lead, cadmium and phosphorous compounds, nitrates, etc. which are known to be inhibitors of the AChE enzyme activity. Lead, cadmium, zinc, mercury, and iron are among the industrial chemical mineral pollutants that decrease the AChE enzyme activity in the extracted brain tissues from various types of fish such as *Oerochrmic niloticus, Seriola dumerilli, Danio rerio, and Snails and Crustaceans*, (Jebali et al 2006, Richetti et al 2011, Sant Anna et al 2011, Sen and Karaytug 2017). These scientists attributed this to the increase of the accumulation of heavy metals in the brain, which enters to the body of the organism through several methods and accumulates with high concentrations in tissues and various organs. Their accumulation leads to a breakdown of the structure of enzymes (Yazkan et al 2004). The cause of inhibition the activity of the AChE enzyme according to (Richetti et al 2011) is the joining of heavy metals such as lead with the functional groups of negative charge of proteins (enzymes) such as carboxyl, sulfhydryl, and imidazole groups in the active locations of the enzyme leading to a change in the structure of the specific locations of the joining of the basic substance. It leads to the non-decomposition to the product of the reaction, so the enzymes lose their catalytic activity due to changes in certain functional groups that play an important role in the active locations of enzymes (Cokugras and Tezcan 1993). The inhibition of the activity of the AChE enzyme may be due to the high rate of organic phosphorous pollutants entering the water because it is commonly used as insecticides in veterinary and agricultural fields (to resist the external parasites in animals). These pollutants are related to the AChE enzyme and inhibit its activity in stimulating the natural decomposition of the basic substance of the AChE enzyme (Tilson 2000). The final consequence of this inhibition is the accumulation of the AChE enzyme in nerve endings of the nervous system (Al-Hamdani et al 2010, Lotti and Moretto 2005). The exposure of four species of local Brazilian fish: *Lagcephalus laevigatus, Genidens genidens, Mugil liza, and Gallus domesticus*, to a phosphorous organic pesticide leads to inhibit the activity of the AChE enzyme in the extracted brain tissues of (Freitas et al 2016). He also indicated that the AChE enzyme was more sensitive to inhibition by phosphorous organic compounds.

CONCLUSIONS

The AChE enzyme activity in fish brains can be used as evidence for the effect of the pollutants, including heavy metals and organic phosphorous pesticides. This study recommends carrying out further studies on aquatic organisms and fish as biological evidence. Also, it conducts periodic studies on the impact of pollutants and wastes on fish and other aquatic organisms in the Tigris river.

REFERENCES

Al-Hamdani AH Chloe MS and Fadel S S2010. The Effect of Pollutants in the Tigris River in Mosul on the Criteria for Lipid Fatigue and Antioxidants for the Tissues of the Common Carp Fish *Cyprinus Carpio*. (In Arabic). *Iraqi Journal of Veterinary Science* **24**(2): 81-88.

Al-Sarraj I S Y 2013. *Study of pollution of the Tigris River with the*

various wastes within the city of Mosul and its impact on a number of local fish, Ph.D. Thesis, College of Science, Mosul University,Mosul, Iraq, (In Arabic).

Afshan S, Ali S, Ameen US, Farid M, Bharwana SA, Hannan F and Ahmad R 2014. Effect of different heavy metal pollution on fish. *Research Journal of Chemical and Environmental Sciences* **2**(1): 74-79.

APHA (American Public Health Association) 1998. *Standard Methods for the Examination of Water and Wastewater*.20th Edition, American Public Health Association, New York, USA.

Cheng W W and Gobas FA 2007. Assessment of human health risks of consumption of cadmium contaminated cultured oysters. *Human and Ecological Risk Assessment* **13**(2): 370-382.

Cokugras AN and Tezcan EF 1993. Inhibition kinetics of brain butyrylcholinesterase by Cd^{2+} and Zn^{2+}, Ca^{2+} or Mg^{2+} reactivates the inhibited enzyme. *The International Journal of Biochemistry* **25**(8): 1115-1120.

Dural M, Goksu A and Ozak 2007. Investigation of heavy metal levels in economically important fish species captured from the Tuzla Lagoon. *Food Chemistry* **102**(1): 415- 421.

Ellman GL, Courtney KD, Andres V and Featherstone RM 1961. A new and rapid colorimetric determination of acetylcholinesterase activity. *Biochemical Pharmacology* **7**(2): 88-95.

Freitas AP, Santos CR, Sarinelli PN, Silva FM, Hauser- Davis R and Lopes RM 2016. Evaluation of a brain acetylcholinesterase extraction method and kinetic constants after methyl- paraoxon inhibition in three Brazilian fish species. *Public Library of Science* **11**(9): 1-10.

Gulfraz M, Ahmad T and Afzal H 2001. Concentration level of heavy and trace metals in the fish and relevant water from Rawal and Mangla Lakes. *Journal of Biological Science* **1**(5): 414-416.

Harrison RM 2006. *An Introduction to Pollution Science*,Royal Society of Chemistry, UK, p 345.

Jebali J, Banni M, Guerbej H, Almeida E, Bannaoui A and Boussetta H 2006. Effects of malathion and cadmium on acetylcholinesterase activity and metallothionein levels in the fish *Seriola Dumerilli*. *Fish Physiology and Biochemistry* **32**(1): 93-98.

Kalay M, Ay Ö and Canli M 1999. Heavy metal concentrations in fish tissues from the Northeast Mediterranean Sea. *Bulletin of Environmental Contamination and Toxicology* **63**(5): 673-681.

Lagler KF 1956. *Fresh Water Fishery Biology*. 2nd Edition. W.M.C. Brown Company, Dubuque, Iowa, USA, p. 545.

Lotti M and Moretto A 2005. Organophosphate-induced delayed polyneuropathy. *Toxicology Review* **24**(1): 37-49.

Lucky Z 1977. *Methods for the Diagnosis of Fish Disease*. Amerind Publishing, New Delhi, India,p140.

Received 13 April, 2020; Accepted 26 August, 2020

Nelson DL and Cox MM 2013. *Lehninger Principles of Biochemistry*, 6th Edition. W.H. Freeman and Company, New York, USA.

Olaifa FE, Olaifa AG, Adelaja AA and Owolabi A 2004. The heavy metal concentration of *Clarias gariepinus* from a lake and fish from in Ibadan, Nigeria. *African Journal of Biomedical Research* **7**(3): 145-148.

Rasheed RO 2012. Assessment of some heavy metals in muscle tissue of *Silurus triostegus* from Derbendikhan Reservoir Kurdistan Region-Iraq. *Al-Raffidin Journal of Science* **23**(1): 11-18.

Richetti SK, Rosemberg DB, Ventura- Lima J, Monserrat JM, Bogo MR and Bonan CD 2011. Acetylcholinesterase activity and antioxidant capacity of the zebrafish brain is altered by heavy metal exposure. *Neurotoxicology* **32**(1): 116-122.

Saadalla AA, Salmen JD and Alkublsi A 1997. A study on bioaccumulation of some heavy metal in four freshwater fish species of Iraq. *Al-Mustansiriya Journal of Science* **8**(3): 82-91.

Sant Anna MC, Soares VM, Seibt KJ, Ghisleni G, Rico EP and Rosemberg DB 2011. Iron exposure modifies acetylcholinesterase activity in Zebrafish (Danio Rerio) tissues: Distinct susceptibility of tissues to iron overload. *Fish Physiology and Biochemistry* **37**(3): 573-581.

Sen G and Karaytug S 2017. Effects of lead and selenium interaction on acetylcholinesterase activity in brain and accumulation of metal in tissues of *Oreochromis niloticus* (L., 1758). *Natural and Engineering Sciences* **2**(2): 21-32.

Senger MR, Rico EP, de Bem AriziM, Frazzon AP, Dias RD, Bogo MR and Bonan CD 2006. Exposure to Hg^{2+} and Pb^{2+} changes NTPDase and ecto-5-nucleotidase activities in central nervous system of zebrafish (*Daniorerio*).*Toxicology* **226** (2-3): 229-237.

Struzynska L, Dabrowska- Bouta B and Koza K 2007. Inflammation-Like Glial response in Lead exposed immature rat brain. *Toxicological Science* **95**(1): 156- 62.

Tiimub BM and Afua MAD 2013. Determination of selected heavy metals and iron concentration in two common fish species in The Densu River at Weija District in the Greater Accra Region of Ghana. *American International Journal of Biology* **1**(1): 45-55.

Tilson HA 2000. New horizon: Further directions in neurotoxicology. *Environmental Health Perspectives* **108**: 439- 441.

Van den Broek JL, Gledhill KS and Morgan DG 2002. Heavy Metal Concentration in the Mosquito fish, *Gambusia holbrooki*, in the Manly Lagoon Catchment. In: *UTS freshwater ecology report*, *Department of Environmental Science, University of Technology, Sydney* 1-25.

Yazkan M, Ozdemir F and Golukcu M 2004. Cu, Zn, Pb and Cd contents in some Molluscs and Crustacea caught in the gulf of Antalya. *Turkish Journal of Veterinary and Animal Sciences* **28**: 95-100.

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Stabilization of Marine Soil of Visakhapatnam Port Area by using Fly Ash Material

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Abstract: Fly ash is one of the by-products which attributes to the improvement of strength and compressibility characteristics of soils. The soil sample for the present study was taken from port trust area of Visakhapatnam in Andhra Pradesh. The raw material fly ash was also taken from Visakhapatnam unit of NTPC (National Thermal Power Corporation) and used for study and experimentation. In the present study, some of the laboratory tests have been carried out to determine the properties of marine clay taken and also highlighted the CBR (California Bearing Ratio) test which was conducted before and after addition of fly ash to determine the strength of soil. The specific gravity of the marine soil is 2.27. The Atterberg limits of the soil sample was silty sand (SM). The maximum dry density was within the range as per unified soil classification and hence can be used as sub grade material. The optimum fly ash content was in the range of 5 to 10 % and hence the soil strength can be increased by adding 5 to 10 % of fly ash to the marine soil.

Keywords: Soil stabilization, Fly ash, Marine soil, Laboratory tests and CBR

Soil stabilization refers to the use of natural or manufactured additives or binders to improve the properties of soils (Koteswararao et al 2012, Ravi et al 2018). Marine soils are abundantly available in coastal areas but not used for construction purposes because of their unusual properties. During the construction of Marina barrage in Singapore, marine clay was found at site. Since marine clay was the cause of Nicoll highway collapse years previous, the construction team removed all the marine clay to ensure the stability of Marina Barrage. Later on, they found marine clay mixed with sea water even in the deeper underground. Geotechnical problems posed by marine clay can be handled by various ground improvement techniques. Marine clay can be stabilized using wastes of various industries like porcelain industry and tree-cutting industries. Chemical additives such as lime, cement, saw dust and other chemical compounds have been used in marine clay stabilization for many years with various degrees of success. Fly ash is one such by-product which attributes to the improvement of strength and compressibility characteristics of soils (Robert 2009). This method is usually adopted in highways where marine clay is used as a sub grade soil. In order to achieve both the need of improving the properties of marine clay and also to make use of the industrial wastes, the present experimental study has been taken up. The main objective is to determine the properties of the marine soil and to evaluate the performance of marine soil when stabilized with fly ash as an admixture and its suitability for the pavement sub grade with an optimum content of fly ash. The disposal of fly ash is one of the major issues for environmentalist as dumping of fly ash as a waste material may cause severe environmental problems hazards. The utilization of fly ash instead of dumping it as waste material can be partly used on economic grounds as pozzolana for partial replacement of cement and partly because of its beneficial effects as lower demand for similar workability and lower evaluation of heat.

MATERIAL AND METHODS

The soil sample for the present study was taken from port trust area of Visakhapatnam in Andhra Pradesh. The raw material fly ash was also taken from Visakhapatnam unit of NTPC (National Thermal Power Corporation) and used for study and experimentation. Fly ash is fine grained pozzolanic material generally spherical in shape and includes substantial amounts of silicon dioxide (SiO_2) (both amorphous and crystalline), aluminum oxide (Al_2O_3) and calcium oxide (CaO). The main mineral compounds in coal-bearing rock strata. The marine soil sample and fly ash material used for experiments are shown in Figure 1 and 2.

Laboratory tests: There are five laboratory tests conducted to the mixtures of marine soil and fly ash. They are particle size distribution by sieve Analysis (Standard reference: IS 2720 Part 4), Specific Gravity of the soil (Standard reference: IS 2720 Part 3), Determination of soil index properties -

Atterberg Limits - Liquid Limit by Casagrande's apparatus and Plastic Limit Test (Standard Reference: IS 2720 Part 5), Determination of the maximum dry density (MDD) and the corresponding optimum moisture content (OMC) of the soil by standard Proctor Compaction Test (Standard Reference IS 2720 Part 7) (Satyam and Nisheet 2016) and California Bearing Ratio (CBR) Test without and with different proportions of fly ash (Standard reference IS 2720 part 16).

RESULTS AND DISCUSSION

Sieve analysis: Greater than 50% of soil is passed through 4.75mm sieve, 91.1 % of soil is passed through 4.75 mm sieve, so the given soil is sand. Greater than 50% of soil is retained on 75 microns sieve, 63.6% of soil is retained on 0.075 mm sieve and therefore it is coarse fraction. Hence the following tests are conducted to determine the various properties of the coarse fraction sand (Fig. 3).

Specific gravity: The specific gravity of the marine soil is 2.27 (Table 2).

Atterberg Limits

Liquid limit: It is the boundary between the liquid and plastic states. It is the water content at which the water has such small shear strength that it flows to close a groove of standard width when jarred in a specified manner. The liquid limit is determined by reading the water content corresponding to 25 blows on the flow curve shown in Figure 4. The liquid limit value of the marine soil is 39%.

Plastic limit: It is the boundary between the plastic and semi solid states. It is the water content at which the soil begins to crumble when rolled into threads of 3mm size. The plastic limit of the marine soil is 26.9%.

- Plasticity index = $I_P = w_L - w_P = 39 - 26.9 = 12.1$, where, w_L = liquid limit, w_P = plastic limit
- A-line equation is $I_P = 0.73 (w_L - 20) = 0.73 (39-20) = 13.8$

Table 1. Particle size distribution by sieve analysis

IS sieve designation (mm)	Weight retained (kg)	Per cent of weight retained	Cumulative per cent of weight retained	Per cent of Finer
4.75	0.089	8.9	8.9	91.1
2.36	0.070	7.0	15.9	84.1
1.20	0.093	9.3	25.2	74.8
0.6	0.056	5.6	30.8	69.2
0.3	0.109	10.9	41.7	58.3
0.15	0.119	11.9	53.6	46.4
0.075	0.100	10.3	63.6	36.4

Table 2. Specific gravity of the soil sample

Test	Sample 1	Sample 2	Sample 3
Mass of density bottle w_1 (g)	26.15	26.5	26.5
Mass of density bottle + dry soil w_2 (g)	47.10	46.60	46.61
Mass of density bottle + dry soil+ water w_3 (g)	84.77	87.42	88.12
Mass of density bottle + water w_4 (g)	73.39	76.07	76.07
Specific gravity of soil Gs = (w2-w1)/((w2-w1)- (w3-w4))	2.23	2.29	2.30

Fig. 1. Collection of marine soil sample

Fig. 2. Collection of fly ash sample

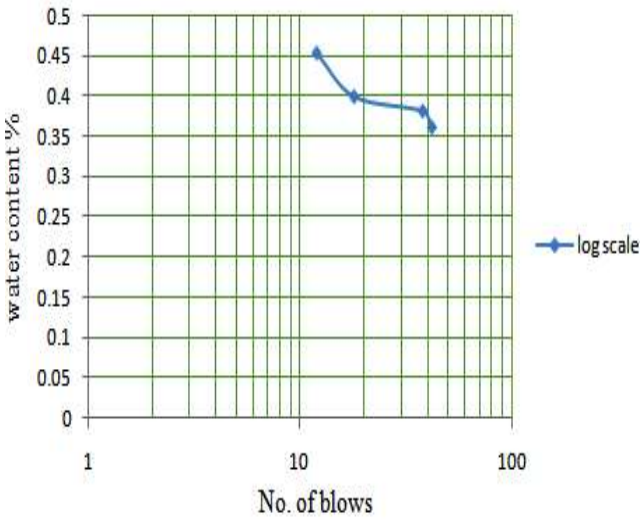

Fig. 3. Particle size distribution by sieve analysis

- I_p from A-line is 13.8
- I_p from Atterberg limits is 12.1

Plasticity index from the experiments is below the A-line, hence it is concluded that the soil taken is silty sand (SM)

Compaction test: Compaction generally leads to reducing the void ratio of soil under short term loading and tests were performed to determine the maximum dry density and optimum moisture content. The optimum moisture content is 14.7 %. The max dry density is 1.92 g/cc. The range of compaction value as per characteristics of unified soil classification is 1.92 - 2.16. The maximum dry density obtained is within the range. It can be used as sub grade material (Fig. 6).

California Bearing Ratio (CBR) Test: It is a penetration test to evaluate sub grade strength of roads and pavement (Izabel and Sangeetha 2016). The results obtained by these tests are used with the empirical curves to determine the thickness of pavement and its component layers. This is the most widely used method for the design of flexible pavements (Varun and Wayal 2016) and the experiment results are presented in Table 3.

Without fly ash

The higher value is reported as the CBR value of the material. The value of CBR at 5mm is greater than 2.5 mm. So, the CBR value of marine soil sample without fly ash is 5.4 %. Similarly, the CBR test is conducted by adding 5%, 10%, 15%, 20%, 25% fly ash to the soil sample and the optimum content of fly ash to be added to the soil to increase its strength is found out. The CBR values corresponding the addition of fly ash contents are shown in Table 4 and the combined graph showing the CBR values without and with addition of fly ash is shown in Figure 5 and 7 and the experiment results are presented in Table 4.

From the Atterberg limits the marine soil is classified as silty sand (SM). The range of CBR value for coarse grained silty sand is 10 to 40 as per unified soil classification. The CBR value of the soil without fly ash content is not in the range as specified, but after addition of fly ash to the marine soil the CBR value is increased and is within the range as given in the unified classification. Therefore, it is proved that by the addition of fly ash to the marine soil its strength is increased. The CBR value of marine soil before addition of fly ash is 5.4 %, with 5 % addition of fly ash to the soil the CBR has increased to 19.84%, with 10 % addition of fly ash to the soil the CBR has increased to 25.51%, with 15 % addition of fly ash to the soil the CBR has increased to 26.33%, with 20 % addition of fly ash to the soil the CBR has increased to 27.94%, with 25 % addition of fly ash to the soil the CBR has increased to 28.34%. After the addition of optimum content of fly ash, the increase in the strength has been decreased. The

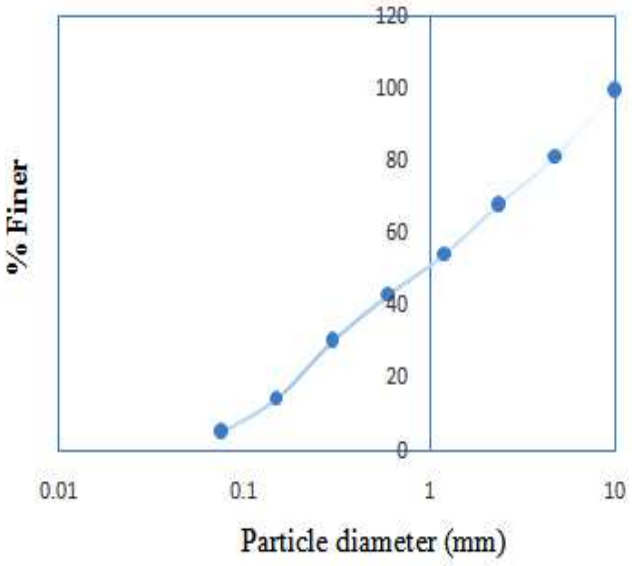

Fig. 4. Flow curve of liquid limit

Table 3. CBR test values without fly ash content

Penetration dial gauge readings	Penetration (mm)	Proving dial readings	Total standard load (kg)	Unit load (kg /cm^2)
50	0.5	0.2*5=1	5.564	0.283
100	1	08*5=4	22.256	1.134
150	1.5	1.4*5=7	38.948	1.984
200	2	2*5=10	55.64	2.835
250	2.5	2.4*5=12	66.76	3.401
300	3	2.8*5=14	77.89	3.968
400	4	3.6*5=18	100.15	5.103
500	5	4.0*5=20	111.28	5.670
600	6	4.6*5=23	127.97	6.520
700	7	5*5=25	139.1	7.087
800	8	5.4*5=27	150.22	7.654
900	9	5.6*5=28	155.79	7.938
1000	10	6*5=30	166.92	8.505
1100	11	6.2*5=31	172.48	8.788
1250	12.5	6.6*5=33	183.61	9.355

***CBR value at 2.5mm = P_T / P_S = ((3.401) / (70)) *100 = 4.85 %
CBR value at 5mm = P_T / P_S = ((5.670) / (105)) *100 = 5.4 %

Table 4. CBR values without and with different proportions of Fly ash

Mix proportion	Per cent of Fly Ash	Soaked CBR
Soil	0	5.4%
Soil + 5% fly ash	5	19.84%
Soil + 10% fly ash	10	25.51%
Soil + 15% fly ash	15	26.33%
Soil + 20% fly ash	20	27.94%
Soil + 25% fly ash	25	28.34%

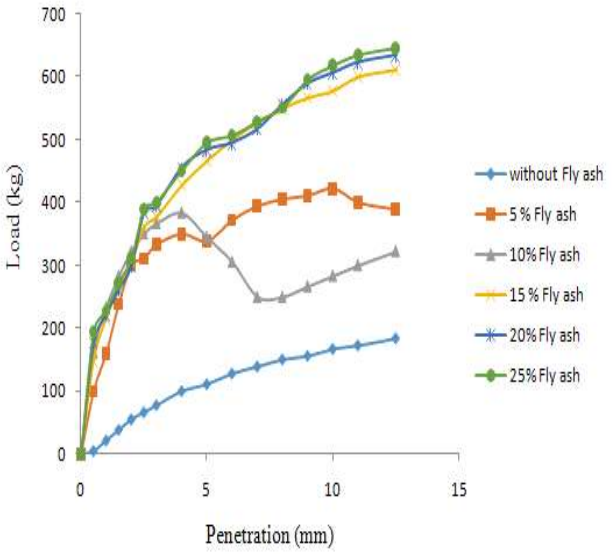

Fig. 5. CBR values without and with different proportions of fly ash

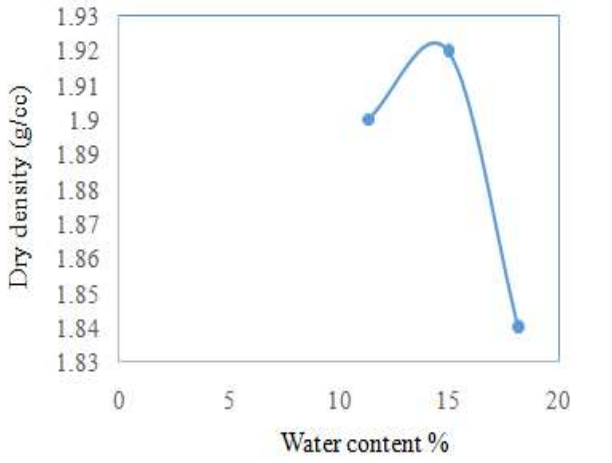

Fig. 6. Compaction value showing the maximum dry density and optimum moisture content

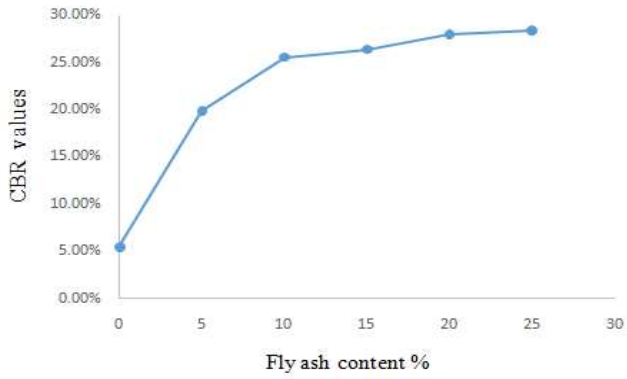

Fig. 7. CBR values for different proportions of fly ash

increase in the strength is more with the addition of 5 to 10 % fly ash and the increase in strength gets decreased with the further addition of fly ash content. Therefore, it is proved that the optimum fly ash content is in the range of 5 to 10 %. Hence the soil strength can be increased by adding 5 to 10 % of fly ash to the marine soil.

CONCLUSION

The present study on the prefixed objective was concluded that, the maximum dry density obtained is within the range as per unified soil classification and hence can be used as sub grade material and the optimum fly ash content is in the range of 5 to 10 % and hence the soil strength can be increased by adding 5 to 10 % of fly ash to the marine soil.

REFERENCES

Dongxiang W, Rachid Z and Nor Edine A 2018. Durability and Swelling of solidified/stabilized dredged marine soils with class-F fly ash, cement, and lime. *Journal of Materials in Civil Engineering* **30**(3): 04018013.

Izabel KJ and Sangeetha S 2016. Stabilization of marine clay using Jerofix. *International Journal of Scientific Engineering and Research* **4**(3): 93-95.

Koteswararao DM, Anusha PRT, Pranav and Venkatesh G 2012. A Laboratory Study on the Stabiization of Marine Clay Using Saw Dust and Lime. *International Journal of Engineering Science and Advanced Technology* **2** (4): 851-862.

Ravi K, Albert J, Muhammad S and Akhil T 2018. Stabilization of lithomargic soil using fly ash and Construction demolition waste. *International Research Journal of Engineering and Technology* **5**(6):1039-1044.

Robert MB 2009. Soil Stabilization with fly ash and rice husk ash. *International Journal of Research and Reviews in Applied Sciences* **1**(3): 209-217.

Satyam T and Nisheet T 2016. Stabilization of marine clay by Biomass Silica (Non-Traditional) Stabilizers article in applied mechanics and materials soil stabilization using waste fiber materials. *International Journal of Innovative Technology and Research* **4** (3): 2927-2930.

Varun B and Wayal AS 2016. Use of fly ash and lime for stabilization of soft soil. *Electronic Journal of Geotechnical Engineering* **21**(18): 6235-6246.

Yaolin Yi, Cheng Li and Songyu Liu 2014. Alkali-activated ground-granulated blast furnace slag for stabilization of marine soft clay. *Journal of Materials in Civil Engineering* **27**(4): 1-7.

Zhang RJ, Santoso AM, Tan TS and Phoon KK 2013. Strength of high water-content marine clay stabilized by low amount of cement. *Journal of Geotechnical and Geoenvironmental Engineering* **139**(12): 2170-2181.

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Study on Carbon Sequestration Potential of Sal Forest in Dry Tropics: Allometric Biomass Assessment Approach

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Abstract: Biomass estimation is essential for understanding carbon stock and sequestration potential that eventually helps in forest management. Present study estimated biomass through allometric model for a dry deciduous sal forest of, West Bengal, India based on ground data and reference allometry to reduce uncertainty. DBH and tree height (n=181) was included in allometric models. Allometric equation with only DBH fitted best for Sal trees in the area with lowest root mean square error (1.33), mean absolute error (0.104) and higher adjusted R^2 (0.963). Biomass of herbs, litter debris and soil carbon stock was estimated. Tree basal area and tree volume was 4.508$m^2 ha^{-1}$ and 20.187 $m^3 ha^{-1}$ respectively. Above ground biomass, below ground biomass and wood litter biomass contributed 77.50% (255.725 t ha^{-1}), 20.61% (68.022 t ha^{-1}) and 1.88% (6.211 t ha^{-1}), respectively within tree biomass (329.958 t ha^{-1}). Herb layer biomass accounted 2.433 t ha^{-1}. Soil carbon stock (424.161 t ha^{-1}) was 2.5 times higher than plant stock (166.195 t ha^{-1}) contributing 71.85% of the total carbon stock. The forest holds 2.74 Mt carbon (sequestering 10.05 Mt CO_2) valued 35,620US$. Our study confirms the need of site specific allometric biomass model development for purposeful biomass and carbon estimation while operating non-destructive harvest.

Keywords: Allometry, basal area, tree volume, biomass, carbon sequestration

Tropical forests play a vital role in climate change mitigation and holds large amount of carbon but the quantification of carbon storage is uncertain in many of the areas. The forest carbon stock measurements are done by several researchers where destructive sampling was conducted (Hauchhum and Singson 2019) but due to restrictions in destructive sampling of trees in many of the forests, regression equation through allometric model approach were also considered by some of the researchers (Salunkhe et al 2014, Banik et al 2018, Banday et al 2018, Biswas et al 2020). Carbon stock estimates were also done in different University campus following volume equations (Nandal et al 2019). The estimation of biomass with the help of regression has proved to be one of the best approaches considering intensive sampling of an area. Tree enumeration mainly includes the measurements of diameter at breast height (DBH) and tree height (H). These ground measurements were transformed into regression form. The major carbon stocks in earth are constituted by forest above ground biomass (AGB), below ground biomass (BGB), dead wood (DW) and soil. The biomass is also considered for different level in forests, viz. trees, shrubs and herbs which also varies with tree density, management strategies etc. (Nagar and Rawat 2016, Rai and Gupta 2018). Soil carbon stock of an area is highly influenced by the climatic factors as well as different tree species present in the area (Nagar et al 2017, Bdoor 2018). The estimation of aboveground biomass of living trees is crucial in determining the amount of carbon stored in the forest growing stock.

The estimation of biomass varies from place to place having same tree species as *Shorea robusta* (Sal) grows in both moist and dry deciduous forest as well as in evergreen moist forests. 14% of the total area of forests in India is contributed by *S. robusta*. Luxuriant sal forests are noticed in South West Bengal which includes our study area the sacred groves of Sal zone of West Bengal. Present study emphasized the assessment of biomass estimation and carbon stock of the dry deciduous sal forest of Sarenga, West Bengal.

MATERIAL AND METHODS

Study area: The study region is selected in the Jangal Mahal of Bankura district, West Bengal, under Bankura (South) Forest Division which falls under Group 5B- Northern Tropical Dry Deciduous Forest type. The proposed study was conducted at Sarenga forest range which was not explored earlier. The total forest area covers 4648.03 ha of land. The climate, especially in the upland tracts to the west, is much drier than in eastern or southern part of the district. Climate of the area is characterized with hot summer and cold winter where temperature increases up to 45°C or more and during winter the temperature drop down to 5°C or less. Norwesters frequently occur in the months of April to early June. Monsoon months are June to September with total average rainfall of about 1400mm.

Sample plot: Forest survey was done based upon the nested quadrat laid in each 25" × 25" grid divided with the help of Arc GIS software. Total 10 plots were laid where nested quadrat was laid for vegetation enumeration in tree and herb layers and collection of soil samples (Fig. 1). Recording of geo-coordinates of the survey and sampling plots in the study area was done with the help of hand-held GPS (Garmin, etrex 10).

Forest survey: Various methods were used for non destructive biomass estimation of sal trees. Tree height was measured through Laser Range Finder (Apresys 600). Diameter at breast height (DBH) of the tree was measured by using the measuring tape where it gives the measurement of circumference which was then converted to diameter following the equation

$C = \pi * DBH$ (1)

Where: C = circumference of tree π = 3.14, DBH = diameter at breast height,

Therefore, $DBH = C/\pi$

Estimation of tree biomass was done based upon allometric model developed for the study area based upon simple allometric equation 2 (Brown 1997) and equation 3 (Brown et al 1989) given as follows

Model 1: $\ln(B) = a + b \ln(DBH)$……(2)

Model 2: $\ln(B) = a + b \ln(DBH^2 \times H)$…….(3)

In our study the estimates of total carbon, Tree Basal Area, Tree Volume and total CO_2 content are also presented. Tree Basal Area (TBA) is calculated based upon the formula Area (A) = πr^2, equation 4,

Therefore,

$$\text{Tree basal area (TBA)} = \left(\frac{DBH}{200}\right)^2 \times 3.14 \ldots\ldots (4)$$

Where, DBH= Diameter at Breast height in cm, π=3.14

Tree volume is calculated by the following formula (equation 5);

$$\text{Tree volume}\,(m^3) = \left(\frac{DBH}{200}\right)^2 \times 3.14 \times \left(\frac{Height}{3}\right)$$

$$\text{On tree volume} = \left(\frac{TBA}{3}\right) \times \text{Height} \ldots\ldots (5)$$

Volume (m^3 $tree^{-1}$) of each tree in a sampling quadrat obtained is converted into the volume on hectare basis.

The observed biomass was calculated by multiplying the tree volume with wood density and Biomass Expansion Factor. To calculate the below ground tree biomass we followed the equation given by Mokany et al (2006). Dead wood litter biomass was determined by collecting litter debris from 3mX3m quadrates of all four corner of a nested quadrat laid in a sampling plot. Total Biomass was obtained by summing the Aboveground Biomass, Belowground Biomass and Dead Organic Matter. The carbon storage for each species was computed by multiplying total biomass with constant factor 0.50 (IPCC 2006) and storage for the area includes C stock in soils.

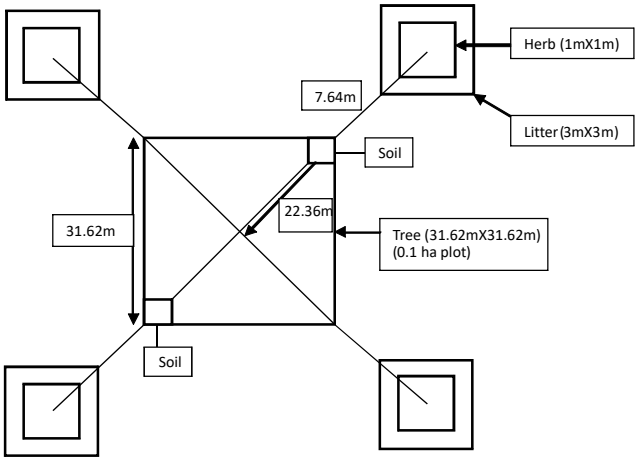

Fig. 1. Sampling design

We used the non destructive method for estimation of biomass including the field measurements where we considered the DBH, H, basal area, tree volume and wood specific gravity for Sal trees (Salunkhe et al 2014). The estimates often varies in regional scale, therefore, based on the ground data and reference allometry, we have established biomass allometric model equation specifically for the present study area to reduce uncertainty. To estimate actual carbon stock of the forests, the herb layer and soil of the area under investigation were also considered.

Data analysis: All statistical analysis was done with the help of XLSTAT (2011) for Microsoft windows 2010.

RESULTS AND DISCUSSION

Site-specific allometric model biomass: In our study, two allometric equations (equation 2, 3) were tested based upon the forest enumeration that includes measurements of DBH and H for 181 individual species of *S. robusta* (sal) as destructive sampling in the area is restricted. The DBH and H of *S. robusta* ranges from 9.554- 31.847cm and 4-25m respectively. The density of *S. robusta* was 226.25 trees ha^{-1}. The out of two model used for biomass estimation for trees, the model 1 based upon allometric equation $\ln(B) = a + b \ln(DBH)$ was more accurate and best fit into the criteria for tree biomass calculation. For best fit of the model, the root mean square error (RMSE), adjusted R^2 and mean absolute error (MAE) were considered where the equation provides lowest RMSE (1.33) and MAE (0.104), higher adjusted R^2 (0.963). The estimates of coefficients along with standard error and

regression statistics for the allometric equation ln (B) = a + b ln (DBH) is given in Table 1 and 2. The regression results henceforth suggested selecting the allometric equation based on DBH which is an important variable for tree biomass calculation through non-destructive approach.

Estimation of biomass: The tree basal area based upon the equation 4 was determined which was found to be 4.508m^2ha^{-1}. Similarly volume of tree was also measured based upon equation 5 which was 20.187m^3ha^{-1}. Depending upon the observed value of AGB for 181 individual tree species, the allometric equation for the study area was modified. Therefore the estimated AGB for the trees enumerated in the study area was found to be 255.725t ha^{-1}.

Table 1. Estimates and coefficients along with the standard error for the regression model ln (B) = a + b ln (DBH)

Regression coefficient	Estimated regression coefficients	Standard error of estimated coefficients
a	-4.759	0.133712
b	3.423	0.04961

Table 2. Regression statistics for the model ln (B) = a + b ln (DBH)

Regression Statistics	
Multiple R	0.981721
R Square	0.963775
Adjusted R Square	0.963573
Standard Error	0.187702
Observations	181

The Figure 2 shows overestimation of tree biomass using the established equation *B* = exp (-2.134 + 2.5430 ln (DBH)) given by Brown (1997) while comparing with estimated tree biomass (site specific biomass model developed for the present study) with DBH. Therefore, it also suggests developing the site specific biomass equation for better accuracy in biomass and carbon estimation of an area. The mean BGB for the area was 68.022t ha^{-1}. Mean value of dead wood biomass of the study area accounts for about 6.211 t ha^{-1}. The dry weight of sub sample of herb species from the nested quadrat was recorded as 2.433 t ha^{-1}. The biomass and carbon stock assessment for shrub layer is presently excluded under this study as sparse species were recorded during the forest survey. Therefore the total biomass of the area was recorded as 332.391 t ha^{-1}(Table 3).

Soil carbon stock: Mean value of soil bulk density was 1.505 while the mean value of organic carbon percent was 9.427. The soil carbon stock in different location of the study area ranged from 338.169 - 568.193 t $ha^{-1}$with mean of 424.161 t ha^{-1} (Table 4).

Carbon sequestration in the forest: Based upon the total biomass of the *S. robusta* in the area, tree carbon stock stands as 329.958t ha^{-1} which is contributed by AGB, BGB and dead wood litter biomass equivalent to 1210.946 CO_2 t ha^{-1}. However, the carbon stock of herb layer accounts to 2.433 t ha^{-1} which is equivalent to 8.93CO_2 t ha^{-1}. Soil carbon storage recorded mean value of 424.161t ha^{-1} equivalent to 1556.67 CO_2 t ha^{-1}. Therefore, the total carbon stock of the study area of Sarenga forest of West Bengal includes

Table 3. Location wise tree measurements

Location	TBA	V	AGB	BGB	DWL	HB	TB	TC (tree and herb layer)
22° 46' 13.70"N 87° 03' 48.95"E	2.880	5.989	9.836	2.616	1.010	0.080	13.542	6.771
22° 46' 18.15"N 87° 04' 37.46"E	2.000	7.810	12.748	3.391	0.859	0.075	17.073	8.536
22° 47' 02.43"N 87° 03' 57.09"E	0.878	1.783	2.990	0.795	0.916	0.124	4.825	2.412
22° 49' 58.71"N 87° 02' 59.20"E	13.669	48.100	72.286	19.228	0.440	0.082	92.036	46.018
22° 49' 59.87"N 87° 03' 17.75"E	3.525	19.406	31.392	8.350	0.595	0.724	41.061	20.530
22° 50' 38.34"N 87° 02' 32.36"E	3.381	21.675	31.774	8.452	0.636	0.247	41.109	20.554
22° 51' 14.09"N 87° 03' 20.13"E	7.112	39.973	70.121	18.652	1.013	0.837	90.623	45.311
22° 51' 41.41"N 87° 03' 31.08"E	2.781	17.108	24.578	6.538	0.742	0.264	32.122	16.061
Mean	4.528	20.230	31.965	8.503	0.776	0.304	41.549	20.774
Total	36.226	161.844	255.725	68.022	6.211	2.433	332.391	166.195

Note: TBA= Total Basal Area (m^2ha^{-1}), V= Volume (m^3ha^{-1}), AGB= Above Ground Biomass (t ha^{-1}), BGB= Below Ground Biomass (t ha^{-1}), DWL= Dead Wood Litter Biomass (t ha^{-1}), HB= Herb Biomass (t ha^{-1}), TB= Total Biomass (t ha^{-1}), TC= Total Carbon (tree and herb layer) (t ha^{-1})

summation of all the carbon stocks from tree layer, herb layer and soil which was 590.351t ha^{-1}. Therefore, extrapolating the mean value for the entire forest range of 4648.03 ha, the total carbon stock in the forest is 2.74 Mt of carbon which is equivalent to 10.05Mt of CO_2 sequestered.

Table 4. Soil bulk density, soil organic carbon and soil carbon stock

Location	BD (g cm^{-3})	OC (%)	SCS (t ha^{-1})
22° 46' 13.70"N 87° 03' 48.95"E	1.541	8.232	380.565
22° 46' 18.15"N 87° 04' 37.46"E	1.443	11.446	495.497
22° 47' 02.43"N 87° 03' 57.09"E	1.522	12.444	568.193
22° 49' 58.71"N 87° 02' 59.20"E	1.580	8.607	407.972
22° 49' 59.87"N 87° 03' 17.75"E	1.402	9.420	396.205
22° 50' 38.34"N 87° 02' 32.36"E	1.467	9.524	419.151
22° 51' 14.09"N 87° 03' 20.13"E	1.486	8.693	387.534
22° 51' 41.41"N 87° 03' 31.08"E	1.598	7.054	338.169
Mean	1.505	9.427	424.161

Note: BD= Bulk Density, OC= Organic Carbon, SCS= Soil Carbon Stock

Forest Survey of India (FSI 2019) recorded carbon stock in tropical dry deciduous forest in India for very dense forest (AGB- 74.3 Mt, BGB- 31.2 Mt, Dead Wood- 0.992 Mt, Litter- 148.6 Mt, Soil Organic Carbon- 119.8 Mt), moderately dense forest (AGB- 344.4 Mt, BGB- 144.6 Mt, Dead Wood- 254.5 Mt, Litter- 788.8 Mt, Soil Organic Carbon- 582.8 Mt) and open forest (AGB- 175.1 Mt, BGB- 735.7 Mt, Dead Wood- 125.9 Mt, Litter- 587.5 Mt, Soil Organic Carbon- 578.8 Mt) as 241.1 Mt, 1082.3 Mt and 834.6 Mt respectively. Total biomass of the present study area accounts for about 332.391t ha^{-1} which is much higher compared to other forest types of India (Table 5) following the trend as tropical deciduous forest of Madhya Pradesh (53.90) > sal mixed forest Chhattisgarh (66.54) > sub-tropical dry forest of India (130.00) > moist deciduous sal forest Tripura (157.58) > dry deciduous sal forest Garhwal (162.00) > dry Siwalik sal forest Garhwal (180.80) > semi-

Table 5. Comparison of Biomass and Carbon stock of different tropical dry forests with present study

Forest type	Biomass (t ha^{-1})	Carbon (t ha^{-1})	Source
Sub-Tropical Dry Forest, India	130.00	65.00	IPCC (2006)
Deciduous Forest, Eastern Ghats, India	251.65	125.82	Ramachandran et al (2007)
Secondary Deciduous Forest , Eastern Ghats, India	241.77	120.88	Ramachandran et al (2007)
Semi Evergreen, Western Ghats, India	202.60	101.30	Kale et al (2009)
Mixed Moist Deciduous,Western Ghats, India	209.30	104.65	Kale et al (2009)
Sal Mixed Forest, Chhattisgarh, India	66.54	33.27	Bijalwan et al (2010)
Dry Siwalik Sal Forest, Pauri Garhwal, India	180.80	83.20	Sharma et al (2010)
Dry deciduous Sal Forest, Pauri Garhwal, India	162.00	74.50	Sharma et al (2010)
Moist Bhabhar Sal Forest, Pauri Garhwal, India	346.50	159.40	Sharma et al (2010)
Pure Sal Forest of Doon Valley, India	494.65	232.49	Mandal and Joshi (2014)
Tropical Deciduous Forest of Madhya Pradesh, India	53.90	25.6	Salunkhe et al (2014)
Sal Forest (undisturbed) of Goalpara Assam, India	239.45	119.73	Rabha (2014)
Mono-specific Sal of Tropical Dry Region, India	352.00	176.00	Chaturvedi and Raghuvanshi (2015)
Mixed Sal Natural Forest, Meghalaya, North East India	272.83	136.41	Upadhyaya et al (2015)
Tropical Moist Deciduous Forest, Tripura, India	42.26	21.13	Majumdar et al (2016)
Forest Land-use System in Mountainous Ecosystem, India		98.08**	Rajput et al (2016)
Rainforest of North East India	425.70	234.15* 72.48** 306.61***	Gagoi et al (2017)
Moist Deciduous Sal Forest, Tripura, India	157.58	78.79* 88.85** 167.64***	Banik et al (2018)
Shiwalik Sal Forest, Northwestern Himalaya, India	301.78	150.89	Banday et al (2018)
Dry Deciduous Forest of Kadapa hill ranges, Andhra Pradesh, India		73.14**	Venkata Ramana and Sridhar Reddy (2019)
Sal Forest (Tropical Dry Deciduous) of Sarenga West Bengal, India	332.391	166.19* 424.16** 590.351***	Present Study

* Total C stock at tree and herb layer; ** Soil C stock; *** Total C stock

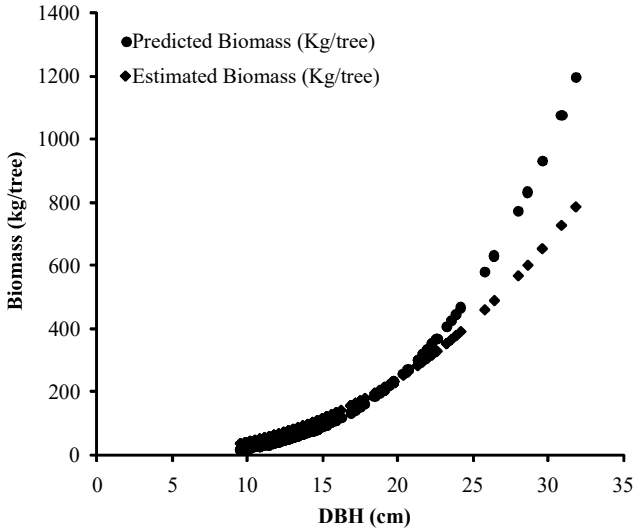

Fig. 2. Graphical representation of predicted and estimated tree biomass (kg tree^{-1}) of the study area

evergreen western ghats (202.60) > mixed moist deciduous western ghats (209.30) > sal forest Assam (239.45) > secondary deciduous forest eastern ghats (241.77) > deciduous forest eastern ghats (251.65) > mixed sal forest Meghalaya (272.83) > shiwalik sal forest north-western Himalayas (301.78) (Salunkhe et al 2014, Bijalwan et al 2010, IPCC 2006, Banik et al 2018, Sharma et al 2010, Kale et al 2009, Rabha 2014, Ramachandran et al 2007, Upadhyaya et al 2015, Banday et al 2018). The estimated biomass for present study is lower than compared to the moist Bhabar Sal forest of Garhwal (346.50t ha^{-1}), pure Sal forest of Doon valley (494.65 t ha^{-1}), mono-specific Sal of tropical dry region (352.00 tha^{-1}) and rainforest of North East India (425.70 t ha^{-1}) (Sharma et al 2010, Mandal and Joshi 2014, Chaturvedi and Raghuvanshi, 2015, Gagoi et al 2017) (Table 5). The carbon stock in the study area is also comparable to the estimated carbon stock from different parts of India (Table 5). Total carbon stock in India's forests has been estimated 7124.6 Mt of which tropical dry deciduous forest in India accounts for 2158.1 Mt. Considering West Bengal, the total carbon stock covering all the forest types recorded about 147.7 Mt (FSI 2019). Total carbon density pattern from different parts of India is moist deciduous sal forest Tripura < rainforest of northeast India < present study (Table 5). The soil organic carbon estimated in present study is higher than forests of northeast India (Rabha 2014, Gagoi et al 2017, Banik et al 2018), central India, Chhattisgarh (Bijalwan et al 2010), Madhya Pradesh (Salunkhe et al 2014). The lowered value in forests of Chhattisgarh and Madhya Pradesh might be due to immature forest stands with lowered DBH size and volume compared to that of the trees in present study. The North East India forests (excluding forest soil carbon stock) have quite similar values (Banik et al 2018) for carbon stock as found in Sarenga forest of West Bengal (Table 5).

CONCLUSION

Present study dealt with the non-destructive method of biomass assessment which is found to be the best method for biomass calculation for trees without destructive harvesting of trees. The allometric equation ln (B) = a + b ln (DBH) was found accurate for calculation of non destructive biomass for trees in the present study. The site specific biomass equation for trees was thus established which also showed variation in estimating biomass. Therefore it is recommended to formulate site specific biomass equation to get accurate measurements for biomass and carbon. The mean biomass and carbon density in our study is higher as compared with other forest types in India. The results also depict the higher carbon sequestration potentiality of tropical dry deciduous forest of Sarenga, West Bengal. In consideration with total carbon stock of the entire forest range, the total amount of CO_2 sequestered is also quite high amount with its valuation.

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REFERENCES

Banday M, Bhardwaj DR and Pala NA 2018. Variation of stem density and vegetation carbon pool in subtropical forests of northwestern Himalaya. *Journal of Sustainable Forest* **37**(4): 389-402.

Banik B, Deb D, Deb S and Datta BK 2018. Assessment of biomass and carbon stock in sal (*Shorea robusta* Gaertn.) Forests under two management regimes in Tripura, Northeast India. *Journal of Forest and Environmental Science* **34**(3): 209-223.

Bdoor BS 2018. Organic carbon stocks in various land-use types of karst landscape in northeastern India. *Indian Journal of Ecology* **45**(1): 77-83.

Bijalwan A, Swamy SL, Sharma CM, Sharma NK and Tiwari AK 2010. Land-use, biomass and carbon estimation in dry tropical forest of Chhattisgarh region in India using satellite remote sensing and GIS. *Journal of Forestry Research* **21**(2): 161-170.

Biswas S, Biswas A, Das A and Banerjee S 2020. Biomass model development for carbon stock estimation in the tropical forest of eastern India: An allometric approach. *Tropical Ecology* doi.org/10.1007/s42965-020-00098-2.

Brown S 1997. *Estimating biomass and biomass change of tropical forests: A primer*. FAO forestry Paper no 134 Rome, Italy, pp 55.

Brown S, Gillespie AJR and Lugo AE 1989. Biomass estimation methods for tropical forests with applications to forest inventory data. *Forest Science* **35**: 881-902.

Chaturvedi RK and Raghubanshi AS 2015. Assessment of carbon density and accumulation in mono-and multi-specific stands in teak and sal forests of a tropical dry region in India. *Forest Ecology and Management* **339**: 11-21

FSI 2019. *State forest report* 2019.

Gagoi A, Sahoo U K and Singh S L 2017. Assessment of biomass and total carbon stock in a tropical wet evergreen rainforest of eastern Himalaya along a disturbance gradient. *Journal of Plant Biology and Soil Health* **4**: 1-8.

Hauchhum R and Singson MZ 2019. Assessment of aboveground biomass and carbon storage in bamboo species in sub-tropical bamboo forests of Mizoram, North-East India. *Indian Journal of Ecology* **46**(2): 358-362.

IPCC, 2006. *Guidelines for National Greenhouse Gas Inventories*. Intergovernmental Panel on Climate Change, IPCC/IGES, Hayama, Japan.

Kale MP, Ravan SA, Roy PS and Singh S 2009. Patterns of carbon sequestration in forests of western ghats and study of applicability of remote sensing in generating carbon credits through afforestation/ reforestation. *Journal of Indian Society of Remote Sensing* **37**: 457-471.

Majumdar K, Choudhary BK and Datta BK 2016. Aboveground woody biomass carbon stocks potential in selected tropical forest patches of Tripura Northeast India. *Open Journal of Ecology* **6**: 598-612

Mandal G and Joshi SP 2014. Biomass accumulation and carbon sequestration potential of *Shorea Robusta* and *Lantana camara* from the dry deciduous forests of Doon valley Western Himalaya India. *International Journal of Environmental Biology* **4**: 157-169.

Mokany K, Raison RJ and Prokushkin AS 2006. Critical analysis of root: shoot ratios in terrestrial biomes. *Global Change Biology* **12**: 84-96.

Nagar B and Rawat S 2016. Carbon mitigation potential of biomass and soil under different density of *Eucalyptus camaldulensis* in Arid Region of India. *Indian Journal of Ecology* **43**(2): 431-435.

Nagar DK, Nagar B, Nagar AL and Kashyap SD 2017. Biomass and carbon density in relation to altitude in moist temperate western Himalayan ecosystem. *Indian Journal of Ecology* **44**(3): 746-754.

Nandal A, Singh N, Yadav SS, Rao AS and Yadav VS 2019. Carbon stock assessment of selected tree species in Maharshi Dayanand University Campus, Rohtak (Haryana) India. *Indian Journal of Ecology* **46**(2): 330-334.

Rabha D 2014. Aboveground biomass and carbon stocks of an undisturbed regenerating sal (*Shorea robusta* Gaertn. F.) Forest of Goalpara District, Assam, Northeast India. *International Journal of Environment* **3**(4): 147-155.

Rai P and Gupta B 2018. Estimation of biomass and carbon stock variations in vegetation of differently managed *Quercus leucotrichophora* forests along an elevation gradient in western Himalaya, India. *Indian Journal of Ecology* **45**(1): 100-106.

Rajput BS, Bhardwaj D, Dwivedi KP and Kumar D 2016. Soil organic carbon stock under different land use system in mountainous ecosystem. *Indian Journal of Ecology* **43**(1): 93-97.

Ramachandran A, Jayakumar S, Haroon RM, Bhaskaran A and Arockiasamy DI 2007. Carbon sequestration: Estimation of carbon stock in natural forests using geospatial technology in the eastern ghats of Tamil Nadu, India. *Current Science* **92**(3): 323-331.

Salunkhe O, Khare PK, Sahu TR and Singh S 2014. Above ground biomass and carbon stocking in tropical deciduous forests of state of Madhya Pradesh, India. *Taiwania* **59**(4): 353-359.

Sharma CM, Baduni NP, Gairola S, Ghilidiyal SK and Suyal S 2010. Tree diversity and carbon stocks of some major forest types of Garhwal Himalaya, India. *Forest Ecology and Management* **260**(12): 2170-2179.

Upadhyaya K, Thapa N and Barik SK 2015. Tree diversity and biomass of tropical forests under two management regimes in garo hills of north-eastern India. *Tropical Ecology* **56**: 257-268.

Venkata Ramana C and Sridhar Reddy M 2019. Soil organic carbon and soil respiration in dry deciduous forest and grass land of Kadapa Hill Ranges, Andhra Pradesh, India. *Indian Journal of Ecology* **46**(3): 668-671.

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Phytoremediation of Zinc Ion Using Faba Bean *Vicia faba* Plant *in vitro*

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Abstract: *Viciafaba* (Faba bean) in the Middle East and North African countries considered as one of the most valuable legume crops. It is a main source of nitrogen in the soil. The objective of this research was to estimate *Vicia faba* response to zinc ion elevation in nutrient media. The investigation in liquid culture media with elevated concentration of zinc (control, 100, 200, 400, 600 and 800 µmol L^{-1}) showed that the tested species can be used as indicator plant, the plant showed stability against zinc toxicity, determined by their ability to germinate and grow as well as the production of access free proline 21 times more than control at 800 µmol $ZnSO_4L^{-1}$ of media. Along with the accumulation of zinc in plant leaves (up to 542.8 µg g^{-1} dry weight of plant leaves at 800 µmol$ZnSO_4$ L^{-1} of media), these results suggest that Faba bean plant *Vicia faba* is a potential phytoremediation plant for moderately contaminated areas with zinc.

Keywords**:** *Vicia faba*, zinc Tolerance, Indicator plants, Phytoremediation

Faba bean (*Vicia faba* L.) is considered as one of the essential cool-season legume crops worldwide and it is the oldest legume in the Mediterranean countries (Göl et al 2017) and is used for both human food and animal feed since it contains approximately 30% of protein (Martínez-Velasco et al 2018). Occurrences of heavy metals are common features in environment. Some of these metals are essential in small amount as nutrients for animals and plants, whereas other elements have no clear biological function (Alobaidi et al 2011, Alobaidi et al 2015). Zinc (Zn) could be considered as one of the essential micronutrients with a significant role in several metabolic processes of plants that its insufficiency reduces plant growth and development. Though the increasing concentration of Zn in soil could expose the plants to serious problems. Farther more, the metals accumulation ability of some plant species isan interesting evolutionary problem, whereas it could have a practical application in phytoremediation of metal contaminated soils (Gupta and Sandalio 2011). However, in previous studies, it has been shown that an extra level of zinc affects plant growth, metabolism, as in various plant species (Maree et al 2012) and hence could cause serious problems to human and animals (Petukhov et al 2019). For example, high exposure to zinc in *Lemma minor* L. resulted in high levels of lipid peroxidation and enriched DNA damage (Moura et al 2012). Several important enzymes contain zinc. Zn plays a role in catalyzing oxidation processes and the formation of carbohydrates in plants. It also has an essential role in many transcription factors and required to maintain the integrity of ribosome (Nagajyoti et al 2010). Studies indicated that Faba bean has a role in the biological process called phytoremediation to remove heavy metals and contaminants from the soil (Alobaidi 2016, Lemtiri et al 2016).

The diverse benefits of *Vicia* species in terms of soil health and productivity make them a promising crop. In recent years, these agronomic advantages have attracted the attention of organic farmers and it is their potential role as phytoremediators that is also emerging as an interesting topic of study (Ibañez et al 2020). The objective of our study was to assess the stability and bioaccumulation of zinc (Zn) in plants *Vicia faba*.

MATERIAL AND METHODS

Plant seed germination: To determine the effect of $ZnSO_4$ on plant seeds germination, Petri dishes lined with filter paper was used filled with 15 ml sterilized distilled water. After washing with tap water for 10 minutes seeds were sterilized by 2.5 % v/v sodium hypochlorite for 10 minutes then washed thoroughly with sterilized distilled water. $ZnSO_4$ solution at a concentration of (100, 200, 400, 600 and 800 µmol), while water served as a control. Finally, seeds added and incubated at 25C° in dark for 2-4 days.

Cultivation of seedling: Seeds spread on the surface of a porous plastic container (40 cm * 30 cm * 8 cm) placed on a tray filled with moist perlite, then cover the container to maintain the desired humidity till seeds sprouting. Removed

the plantlets from the perlite carefully after 14 days. Roots washed thoroughly with sterilized distilled water to remove particles of perlite. The plantlets were then transferred to pot contain 1-liter MS liquid media pH 5.8, three plantlets per pot, incubated in a growth chamber at a temperature of 25-30 / 20-25 °C (day/night, respectively), 12-hour light photoperiod. The culture media were changed every 7 days. After 4-5 weeks, plants were used for the exposure experiment which started by adding $ZnSO_4$ to the culture media at different concentrations (100, 200, 400, 600 and 800 µmol). Duration of $ZnSO_4$ exposure was 7 days. Pots containing MS liquid media without adding an extra amount of $ZnSO_4$ (MS media already contain 0.25 µmol $ZnSO_4$) considered as control.

Measurement of plant biomass: Plants were exposed to different concentrations of $ZnSO_4$ for 7 days then biomass of all plant material was measured by sensitive balance and compared with control plant (cultured without an extra amount of $ZnSO_4$).

Estimation of Zn content: Estimation of zinc content done by using wet ashing method (Yang et al 2013). The 50 µg of dried plant material placed in a test tube filled with a mixture of 1.6 ml of nitric acid and 0.5 ml of hydrochloric acid then left overnight. The next day, the sample tubes were incubated at 110 °C for 1 hr., then a further incubated at 180 °C for 2 h, after that one drop of concentrated hydrogen peroxide added to each tube. The samples volumes were adjusted with distilled water to 15 ml. Estimation the concentration of Zn was carried out using atomic absorption spectrophotometer A500 «PG Instruments" (USA). At each measurement, the instrument was calibrated, and the coefficient from the calibration curve was used to recalculate the zinc content in the leaves, which is expressed in µg/g dry weight.

Determination of proline content: The free proline was determined using the acid ninhydrin reagent method (Ábrahám et al 2010). To estimate the content of proline in the plant extract, 1 ml of extract added in test tubes, then a mixture of glacial acetic acid (1 ml) and 1 ml of ninhydrin reagent added to each tube. The tubes incubated in a water bath for 1 hour at 100 °C, then shocked in ice. The optical density was determined using a spectrophotometer at 520 nm «ThermoFisher Scientific, Genesys 20" (USA). Proline content calculated using a calibration curve.

RESULTS AND DISCUSSION

Effects of different Zn concentrations of ZnSO4 on seedling root and biomass Accumulation: The seeds germination and roots length were monitored under different concentrations of zinc ion. Elevated concentrations of zinc negatively affected seeds germination and roots length of *V. faba*, complete inhibition of seeds germination seen at 900 µmol ZnSO4. While at 100 µmol $ZnSO_4$ *V. faba* show more stability than other concentrations (Table 1). The higher level of $ZnSO_4$ significantly reduces the roots length of *V. faba* seedling. The decrease in root growth began at 200 µmol $ZnSO_4$ and reaching 66 % of control at the highest concentration (800 µmol $ZnSO_4$). Elevated concentrations of $ZnSO_4$ dramatically inhibit the growth of *V. faba* as indicated in table 1. As compared with control, reduction of plant biomass was significant at 400 µmol $ZnSO_4$ with 37 % reduction of biomass weight, while at 600 µmol $ZnSO_4$ raw biomass reduced by 51 % and at 800 µmol ZnSO4 reductions of raw biomass reached to 64% . The small amount of increased zinc in nutrient media many physiological parameters was affected and with increasing concentration of zinc in media, inhibition of parameters increased (Maree et al 2012). Effects started with the inhibition of normal development of the root system which considered as a clear sign of the negative effect of zinc ions (Table 1).

Effect of zinc on the free proline accumulation in plant leaves: Detection of proline accumulation in *V. faba* leaves indicated that with increasing in $ZnSO_4$ concentration proline accumulation significantly increased. The maximum accumulation of proline at 800 µmol $ZnSO_4$ up to 17.5 µmol/g). Significant increasing in proline accumulation started with the lowest ZnSO4 concentration used (l00 µmol)

Table 1. Influence of elevated concentration of $ZnSO_4$ on *V. faba*

Concentration of ZnSO4 (µmol)	Roots length (mm)	(%)	Raw biomass (g)	(%)	Proline accumulation in leaves (µmol/g biomass)	Folds	Zn accumulation in leaves (µg/g dry weight)	Folds
Control	14.5	100	8.00	100	0.84	1	56.6	1
100	11.0	76	7.84	98	4.2*	5	84.9	1.5
200	8.0	55	6.85	86	7.9*	9.4	132.4*	2.3
400	6.5*	45	5.05*	63	10.1	12	209.4	3.7
600	6.1*	42	3.94*	49	14.9	17.7	278.5	4.9
800	5.0*	34	2.91*	36	17.5*	20.8	542.8*	9.6

CD (p=0.05), (*) Significant differences

which reaches to 5 times more than control and elevated up to 20.8 times at 800 µmol $ZnSO_4$ (Table 1).

A number of mechanisms by which Proline increases the tolerance of plants to heavy metals toxicity have been proposed. Proline plays various roles including adaptation, recovery, and signaling when it comes to combating stress in plant (Fidalgo et al 2013). Proline acts as a metabolic osmolyte, free radical scavenger, antioxidant, and macromolecules stabilizer. Nonenzymatic response to the negative effect caused by a wide range of abiotic stressors such as HMs is the production of an excess amount of Proline by plants (Szabados and Savoure 2010). Also, proline act as a chemical chaperone, protecting the structure and conformation of macromolecules and membranes under stress (Arif et al 2019). Therefore In our studies, the content of proline increased under the elevated concentration of heavy metals ions, as shown in Table 1.

Accumulation of zinc in plant tissues: The significant zinc accumulation in plant leaves was detected in response to increasing $ZnSO_4$ concentration in nutrient media (Table 1). At higher $ZnSO_4$ concentration more zinc accumulation observed which reaches up to 9.6 times more than the control. Plants have their special mechanism to absorb the nutrient, water and minerals from soil combined with many elements present in its rhizosphere environments (Kabata-Pendias 2010). Various factors determined the amounts of zinc accumulation in plants tissue such as type of plants, the concentration of zinc ions in media., time and duration of exposure to the zinc ions. The accumulation of zinc increased in *V. faba* tissue with elevated concentration of zinc ion in media, also accumulation increased at longer exposure time. One of the important parameters to make plants candidate for phytoremediator is the efficient accumulation of heavy metals in aerial plant tissue such as leaves, results confirm the ability of *V. faba* to highly accumulate zinc ions in aerial tissue which indicate the significant mechanism of plant for heavy metals phytoextraction from surrounding media.

CONCLUSIONS

Increasing concentration of proline in plants tissue with increasing concentration of zinc in media indicated the presence of stress-defense mechanisms of plants against the toxic effect of high concentrations of zinc ions in the medium. The initial stages of Faba bean plant showed fairly good resistance to high concentrations of $ZnSO_4$, and thus allow to consider *Vicia faba* as a promising species for phytoremediation of moderately polluted areas because plants accumulate well-developed biomass at a relatively high accumulation of zinc in the aboveground organs.

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REFERENCES

Ábrahám E, Hourton-Cabassa C, Erdei L and Szabados L 2010. Methods for determination of proline in plants. *Plant Stress Tolerance,* Springer. 317-331

Alobaidi KH 2016. Tolerance of *Vicia faba* to elevated concentrations of copper ions in nutrient medium. *International Journal of Current Microbiology and Applied Sciences* **5**: 642-651.

Alobaidi KH, Bashmakova EB and Kholodova VP 2015. Response of two brassica species to the toxic effect of different copper concentration. *Journal of Environmental Protection* **6**(7): 719-725.

Alobaidi KH, Bashmakova EB and Kholodova VP 2011. Comparative analysis of the stability of the genus Brassica at the initial stage of ontogeny to excess copper. *Bulletin of the Tomsk State University. Biology* **16** (4): 92-95.

Arif N, Sharma NC, Yadav V, Ramawat N, Dubey NK, Tripathi DK, Chauhan DK and Sahi S 2019. Understanding heavy metal stress in a rice crop: Toxicity, tolerance mechanisms, and amelioration strategies. *Journal of Plant Biology* **62** (4): 239-253.

Fidalgo F, Azenha M, Silva AF, de Sousa A, Santiago A, Ferraz P and Teixeira J 2013. Copper-induced stress in S olanum nigrum L. and antioxidant defense system responses. *Food and Energy Security* **2**(1): 70-80.

Göl Ş, Doğanlar S and Frary A 2017. Relationship between geographical origin, seed size and genetic diversity in faba bean (*Vicia faba* L.) as revealed by SSR markers. *Molecular Genetics and Genomics* **292**(5): 991-999.

Gupta DK and Sandalio LM 2011. *Metal toxicity in plants: perception, signaling and remediation*, Springer Science & Business Media.

Ibañez S, Medina MI and Agostini E 2020. Vicia: A green bridge to clean up polluted environments. *Applied Microbiology and Biotechnology* **104**(1): 13-21.

Kabata-Pendias A 2010. *Trace elements in soils and plants*, CRC press

Lemtiri A, Liénard A, Alabi T, Brostaux Y, Cluzeau D, Francis F and Colinet G 2016. Earthworms Eisenia fetida affect the uptake of heavy metals by plants Vicia faba and Zea mays in metal-contaminated soils. *Applied Soil Ecology* **104**: 67-78.

Maree M, Raldugina G and Alobaidi K 2012. Comparative analysis of stabilty of 2 varieties of springrape (*Brassica napus* L.) to the effect of the ions copper and zinc. *RUDN Journal of Agronomy and Animal Industries* **2**: 16-24.

Martínez-Velasco A, Lobato-Calleros C, Hernández-Rodríguez BE, Román-Guerrero A, Alvarez-Ramirez J and Vernon-Carter EJ 2018. High intensity ultrasound treatment of faba bean (*Vicia faba* L.) protein: Effect on surface properties, foaming ability and structural changes. *Ultrasonics sonochemistry* **44**: 97-105.

Moura DJ, Péres VF, Jacques RA and Saffi J 2012. Heavy metal toxicity: oxidative stress parameters and DNA repair. *Metal toxicity in plants: Perception, signaling and remediation.* Springer, 187-205

Nagajyoti PC, Lee KD and Sreekanth T 2010. Heavy metals, occurrence and toxicity for plants: A review. *Environmental Chemistry Letters* **8**(3): 199-216.

Petukhov V, Afonina I, Kleshev M, Sebezhko O, Korotkevich O, Kostamakhin N, Konovalova T, Narozhnykh K, Adushinov D and Goncharenko G 2019. Influence of elevated Zn on the hematology, serum biochemistry and productive indicators in laying hens. *Indian Journal of Ecology* **46**(4): 901-906.

Szabados L and Savoure A 2010. Proline: a multifunctional amino

acid. *Trends in Plant Science* **15**(2): 89-97.

Yang L, Li Y, Ma X and Yan Q 2013. Comparison of dry ashing, wet ashing and microwave digestion for determination of trace elements in *periostracum serpentis* and *periostracum cicadae* by ICP-AES. *Journal of the Chilean Chemical Society* **58**(3): 1876-1879.

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Spatial Characteristics and Heavy Metals Pollution in Urban Soils of Basrah, Iraq

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Abstract: A detailed study was conducted to determine the concentrations for ten heavy metals (As, Cd, Co, Cr, Cu, Fe, Mn, Ni, Pb and Zn) in 16 urban soil samples of Basrah city by using Inductively coupled plasma-mass spectrometry technique to assess the pollution levels according to some pollution indices. The samples were collected from four traverses, includes the industrial, urban park, open space, commercial and residential sites. The mean values of As, Cd, Co, Cr, Cu, Fe, Mn, Ni, Pb and Zn were 9.03, 0.23, 6.10, 509.19, 47.49, 23971.06, 415.04, 130.02, 33.08 and 71.77 mg/kg, respectively, these values indicate that vehicle exhausts and industrial emissions are the main sources of these metals in soil. The results of Igeo and PI indices showed high pollution levels for Cr and Ni. Er index indicated that most metals caused low risk in all stations excepted As, Cd and Pb have a moderate risk in industrial areas. IPI indicates medium to high pollution levels of heavy metals. Spatial distribution patterns of heavy metals indicated that the hotspot areas of metal pollution were mainly concentrated at the northern and western parts (commercial, residential and industrial areas) closely related to high traffic conditions and the industrial activities.

Keywords: Urban soil, Integrated pollution index, Heavy metals, Spatial distribution, Basrah

In recent decades, the rapid urban development of modern human life requires many human activities including industrial processes, municipal operations, construction activities and traffic emissions (Alloway 2013). Later, these human activities have liberate trace metals in different urban environmental compartments, including urban soil (Yang et al 2017). Topsoil is known as one of the main sinks of pollutants in urban environments (Padoan et al 2017). Soil properties, such as the concentration of aqueous metal oxides, organic matter content, CEC, oxidation potential, pH, and clay content are the most factors affecting the movement of trace metals, which makes each soil unique in terms of pollution management (Ross 1994). Heavy metals may arise from human sources like diesel, coal combustion and petroleum, in addition to industrial activities (Manasreh 2010). Heavy metals enter the soil primarily and then into the human body through three exposure ways: inhalation, skin, and Ingestion contact, posing a threat to human health (Castro Gonzalez et al 2017). Heavy urban environmental geochemistry metals have been studied worldwide due to growing awareness of their impact on the environment, human health (Wong et al 2006 and Thornton et al 2008). Metals pollutants like Cr, Cd, Ni and Pb have cumulative impacts, producing delayed development in children, kidney disease, cancer and several other hazardous health effects (Jiries 2003). Particle matter emissions from vehicles depend on the engine type and age and maintenance and contain carbon with smaller amounts of trace metals and ions (Peltier et al 2011). Basrah is the second largest cities in Iraq with a population 2,908,491 (CSO 2020), and it is an industrial centre and a hub of commercial, moreover increases in random housing, which tends to increase in the quantities of waste and garbage and the accumulation of wastes throughout the city and causes an increases in the heavy metals concentration and causes the emergence of diseases and epidemics, especially for children who are in permanent contact with the topsoil, as well as the huge car exhaust waste inside Basrah which causes respiratory diseases, due to the increases of vehicle population from 51,616 (2003) to 130000 (2019) (Directorate general traffic 2019), fuel spills, car garage, auto-fuel stations, industrial workshops the construction processes causes pollution inside city, also oil refineries, petrochemical, fertilizers factories, and electric power stations around city contribute to the release of gases and toxic materials such as iron oxides, pb, Ni, As, Cd, Cd, cyanide, Cu, and formaldehyde sulfate, formalin, dioxins some of which are considered carcinogens and can be transported by air particles and then deposited in the soil. The objectives of this study are: (1) Measuring heavy metals concentrations in urban soils in order to assess the degree of urban soil pollution by using Geo - accumulation index (Igeo), Ecological Risk Index (RI) and integrated pollution index (IPI), (2) evaluate the relationship between heavy metals and their possible sources using GIS spatial analysis.

MATERIAL AND METHODS

Study area: Basrah (30° 32′ 10. 47″ N, 47° 48′ 56. 95″ E) is

located in the south of Iraq (Fig. 1). The city has an area of about 194km^2. It is surrounded by many oil and gas fields, electrical, petrochemical, Fertilizer industry plants. The Basrah's climate is characterized by its cold to mild in the winter, hot and very dry during the summer. The study area is covered by recent sediments and some quaternary deposits which mainly composed of sand, silt, clay and gravel deposits belong to the upper part of the Dibdiba formation (Al-Khafaji et al 2010).

Sample collection and preparation: A total of 16 surface urban soil samples (0-20 cm) depth were collected on September 2019 along four main roads traverses inside Basrah include open space, roadsides of traffic Jams, commercial, residential, industrial areas as well as rural soil as standard unpolluted soil. Approximately 500 g of soil samples were collected at each location (Fig. 1) Using a hand shovel stainless steel and put it in polyethylene bags. Materials of human origin (pieces of glass or plastic and cigarettes and scrap pieces) were removed from samples, then samples were dried at room temperature and desegregates by using porcelain pestle carefully, the samples were transferred to the laboratory for analysis.

Physicochemical properties of soil: Geochemical property measurements were conducted include quantification of PH, EC, TOC at University of Basrah. The pH was measured in a solution of 1:1 water/soil ratio according to Page et al (1982), while the electrical conductivity (EC) was measured using a device, EC meter (Jenway 4510 Conductivity/TDS Meter) (Page et al (1982). Total organic carbon (TOC) was determined (Walkey and black 1934). Grain size analysis of 12 samples was determined by sieving using stainless-steel sieves (2, 1, 0.5, 0.250,0.125, 0.63 mm) respectively. Pipette method was used for counting silt and clay size percentages according to Folk method (1974). Ten metals were measured by using Agilent 7700 inductively coupled plasma-mass spectrometry (ICP-MS) in the lab of Kansaran Penaluod company-Iran. Panalytical PW3830 X-ray diffraction technique was used to identify clay and non-clay minerals.

Pollution assessment methods for heavy metals: Geoaccumulation Index (Igeo): Igeo is the most common indicator used to assess pollution Müller (1969). It is defined by the following formula:

$$\text{Igeo} = \log_2\left(\frac{\text{Cn}}{1.5\text{Bn}}\right) \quad \ldots\ldots (1)$$

Where, Cn is a concentration of heavy metals in soil, Bn is geochemical background reference value in soil. In this study worldwide soils in Reimann and Caritat(2012) were chosen as the background values. The background values (1.5) were used to reduce the variance (Pan et al 2017). The standard classes of Igeo for heavy metals are given according to Müller (1969) listed in Table 1

Potential Ecological Risk Index (RI): The RI was primarily introduced by Hakanson (1980) and quantitatively expresses the potential ecological risk of heavy metals in the environment. The RI is calculated as follows:

$RI = \sum Er$, ……(2)

$Er = Tr \times Cf$,……..(3)

$Cf = Cs / Bn$ …..(4)

Where RI is the sum of all risk factors for heavy metals

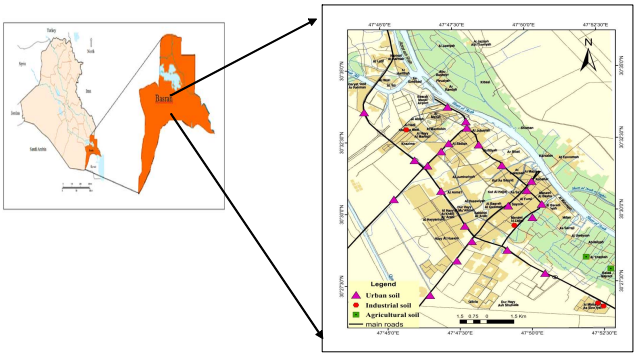

Fig. 1. The studied area and sampling locations

Table 1. The classification of indexes

Index	Category	Description
Geo-accumulation index (Igeo)	Igeo ≤ 0	Practically unpolluted
	0 < Igeo ≤ 1	Unpolluted to moderately polluted
	1 < Igeo ≤ 2	Moderately polluted
	2 < Igeo ≤ 3	Moderately to heavily polluted
	3 < Igeo ≤ 4	Heavily polluted
	4 < Igeo ≤ 5	Heavily to extremely polluted
	5 < Igeo	Extremely polluted
Pollution Index(PI)	PI ≤ 1	Low pollution
	1 <PI ≤ 3	Medium pollution
	PI> 3	High pollution
Integrated pollution index (IPI)	IPI ≤ 1	Low level of pollution
	1 <IPI ≤2	Medium level of pollution
	>2IPI ≤ 5	High level of pollution
	IPI> 5	Extreme high level of pollution
Single-potential ecological risk (Er)	<40	Low potential ecological risk
	40≤Er<80	Moderate potential risk
	80≤Er<160	Considerable potential risk
	160≤Er<320	High potential risk
Comprehensive-potential ecological risk (RI)	RI ≤ 50	Low ecological risk
	50 < RI ≤100	Moderate ecological risk
	100 < RI ≤ 200	Considerable ecological risk
	(RI > 200)	Extreme ecological risk

in soil, Er is the ecological risk factor of metals and Tr is the toxic response factor of metals ,Cf is the metal pollution factor, Cs and Bn are the content of metals and geochemical background reference values (Reimann and De Caritat 2012). Based on the standardized heavy metal toxic factor developed by (Wang et al., 2011; Yang et al 2009) known for As, Cd, Cr, Cu, Mn, Ni, Pb, and Zn to be 10, 30, 2, 5,1, 5, 5, and 1, respectively. Indices of potential ecological risks are listed in Table 1 according to Zhu et al (2008).

Pollution Index (PI): Soil quality was assessed by calculating the pollution index (PI) for each heavy metal and the integrated pollution index (IPI) for each sample, the PI is defined according to the following (Chen et al 2005):

PI= Cn/Bn …….(5)

Where Cn (ppm) is concentrations of elements in topsoils and Bn is the mean concentration of the elements in worldwide soils according to (Reimann and Caritat 2012). PI was calculated for each metal and classified. Based on the ArcGIS 10.4 software, and Ordinary Kriging analyzed methods (OK) map of the spatial distribution of heavy metals in urban soil were prepared. The generalized aim for the geochemical mapping is to obtain information about the distribution and sources of chemical elements that have practical applications in assessing health-risks to people within the urban environment, the method was applied by several studies (Lee et al 2006, Wong et al 2006, Albanese et al 2018, Johnson and Ander 2008).

RESULTS AND DISCUSSION

Physiochemical properties and grain size analyses of soil: The maximum pH values are closer to industrial and high traffic areas, minimum pH values (slightly acid) were in rural soil (Table 2). The acidic function of the soil system is a very significant parameter, as it directly affects dissolution and sorption / desorption, oxidation - reducing reactions and complex formation. All heavy metals are deposited only under alkaline conditions in the form of oxide, hydroxide, phosphate and carbonate. The total organic matter ranged from 0.24 to 2%. The highest was in the industrial area while the minimum in rural soil and open space soil. The electrical conductivity of soils changed depending on the amount of moisture held by soil particles. EC consequently correlates strongly to soil particle size and texture (Grisso et al 2009). Salinity reaches very high levels, in industrial areas (23.2ms /cm in Hamdan station), as compared to the level of salinity in the rural area. This may indicate the effect of commercial activities in the city which causes high salinity in comparison to the areas far from human activity. The results of grain size analysis revealed the gravelly to slightly gravelly muddy sand (Table 3). The texture class influence the contamination, since fine earth like clays is able to adsorb more cations (e.g Cd, Pb and Ni) than coarser fractions (Meuser 2013). Topsoil is characterized permanent changes due to the human activities taking place above it, therefore topsoil is considered more vulnerable to natural and human changes compared to the normal soils with a thick section (Wong et al 2006).

Mineralogy of soil: The X-ray diffraction patterns of bulk soil samples show that Quartz, Calcite and Gypsum are the main non-clay minerals with trace of halite and dolomite (Fig. 2). The high contents of carbonate in some samples resulting from evaporation of water continuously under the prevailed arid climate as well as associated with clay carbonate complex phase. The main clay minerals are Montmorillonite - Chlorite mixed layer, followed by Kaolinite, Palygorskite, Illite and Chlorite (Fig. 2). Clay minerals can uptake heavy metals in a series of complex adsorption mechanisms, like direct bonding between metal cations and the surface of clay minerals, ion exchange and surface complexation etc (Yuan et al 2013). Clay minerals have a high specific surface area, especially montmorillonite, which have excellent adsorption capacity, uniqueness and surface charge and usually acts as an adsorbent of cadmium, copper, lead, zinc, chromium (VI), nickel, etc (Uddin 2017).

Heavy metals concentrations in urban soils: The concentrations of As, Cd, Co, Cr, Cu, Fe, Mn, Ni, Pb and Zn in the urban soils of Basrah indicate that the mean concentration of As, Cr, Cu, Ni, Pb and Zn in urban soils exceeded the geochemical background values in world soil (Reimann and Caritat 2012) and upper crust (Rudnick and Gao 2003) (Table 2). Zn mean concentration (71.77 mg/kg) was close to the background value 70 mg/kg. The mean of Cd, Co, Fe, Mn were generally below the background values. The heavy metal concentrations in the industrial soils were generally higher than those in urban soils because of more anthropogenic activities (industrial waste of car workshops). This suggests Basrah urban soils were seriously influenced

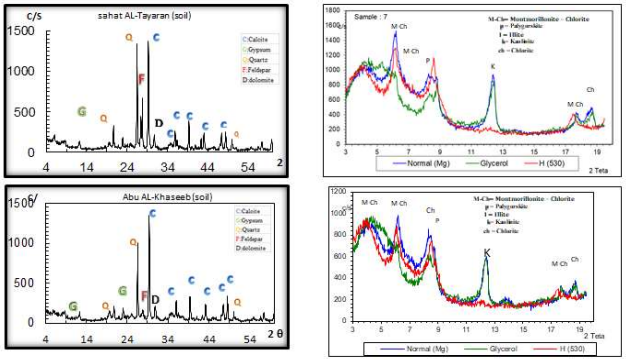

Fig. 2. XRD pattern of bulk soil samples for (a) non clay minerals and (b) clay minerals

Table 2. Heavy elements concentrations (mg/kg) and chemical properties of urban soil (0 – 20 cm) and compared to the worldsoil background and Upper earth's crust

Traverse	Sampling stations	pH	EC(ms/)	TOC%	As	Cd	Co	Cr	Cu	Fe	Mn	Ni	Pb	Zn	Site Description
1	AL Garma	7.15	1.65	0.86	18.7	0.13	5.92	800	26.87	15718	244	300	8.32	21.51	Commercial and residential area
	5mile	8.46	11.92	2	10.9	0.59	3.28	304	199.25	33733	377	118.5	140.7	150.6	Industrial and residential areas
	Baghdad main street	7.25	3.94	0.95	7.9	0.16	5.3	520	30.61	16300	420	260.5	17.31	50.35	Main street
	Hamdan Industrial area A	7.34	23.5	1.03	22.08	0.18	4.51	168	28.14	15668	290	76.6	23.37	49.68	Industrial area
	Hamdan Industrial area B	7.04	23.2	0.88	17.3	0.21	4.95	180	30.6	19503	310	90.3	32.2	60.7	Industrial area
	mean	7.448	12.842	1.144	15.376	0.254	4.792	394.4	63.094	20184.4	328.2	169.18	44.38	66.56	
2	AL-Maaqal	7.6	20.2	0.88	15.78	0.18	5.94	608	42.69	22937	391	113.8	43.02	86.29	Commercial and residential area
	Sahat AL_Ttayaran	7.17	1.456	0.24	0.19	0.2	9.04	273	36.17	28089	524	132.1	29.98	74.91	Open space
	AL khorah park	7.5	0.94	1.09	8.6	0.25	8.36	560	40.3	25601	490	110	30.1	80.6	Urban parks
	AL-Janabi	7.04	3.6	1.7	0.25	0.15	1.86	139	87.51	24821	302	52.8	46.34	117.8	Industrial and commercial areas
	mean	7.3275	6.549	0.9775	6.205	0.195	6.3	395	51.6675	25362	426.75	102.17	37.36	89.9	
3	Zubair road	8.38	0.679	0.56	7.5	0.31	7.15	420	36.4	22112	610	121	28.3	69.7	Main street
	Abdul Karim Qasim	7.6	3.1	1.04	3.08	0.21	8.28	699	41.84	28792	500	167.2	35.15	90.61	Commercial area
	Al Ashar	7.3	5.44	0.66	2.66	0.26	6.45	954	42.78	24716	422	111.9	35.19	83.72	Commercial area
	mean	7.76	3.073	0.7533	4.4133	0.26	7.2933	691	40.34	25206.6	510.66	133.36	32.88	81.34	
4	Yassin khraibet	8.45	0.887	1.06	5.6	0.24	7.16	720	35.6	32320	390	150	22.6	70.7	Residential area
	AL-skary intersection	7.6	5.3	1.08	4.49	0.2	5.17	900	23.11	23204	422	58.1	21.32	57.04	Commercial and Residential area
	Al jninah intersection	7.8	8.83	1.09	7.43	0.14	3.83	655	24.22	17437	298	52.3	10.53	35.55	Commercial a nd Residential area
	mean	7.95	5.0057	1.0767	5.84	0.1933	5.3867	758.3333	27.6433	24320.3	370	86.8	18.15	54.43	
Re	Abu AL-Khaseeb	6.2	7.88	0.24	12	0.2	10.4	247	33.8	32586	665	165.2	4.8	48.5	Rural soil
Minimum		6.2	0.679	0.24	0.19	0.13	1.86	139	23.11	15668	244	52.3	4.8	21.51	
Maximum		8.46	23.5	2	22.08	0.59	10.4	954	199.25	33733	665	300	140.7	150.6	
Total mean		7.49	7.66	0.96	9.03	0.23	6.10	509.19	47.49	23971.06	415.94	130.02	33.08	71.77	
World soil Background [a]		–	–	–	5	0.3	10	80	25	35000	530	20	17	70	
Upper crust content[b]		–	–	–	4.8	0.09	17.3	92	28	–	–	47	17	67	

a Reimann & Caritat (2012), b Rudnick and Gao (2003) , .Re: Reference soil, –no value

by discrete inputs related to anthropogenic activities, especially, vehicles and industrial emissions, fossil fuel combustion, garages, metal workshops and waste dumps. The mean concentrations of Cr and Ni are higher than in previous studies (Table 4). The mean of As and Cd are lower than National safe limit, the topsoil of Europe, Erbil City, Baghdad, China, but higher than western Australia (Table 4). The mean of Co is lower than in previous studies. Pb is higher than in Baghdad soil and lower than other studies. Generally, every urban area has its own typical signature for heavy metal combinations depending on the density of industrial activities in the city and technologies used, also local weather conditions and wind patterns.

Spatial distribution patterns of heavy metals: The Arsenic distribution patterns exhibited high-values in the north and south part of the study area. Dissimilar distribution trends were found in the concentration of Cd, Cr, Cu, Fe and Ni distribution patterns exhibited that very high concentration was found in the vicinity of AL-Garma, AL-Maaqal and 5 mile stations which were located in the northern part of the study area. Pb and Zn exhibited the same distribution patterns and have high-values in industrial and urban areas, resulting from the human activity connected with urban wastes and heavy traffic (Fig. 3). Generally, it was expected that the highest concentrations of heavy metals in urban soil around the industrial areas. However, the spatial distribution showed that relatively high concentrations of heavy metals occurred in dense residential areas with high traffic volumes and commercial areas. The spatial distribution suggested that the prevailing wind (north-west) has a significant influence on the transfer of heavy metals from the areas around the oil and gas fields, electrical, petrochemical, fertilizer industries across Basrah city.

Assessment of heavy metal pollution in urban soil

Evaluation of Geo-accumulation index (Igeo): According

Table 3. Grain size analysis of soil (depth 0 - 20cm)

Traverse	Sampling stations	Gravel %	Sand %	Silt %	Clay %	Mud %	Textural class
1	AL- Garma	5	81	11	3	14	Gms
	Baghdad main street	2	82	12	4	16	Gms
	Hamdan Industrial	3	79	14	4	18	Gms
2	Saha AL-Tayaran	7	78	11	4	15	Gms
	AL-Khorah park	7	82	8	3	11	Gms
3	Zubair road	4	82	10	4	14	Gms
	Abdul Karim Qasim sequare	1	80	15	4	19	Gms
	Al -Ashar	12	78	7	3	10	Gms
4	Yassin khraibet	20	70	7	3	10	Gms
	AL-skary intersection	9	83	3	5	8	Gms
	Al-Jninah intersection	3	87	7	3	10	Gms
Re	Abu Al-Khaseeb	1	86	7	6	13	Gms

GmS : Gravelly muddy sand, gmS: Slightly gravelly muddy sand

Table 4. Comparison of mean heavy metals concentrations (mg/kg) in urban soil of Basrah and other local and world cities

Location	As	Cd	Co	Cr	Cu	Fe	Mn	Ni	Pb	Zn	Refrences
National safe limit	29	0.8	–	100	36	–	–	35	85	140	Pronk (2000)
Topsoil of Europe	11.6	0.28	10.4	94.8	17.3	–	524	37	32	68.1	De Vos (2006)
Wuhan	–	0.2	16	85	34	–	630	34	33	85	Gong et al (2010)
Erbil city	9.72	0.34	–	–	4.57	–	–	14.45	52.65	0.54	Sherwan and Ammar (2014)
Baghdad	36	4	11	84	22	–	534	104	7.1	87	Hamad et al (2014)
Basra city Al- Zubair	–	3.80-0.1	27.00-1.5	34.50-1.5	–	–	–	38.60-1.5	178.00-10.1	–	Abass et al (2015)
China	10.9	0.22	–	66.1	24	–	–	23	147.6	47.5	Li D & Liao Y (2018)
Western Astralia	2.97	0.13	–	12.4	82.3		70.9	5.45	253	125	Rate (2018)
South india	–	–	16.538	43.24	40.64	–	–	7.55	47.48	34.68	Adimalla et al (2020)
Urban soil (Basrah)	9.03	0.23	6.10	509.19	47.49	23971.06	415.94	130.02	33.08	71.77	This work

–No value

to Igeo values (Table 5 and Fig. 5a), the pollution levels of Ni and Cr in all stations were higher than the other metals. Co, Fe and Mn fall into the category of practically unpolluted. Zn fall into practically unpolluted except for 5mile station with practically unpolluted to moderately polluted category. As falls into unpolluted to moderately polluted, while Cd falls into 'practically unpolluted' category except for 5mile area which showed unpolluted to moderately polluted category. Pb falls into the category of practically and unpolluted to moderately polluted except for 5mile showed moderately to strongly polluted. Generally, the Igeo has the following order; Ni> Cr > Cu > Pb > As > Zn > Mn> Cd> Co> Fe, indicating that human activity in the study area like industrialization, urbanization, urban and industrial wastes and vehicle emissions are the main source of pollution. Similar results were recorded in China (Wei and Yang 2010; Jiang et al 2020), South India (Adimalla et al 2020) and South Korea (Cho et al 2019).

Evaluation of ecological risk (RI): All the areas showed a low potential ecological risk (Er <40) excepted for 5mile area which showed a Moderate potential risk for both As (59) and pb (41.382), as well as As have Er (44.16) in the Hamdan industrial area (A) (Fig. 4). The ecological risk index for the pollution caused by As, Cd, Cr, Cu, Mn, Ni, Pb and Zn indicated that Basrah urban soil was classified as moderate to considerable ecological risk (Table 6). Sahat Al-Tayaran site has the lowest ecological risk, because it considers a green

Table 5. Extent of heavy metals pollution in urban soils in Basrah city

Elements	Range of Igeo	Mean of Igeo	Pollution level according to Igeo (Muller 1969)
As	-5.303~ 1.558	-0.47	Practically unpolluted'
Cd	-1.791~ 0.391	-1.099	Practically unpolluted'
Co	-3.012~ 0.526	-1.408	Practically unpolluted'
Cr	0.212~ 2.991	1.846	Moderate pollution
Cu	-0.698~ 2.41	0.071	Unpollution ~ moderate pollution
Fe	-5.009~ 0.638	-2.247	Practically unpolluted'
Mn	-1.704~ 0.14	-0.988	Practically unpolluted'
Ni	0.802~ 3.536	1.95	Moderate pollution
Pb	-2.483~ 2.464	-0.028	Practically unpolluted'except in 5mile fill in moderately to strongly polluted
Zn	-2.287~ 0.52	-0.683	Practically unpolluted except the station 5mile and Janabi fall in an unpolluted to moderately polluted category

Table 6. Potential ecological risk factor, risk index and pollution degree of hazardous metals in urban soils of Basrah

Traverse	Sampling station	Single Potential Ecological Risk (Er)								RI	Ecological Risk
		As	Cd	Cr	Cu	Mn	Ni	pb	Zn		
1	Al-Garma	37.4	13	20	5.374	0.460	20.690	2.447	0.307	99.678	Mer
	5 mile	21.8	59	7.6	39.85	0.711	8.172	41.382	2.151	180.668	Cer
	Baghdad main street	15.8	16	13	6.122	0.792	17.966	5.091	0.719	75.490	Mer
	Hamdan industrial area A	44.16	18	4.2	5.628	0.547	5.283	6.874	0.710	85.401	Mer
	Hamdan industrial area B	34.6	21	4.5	6.12	0.585	6.228	9.471	0.867	83.370	Mer
2	AL-Maaqal	31.56	18	15.2	8.538	0.738	7.848	12.653	1.233	95.770	Mer
	Sahat AL_Tayaran	0.38	20	6.825	7.234	0.989	9.110	8.818	1.070	54.426	Mer
	AL-khorah park	17.2	25	14	8.06	0.925	7.586	8.853	1.151	82.775	Mer
	AL-Janabi	0.5	15	3.475	17.502	0.570	3.641	13.629	1.683	56.000	Mer
3	Zubair street	15	31	10.5	7.28	1.151	8.345	8.324	0.996	82.595	Mer
	Abdul Karim Qasim site	6.16	21	17.475	8.368	0.943	11.531	10.338	1.294	77.110	Mer
	AL-Ashar	5.32	26	23.85	8.556	0.796	7.717	10.350	1.196	83.785	Mer
4	Yassin khraibet	11.2	24	18	7.12	0.736	10.345	6.647	1.010	79.058	Mer
	AL-Askari intersection	8.98	20	22.5	4.622	0.796	4.007	6.271	0.815	67.991	Mer
	AL-Jninah intersection	14.86	14	16.375	4.844	0.562	3.607	3.097	0.508	57.853	Mer
Re	Abu AL-Khaseeb	24	20	6.175	6.76	1.255	11.393	1.412	0.693	71.687	Mer
Minimum		0.38	13	3.475	4.622	0.460	3.607	1.412	0.307	54.426	Mer
Maximum		44.16	59	23.85	39.85	1.255	20.690	41.382	2.151	180.668	Cer
Mean		18.058	22.563	12.730	9.499	0.785	8.967	9.728	1.025	83.354	Mer

Mer: Moderate ecological risk, Cer: considerable ecological risk

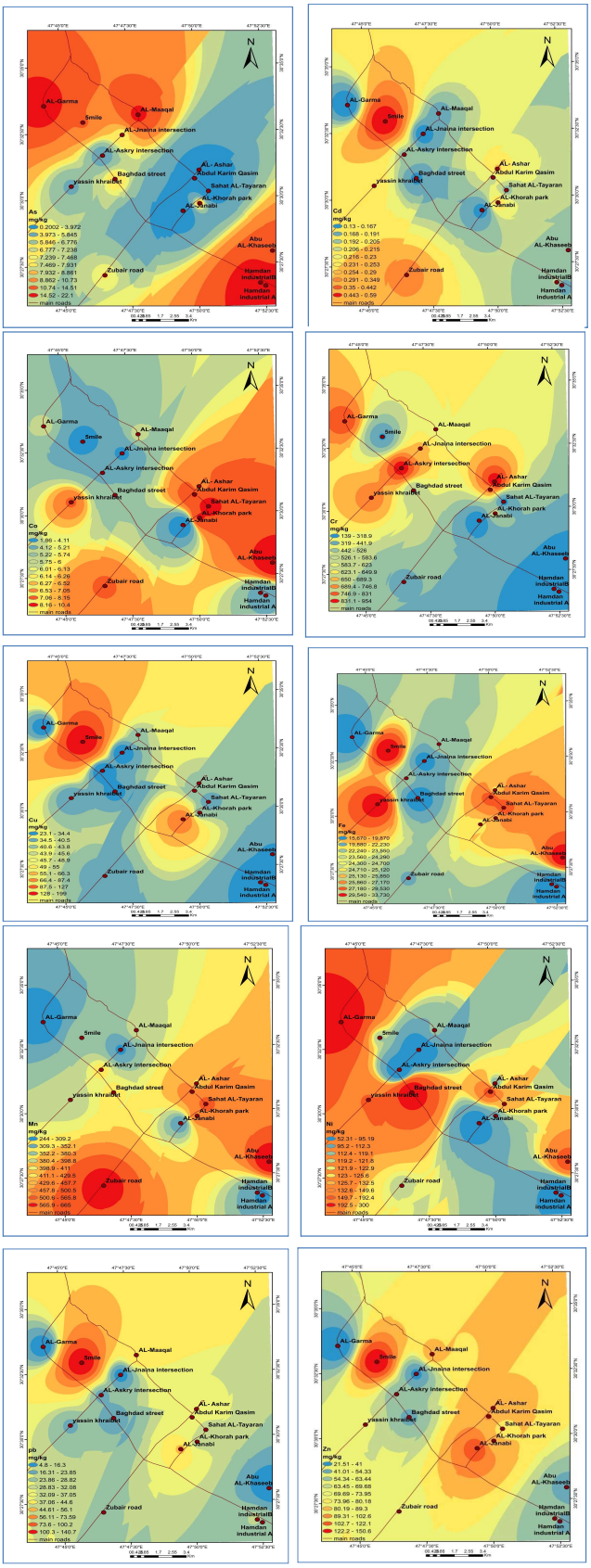

Fig. 3. The spatial distribution of heavy metals concentrations in urban soil of Basrah

area and open space and protected by trees from direct effects of particles and traffic emissions. The continuous vehicular traffic is the major local source of soil contamination, especially in the residential and industrial area (especially 5 mile site)

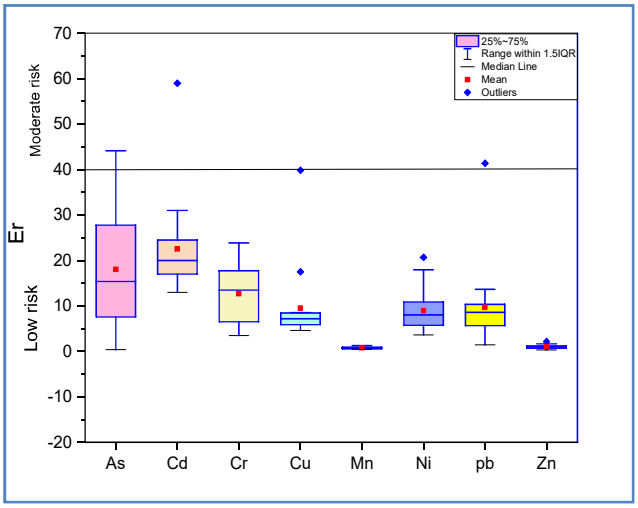

Fig. 4. Box-plots of Er for heavy metals. Boxes enclose the 25th and 75th percentiles. The bars at the ends of the tails mark the extremes. The small square and horizontal line within the box indicates the mean and median data, respectively

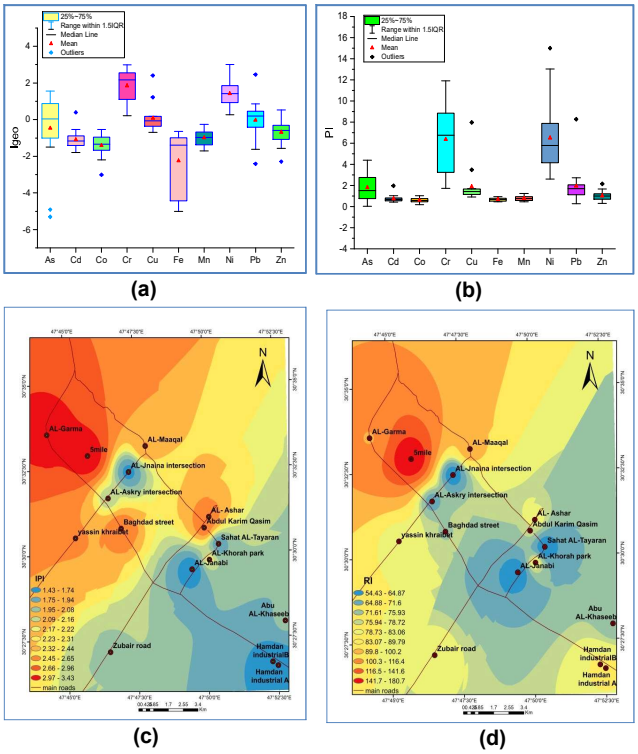

Fig. 5. Pollution assessment results: (a) the levels of Igeo; (b) levels of PI ; (c) geochemical distribution and levels of IPI;(d) spatial distribution of RI in urban soil of Basra city

Table 7. Pollution index (PI) and integrated pollution index (IPI) of heavy metals in urban soil

Traverse	Sampling sitation	PI											Description
		As	Cd	Co	Cr	Cu	Fe	Mn	Ni	pb	Zn	IPI	
1	Al-Garma	3.74	0.433	0.592	10	1.075	0.449	0.46	15	0.489	0.307	3.255	High pollution
	5mile	2.18	1.967	0.328	3.8	7.97	0.964	0.711	5.925	8.276	2.151	3.427	High pollution
	Baghdad main street	1.58	0.533	0.53	6.5	1.224	0.466	0.792	13.025	1.018	0.719	2.639	High pollution
	Hamdan industrial area A	4.416	0.6	0.451	2.1	1.126	0.448	0.547	3.83	1.375	0.71	1.56	Medium pollution
	Hamdan industrial area B	3.46	0.7	0.495	2.25	1.224	0.557	0.585	4.515	1.894	0.867	1.655	Medium pollution
2	AL-Maaqal	3.156	0.6	0.594	7.6	1.708	0.655	0.738	5.69	2.531	1.233	2.45	High pollution
	Sahat AL_Tayaran	0.038	0.667	0.904	3.413	1.447	0.803	0.989	6.605	1.764	1.07	1.77	Medium pollution
	AL-khorah park	1.72	0.833	0.836	7	1.612	0.731	0.925	5.5	1.771	1.151	2.208	High pollution
	AL-Janabi	0.05	0.5	0.186	1.738	3.5	0.709	0.57	2.64	2.726	1.683	1.43	Medium pollution
3	Zubair street	1.5	1.033	0.715	5.25	1.456	0.632	1.151	6.05	1.665	0.996	2.045	High pollution
	Abdul Karim Qasim site	0.616	0.7	0.828	8.738	1.674	0.823	0.943	8.36	2.068	1.294	2.604	High pollution
	AL-Ashar	0.532	0.867	0.645	11.925	1.711	0.706	0.796	5.595	2.07	1.196	2.604	High pollution
4	Yassin khraibet	1.12	0.8	0.716	9	1.424	0.923	0.736	7.5	1.329	1.01	2.456	High pollution
	AL-Askari intersection	0.898	0.667	0.517	11.25	0.924	0.663	0.796	2.905	1.254	0.815	2.069	High pollution
	AL-Jninah intersection	1.486	0.467	0.383	8.188	0.969	0.498	0.562	2.615	0.619	0.508	1.629	Medium pollution
Re	Abu AL-Khaseeb	2.4	0.667	1.04	3.088	1.352	0.931	1.255	8.26	0.282	0.693	1.997	Medium pollution
	Minimum	0.038	0.433	0.186	1.738	0.924	0.448	0.46	2.615	0.282	0.307	1.43	Medium pollution
	Maximum	4.416	1.967	1.04	11.925	7.97	0.964	1.255	15	8.276	2.151	3.427	High pollution
	Mean	1.8058	0.7521	0.61	6.365	1.8998	0.6849	0.7848	6.5009	1.9457	1.0252	2.2374	High pollution

which shows a considerable ecological risk, because of the daily industrial activities and vehicle exhaust emissions.

Pollution index (PI): Cd, Co, Fe, and Mn have lower values of PI, ranging from 0.43 to 1.96, 0.18 to 1.04, 0.4 to 0.9 and 0.4 to 1.25, respectively (Table 7, Fig. 5b), while metals As, Cu, Pb and Zn with low to high pollution, Cr and Ni medium to high PI. Residential areas and city parks are confronted with the risks of heavy metal contamination due to high population density and intense human activities (Meza-Figueroa et al 2007), traffic sources, urban construction and demolition activities , industrial workshops are all potential sources for heavy metal pollution in an urban environment (Han et al 2008).

Spatial distribution of integrated pollution index (IPI): To further assess the pollution levels in the urban Basrah city, an integrated pollution index (IPI) was used to prepare the geochemical maps which represent distribution and degree of pollution of ten heavy metal in urban soil (Fig. 5c). The northern and western parts of Basrah city were more polluted than the other parts of the city which indicated that the soils in these areas have elevated concentrations of heavy metals. In particular, the soil of AL-Garma, 5mile, AL-Maaqal, Yassin Khrabit, Baghdad street, AL-Ashar and Abdul Karim Qasim station areas are most affected by continuous vehicular emissions (intense traffic activities) which lead to the enrichment of heavy metals in these areas. The wind has an ability to transport the dust bearing metals, As, Ni, Cr, Cu, Pb, and Zn from theses high polluted areas to the surrounding areas. In addition oil refineries also increase of toxic metals around the refinery urban and residential areas.

CONCLUSION

Urban soil of Basrah has high concentrations of As, Cu, Cr, Ni, Pb and Zn higher than the geochemical background values, indicating the dominance of human sources, while Cd, Co, Fe, Mn generally were within allowable limit values. The urban areas have been affected by pollution from hazardous waste, transport activities, vehicles emissions and industrial waste. The pH and EC value indicate that the urban soil of Basrah city was considered neutral to strongly alkaline and low to high salinity. Quartz, Calcite and Gypsum are the main mineral component of urban soil with a trace of Dolomite, Feldspar and Halite. The major clay minerals are Montmorillonite-Chlorite mixed layer, kaolinite, Palygorskite, Illite and chlorite. The high organic matter is due to anthropogenic sources related to traffic and the burning of fossil fuels, agricultural fertilizer, and industrial waste, these organic matters have ability to form water-soluble and water-insoluble complexes with metal ions and interact with clay minerals and sorb and desorb both naturally-occurring and anthropogenically -introduced organic compounds. The Igeo showed that the pollution levels ranged from practically

unpolluted to moderate pollution. Ecological risk (Er) indicated that most metals only caused low risk in all the sample stations, while As, Cd and Pb caused moderate risk in industrial areas. The pollution index (PI) result showed low to high pollution by As, Cu, Pb and Zn, Cr and Ni showed middle to high pollution, while Cd, Co, Fe, Mn showed low pollution. The IPI has medium to high pollution levels of heavy metals. Geochemical distribution maps indicated that the most pollution stations were located in the northern and western parts (commercial, residential and industrial areas).

REFERENCES

Abass MH, Hassan ZK and Al-Jabary KM 2015. Assessment of heavy metals pollution in soil and date palm (Phoenix dactylifera L.) leaves sampled from Basrah/Iraq governorate. *Advances in Environmental Sciences* **7**(1): 52-59.

Adimalla N, Chen J and Qian H 2020. Spatial characteristics of heavy metal contamination and potential human health risk assessment of urban soils: A case study from an urban region of South India. *Ecotoxicology and Environmental Safety* **194**: 110406.

Albanese S, Cicchella D, Lima A and De VB 2018. Geochemical mapping of Urban Areas, pp 151-133. In: De VB, Belkin HE and In Lima, A. (eds). *Environmental Geochemistry: Site Characterization, Data Analysis and Case Histories,* Elsevier, Amsterdam.

Al-Khafaji SJ, Alali SH and Alsaad HA 2010. Identification and upgrading of feldspar in some sand deposits, southern Iraq. *Journal of Basrah Research* (36): 12-35 (in Arabic)

Alloway BJ 2013. Sources of heavy metals and metalloids in soils, pp 50-11. In Alloway B J (eds). *Heavy Metals in Soils*, Springer, Dordrecht.

Castro-G NP, Calderon SF, Moreno RR, Moreno OA and Tamariz FJV 2017. Health risks in rural populations due to heavy metals found in agricultural soils irrigated with wastewater in the Alto Balsas sub-basin in Tlaxcala and Puebla, Mexico. *International Journal of Environmental Health Research* **27**(6): 476-486.

Chen TB, Zheng YM, Lei, M, Huang ZC, Wu HT, Chen H and Tian QZ 2005. Assessment of heavy metal pollution in surface soils of urban parks in Beijing, China. *Chemosphere* **60**(4): 542-551.

Cho I G, Park MK, Cho HK, Jeon JW, Lee SE and Choi SD 2019. Characteristics of metal contamination in paddy soils from three industrial cities in South Korea. *Environmental Geochemistry and Health* **41**(5): 1895-1907.

Crissso R, Alley M, Holshouser D and Thomason W 2009. *Precision Farming Tools; Soil Electrical Conductivity*, Report produced by Vrgina coopevative extension, publications, pp 442-508.

CSO 2020. Ministry of Planning - central statistical organization of Iraq, http://cosit.gov.iq/ar/

De Vos W, Tarvainen T, Salminen R, Reeder S, De Vivo B, Demetriades A and OConnor PJ 2006. *Geochemical Atlas of Europe. Part 2 Interpretation of Geochemical Maps, Additional Tables, Figures, Maps and related publications*, Espoo: Geological Survey of Finland, p 692.

Directorate General traffic 2019. Ministry of Interior. Statistical Yearbook of vehicle registration and driving licenses. Basrah: General Directorate of Traffic; 2019 (unpublished).

Folk RL 1974. *Petrology of sedimentary rocks*, Austin. Texas, Hemphill pub, p182.

Gong M, Wu LB , Ren LM, Wang L, Ma ZD and Li ZG 2010. Assessing heavy-metal contamination and sources by GIS-based approach and multivariate analysis of urban-rural topsoils in Wuhan, central China. *Environmental Geochemistry and Health* **32** (1): 59-72.

Hakanson L 1980. An ecological risk index for aquatic pollution control. A sedimentological approach. *Water Research* **14**(8): 975-1001.

Hamad SH, Schauer JJ, Shafer MM, Abd Al-Rheem E, Skaar PS, Heo J and Tejedor-Tejedor I 2014. Risk assessment of total and bioavailable potentially toxic elements (PTEs) in urban soils of Baghdad–Iraq. *Science of the Total Environment* **494**: 39-48.

Han Y, Cao J, Posmentier ES, Fung K, Tian H and An Z 2008. Particulate-associated potentially harmful elements in urban road dusts in Xi'an, China. *Applied Geochemistry* **23**(4): 835-845.

Jiang HH, Cai LM, Wen HH, Hu GC, Chen G and Luo J 2020. An integrated approach to quantifying ecological and human health risks from different sources of soil heavy metals. *Science of the Total Environment* **701**: 134466.

Jiries A 2003. Vehicular contamination of dust in Amman, *Jordan. Environmentalist* **23**(3): 205-210

Johnson CC and Ander EL 2008. Urban geochemical mapping studies: How and why we do them. *Environmental Geochemistry and Health* **30**(6): 511-30.

Lee CS, Li X, Shi W, Cheung SC and Thornton I 2006. Metal contamination in urban, suburban, and country park soils of Hong Kong: a study based on GIS and multivariate statistics. *Science of the Total Environment* **356**(1-3): 45-61.

Li D and Liao Y 2018. Spatial characteristics of heavy metals in street dust of coal railway transportation hubs: A case study in Yuanping, China. *International Journal Of Environmental Research and Public Health* **15** (12): 2662.

Manasreh WA 2010. Assessment of trace metals in street dust of mutah city, Kurak, Jordan. *Carpathian Journal of Earth and Environmental Sciences* **5**(1): 5-12.

Meuser H 2013. *Contaminated urban soils*, springer science, Busines media, B.V, p 339.

Meza FD, De la OM, and De la Parra ML 2007. Heavy metal distribution in dust from elementary schools in Hermosillo, Sonora, México. *Atmospheric Environment* **41**(2): 276-288.

Muller G 1969. Index of geoaccumulation in sediments of the Rhine River. *Geojournal* **2:** 108-118.

Padoan E, Romè C and Ajmone MF 2017. Bioaccessibility and size distribution of metals in road dust and roadside soils along a peri-urban transect. *Science of the Total Environment* **601**: 89-98.

Page AL, Miller RH and Keeney DR 1982. *Methods of soil analysis part*2, 2 nd (Ed). Agron.9, pub. Madison Wisconsin, U.S.A, p1159

Pan LB, Ma J, Wang XL and Hou H 2017. Heavy metals in soils from a typical county in Shanxi Province, China: Levels, sources and spatial distribution. *Chemosphere* **148**: 248-254.

Peltier RE, Cromar KR, Ma Y, Fan ZHT and Lippmann M 2011. Spatial and seasonal distribution of aerosol chemical components in New York City: (2) Road dust and other tracers of traffic-generated air pollution. *Journal of Exposure Science and Environmental Epidemiology* **21**(5): 484-494.

Pronk JP 2000. Circular on target values and intervention values for soil remediation. *Ministry of Housing, Spatial Planning and Environment Report No. DBO/1999226863. The Hague, Netherlands*.

Rate AW 2018. Multielement geochemistry identifies the spatial pattern of soil and sediment contamination in an urban parkland, Western Australia. *Science of the Total Environment* **627**: 1106-1120.

Reimann C and De Caritat P 2012. *Chemical elements in the environment: factsheets for the geochemist and environmental scientist*. Handbook Springer Science and Business Media, p 397.

Ross S 1994. *Toxic metals in soil-plant systems*. Chichester, West

Sussex, England: Wiley, p 469

Rudnick RL and Gao S 2003. Composition of the continental crust. *The crust* **3**: 1-64.

Sherwan K and Ammar K 2014. heavy metals concentration in surface soils of some community parks of the Erbil City, *Zanco Journal of Pure and Applied Sciences* **26** (2): 31-38.

Thornton I, Farago ME, Thums CR, Parrish RR, McGill RA, Breward N and Crout NM 2008. Urban geochemistry: Research strategies to assist risk assessment and remediation of brownfield sites in urban areas. *Environmental Geochemistry and Health* **30** (6): 565-576

Uddin MK 2017. A review on the adsorption of heavy metals by clay minerals, with special focus on the past decade. *Chemical Engineering Journal* **308**: 438-462.

Walkley A and Black IA 1934. An examination of the Degtjareff method for determining soil organic matter, and a proposed modification of the chromic acid titration method. *Soil Science* **37**(1): 29-38.

Wang Y, Yang Z, Shen Z, Tang Z, Niu J and Gao F 2011. Assessment of heavy metals in sediments from a typical catchment of the Yangtze River, China. *Environmental Monitoring and Assessment* **172**(1-4): 407-417.

Wei B and Yang L 2010. A review of heavy metal contaminations in urban soils, urban road dusts and agricultural soils from China. *Microchemical Journal* **94**(2): 99-107.

Wong CS, Li X and Thornton I 2006. Urban environmental geochemistry of trace metals. *Environmental pollution* **142**(1): 1-16.

Yang Z, Wang Y, Shen Z, Niu J and Tang Z 2009. Distribution and speciation of heavy metals in sediments from the mainstream, tributaries, and lakes of the Yangtze River catchment of Wuhan, China. *Journal of hazardous materials* **166**(2-3): 1186-1194.

Yang Y, Christakos G, Guo M, Xiao L and Huang W 2017. Space-time quantitative source apportionment of soil heavy metal concentration increments. *Environmental Pollution* **223**: 560-566.

Yuan GD, Theng BKG, Churchman GJ and Gates WP 2013. Clays and clay minerals for pollution control. *Developments in Clay Science* **5**: 587-644.

Zhu W, Bian B and Li L 2008. Heavy metal contamination of road-deposited sediments in a medium size city of China. *Environmental Monitoring and Assessment* **147**(1-3): 171-181.

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Influence of Ameliorants on Soil Respiration of Volleyers of The Rostov Zoo

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Abstract: Soils of the Rostov-on-Don Zoo were investigated in 2017-2020. The objects of research were aviaries with birds (*Grus grus , Pavo cristatus , Branta canadensi and others*), Chapman's zebras (*Equus burchelli chapmani*), red deer (*Cervus elaphus*), which were subjected to seasonal migrations-in the spring to the emu aviary (*Dromaius Vieillot*), in the summer in the guanaco aviary (*Ama glama*), two-humped camel (*Camelus bactrianus*), blue rams (*Seudois nayaur*), the arnee Buffalo, the white rhinoceros (*Ceratotherium simum*), the Rothschild giraffej (*Giraffa camelopardalis rothschildi*), domestic donkeys (*Equus asinus dom*). The control was a section of the park zone of the zoo with minimal anthropogenic impact. The soil and vegetation of the control site was typical of most of the zoo. The soil of the study area is ordinary black soil (haplic chernozem Loamic), widely distributed in the steppe zone of Russia. Soil monitoring showed a significant violation of the ecological condition of soils and soil cover. The main problem of the soil in the enclosures of the zoo is to increase the bulk density, the destruction of the soil structure, and soil pollution by waste products of animal vital activity. Soil respiration in the enclosures of the zoo is increased due to the additional intake of organic substances into the soil with animal metabolic waste. The use of various ameliorants (river sand, glauconite, acrylic hydrogel, sawdust, microbiological preparation) can help improve the ecological condition of soils and increase biological activity. This will help accelerate the processes of biological decomposition of pollutants accumulated in soils. Sawdust proved to be better than other ameliorants for optimizing the ecological state of the zoo's soil.

***Keywords*:** Soil quality, Biological activity, Animals, Bioindication, Ecological state

Assessment of soil quality is an important component of environmental monitoring and, along with pollution, includes the whole range of ecological functions of soils (Bünemann et al 2018). Therefore, an important component of soil quality assessment is the identification of a set of sensitive soil features that reflect the ability of the soil to function and can be used as indicators of soil quality. The biological properties of soils have great potential for assessing the ecological state of soils (Karlen et al 2019). Soil respiration is an indicator of soil quality in the United States along with other important indicators (organic carbon, microbial biomass, potential mineralized carbon and nitrogen, active carbon, soil protein, beta-glucosidase, etc.) (Karlen et al 2019). Its response to external influences is determined in connection with the need to increase the sensitivity and accuracy of assessments of the state of the soil. Soil carbon dioxide emission, also called soil respiration, includes the processes of microbiological decomposition of organic substances and autotrophic root respiration. Soil is one of the main sources of carbon dioxide emissions into the atmosphere, far superior to other sources (Oertel et al 2016). The five main biogenic sources of CO_2 emission from soils were isolated and described under their turnovers and average carbon residence time (Kuzyakov 2006). These are root respiration, root microbial respiration, decomposition of plant debris, the primary effect caused by exudation of the root or the addition of plant debris, and basal respiration by microbial decomposition of soil organic matter.

Soil respiration is one of the indicators of soil biological activity. The total respiration rate of the soil is determined by all its biological activity. The emission of CO_2 may be an indicator of the decomposition rate of soil organic matter and allows one of the most important aspects of the biological carbon cycle to be characterized. The biological properties of soils are largely dependent on environmental conditions and, above all, on temperature and moisture (Kazeev et al 2015, Pal et al 2020). The respiration rate of soils is also regulated by many factors and, above all, hydrothermal conditions (Ivanov et al 2018, Lopes et al 2018,Trushkov et al 2019). Negative effects (fires, pollution, soil compaction using agricultural machinery, erosion, etc.) lead to a decrease in soil biological activity and respiration (Daoud et al 2019, Odabashyan et al 2019, Oertel et al 2019). These studies are necessary for monitoring and developing a system for improving the ecological condition of soils. An environmental assessment of ameliorants is needed to improve the conditions of animals in the zoo and reduce the risk of pathogenic microorganisms in soils.

MATERIAL AND METHODS

Rostov-on-Don Zoo is one of the largest zoos in Russia (the area is 57 hectares). Located in the center of Rostov-on-Don with a population of more than million people. Since 2017, the environmental status of the territory has been monitored on the territory of the Rostov-on-Don Zoo using biological and environmental indicators. The objects of research were the soils of the territory of the Rostov-on-DonZoo: aviaries with birds (gray cranes *Grus grus*, peacocks *Pavo cristatus*, *kazarks Branta canadensi*, etc.), Chapman's zebras (*Equus burchelli chapmani*), red deer (*Cervus elaphus*), which were subjected to seasonal migrations – in the spring to the aviary emu (*Dromaius vieillot*), in summer – in the aviary guanaco (*Lama glama*), the Bactrian camel (*Camelus bactrianus*), blue rams (*Pseudois nayaur*), buffalo Arnie (*Bubalus bubalis arnee*), white rhinos (*Ceratotherium simum*), Rothschild giraffe (*Giraffa camelopardalis rothschildi*), domestic donkeys (*Equus asinus dom*). For control was taken as the area of parkland with a minimal anthropogenic violation, with soil and vegetation typical of much of the zoo. The recreationally disturbed site is located 50 m from the control site and is characterized by a significant violation of the soil surface. The soil cover of the study area is represented by ordinary Chernozem (Haplic Chernozem Loamic), widely distributed in the South of Russia. The humus content in the surface horizon is 4-6%, characterized by high biological activity, the biodiversity of the mesofauna, and microorganisms.

Soils from different parts of the zoo were incubated to determine the potential emission rate of CO_2. To do this, the soil was dried, sifted through a sieve with 3 mm holes, 200 g were weighed into 500 ml plastic containers. Soil moisture was brought up to 40% of the pore spacewater. The containers were aired before each measurement event to a concentration of CO_2 in the environment, then they were tightly closed for 1 hour. An aliquot of gas with a volume of 10 ml was taken with a syringe to puncture the container wall if determined with a gas analyzer PGA-7 (CJSC SPC Elektronstandart, St. Petersburg, Russia). In another experiment, the determination of CO_2 was carried out directly in the container after the insertion of Testo 535 gas analyzer probe (Testo SE & Co. KGaA, Germany)withaccuracy of ± 75 ppm CO_2.The measurement of CO_2 emission was carried out after 14, 17, 32 days. The change in soil moisture was determined whenever determining CO_2 and corrected to 40% WFPS.

In the second experiment, the influence of ameliorants on the intensity of soil carbon dioxide emission was determined. In soil contaminated with waste products from the enclosure with a deer, ameliorants were added at a dose of 5% by weight of the soil. Ameliorants were glauconite sand, wood shavings, and sawdust, acrylic-based hydrogel. The microbiological preparation Tamir was used to increase the rate of biodegradation of organic substances in this experiment. The control was relatively undisturbed soil from the park zone of the zoo. Respiration was determined by measuring the accumulation of gas in a container insulated for 1 hour. The determination of carbon dioxide emissions was carried out 14, 21, and 28 days after the laying of the experiment. Soil respiration was determined after a long time to take into account the Birch effect, which has been known among soil ecologists for about a century (Birch 1964). This effect is associated with a short-term, but powerful mineralization of organic substances in the soil and the pulsed release of CO_2 in response to moisture after long-term drying.Chamber methods for determining carbon dioxide emissions using gas analyzers are widely used in soil science and ecology (Ivanov et al 2018,Lopes et al 2018). The repetition of the experiment (the number of insulating chambers) is 3-5 times. Recalculation of the measurement results into the value of the C-CO_2flux was performed using the Mendeleev-Clapeyron equation:

$$SR = \frac{12 \times 10^{-6} \times C \times P \times V}{8.314\ (t+273)}$$

where: *SR*- change in the mass of carbon in the chamber, g C/12 - a molar mass of carbon, g C/mol; 10^{-6} - conversion factor from ppm to volume fractions, 1/ppm; *C*- change in the concentration of CO_2 in the chamber, ppm; *P* - atmospheric pressure, Pa; *V* - chamber volume, m^3; 8.314 - universal gas constant, Pa m^3/°K per mole; *t* - air temperature, °C; 273 - parameter for recalculating the air temperature, °K. Given the exposure time and the area of the base of the chamber, we estimated the emission intensity in g C-CO_2/m^2/24 h.

RESULTS AND DISCUSSION

The soils of the zoo are more or less altered compared to their natural counterparts due to human and animal exposure. The degree of soil surface damage depends on the size of the enclosure, the number and size of the animals contained in them. Monitoring of the ecological state of the enclosures of the Rostov Zoo showed a high degree of degradation of the physical properties of soils and their contamination with metabolic products of animals (Kazeev et al 2018, Zhadobinet al 2019). A significant load from the maintenance of animals leads to unfavorable water-physical properties in the clay composition of the soil. This affects animals living in enclosures. Significant changes in the physical, chemical and biological properties of soils occur in

relatively small enclosures with large ungulates, such as red deer (Fig. 1, 2). A significant amount of nutrients with animal excretion products enters the soil of the enclosures. Deer droppings are removed from the enclosure every day. However, it is not possible to remove the products of nitrogen evolution. Therefore, due to the limited size of the enclosure and the size of the deer (about 300 kg), the flow of urine per square meter of soil exceeds 3.8 liters per year. This significantly violates the biological processes in the soil. The high biological activity of chernozems can significantly neutralize biological pollution in the aviary. The values of the respiration rate were to a large extent very dynamic. In general, the control soil of the Park released less carbon dioxide than the soil of the deer enclosure polluted by the release products (Fig. 3). This is due to the increased content of biogenic elements in the aviary. The difference is especially high during the entire observation period 2017-2019. The mobile phosphorus was 2 or more times higher in the soil of the deer aviary. Nutrient availability is paramount for microbial and plant respiratory processes. Consequently, the natural content of nitrogen and carbon in the soil, as well as organic and mineral fertilizers play an important role in regulating soil respiration. An increase in the nitrogen content of the soil usually leads to higher soil respiration. In the deer enclosure, the soil contained approximately 50% more exchange ammonium than in the soil of the control plot. Soil respiration decreases during the long-term experiment on the addition of nitrogen. Therefore, in the enclosure, soil respiration is limited by this indicator, since the bulk density in it (1.3-1.6 g/cm^3) has always been significantly higher than the control values (1.1-1.2 g/cm^3). However, this factor was not taken into account in the model experiment, since all soils had the same composition.

One of the methods for soil reclamation is the technology used in the zoo to improve the physical properties of soils using sand, which is added to the soil of some of the most degraded areas (enclosures with sheep, rhinos, buffalo, and zebras). The amount of added sand varies in different studied areas. In conditions of slight disturbance of the soil cover, sand is not applied at all, and in some enclosures with the largest animals (elephants, bison's), sand completely covers the soil with a thick layer. The use of alternative ameliorants was aimed at increasing the rate of decomposition of animal waste and improving the ecological condition of soils. A model experiment was carried out for the soil of one of the most polluted aviaries (male red deer). Soil respiration was maximum in the soil of the aviary in the aviary with birds during the entire observation period (Fig. 4). This is due to the minimal impact of birds on the soil cover. Here, the ecological properties of soils were optimal compared to the soils of other sites.

Biological indicators respond to ameliorants in different ways. In the conducted model study, the use of hydrogel showed the lowest efficiency. When it is introduced, the soil moisture is significantly reduced, which led to its desiccation and a sharp decrease in the intensity of biological processes. Although some scientists believe that the use of an acrylic-

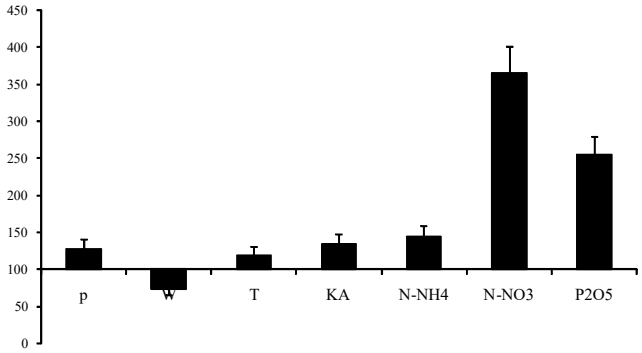

Fig. 2. Ecological properties of the soil of an aviary with a deer compared to the control (100%), May 2019: p - bulk density; W - soil moisture; T - temperature; KA - catalase activity; $N\text{-}NH_4$, $N\text{-}NO_3$, P_2O_5 - content of plant nutrients (ammonium, nitrates and mobile phosphorus)

Fig. 1. The condition of the soil in the cage with deer

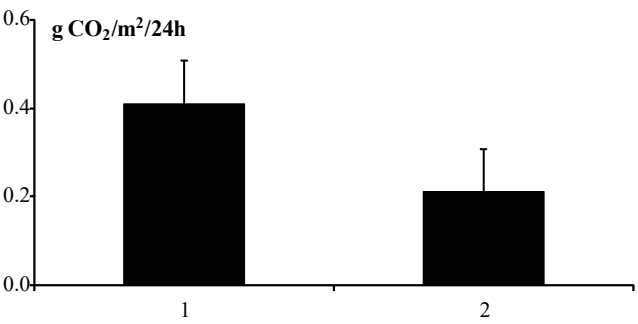

Fig. 3. The average value of the respiration of the soil of the enclosure with a deer (1) and the control plot (2), 12 determinations within 24 days of the experiment

containing hydrogel does not inhibit the heterotrophic soil microflora (Mellelo et al 2019). The use of inert glauconite sand, in general, did not significantly affect the respiration rate of soils and even significantly decreased in the first determination period after 14 days. The maximum effect on the studied indicator of activation of biological processes had the introduction of wood sawdust. An increase in respiration intensity was noted at all three periods of determination when they were introduced, and a maximum of activation was revealed at the end of the experiment (an increase of 2.9 times relative to the soil without ameliorant). The use of the microbiological preparation Tamir slightly increased respiration a month after the start of the experiment. Its combined use with sawdust led to a significant increase in the intensity of CO emission$_2$ (an increase of 2.5 times). Thus, the activation of biological processes as a result of the use of sawdust was revealed, which, also, can adsorb excess animal nutrients much better than sand. At the same time, wood sawdust in its composition and structure is very similar to forest litter and steppe felt of natural ecosystems in which the animals contained in the zoo live.

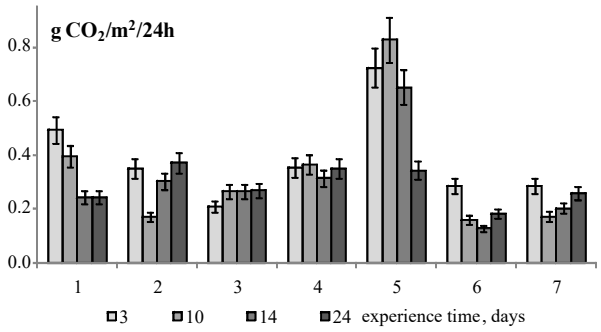

Fig. 4. Soil respiration in different parts of the Rostov Zoo, 1 hour exposure: 1) zebras; 2) deer / emu; 3) deer; 4) rams; 5) birds; 6) recreationally disturbed site; 7) control

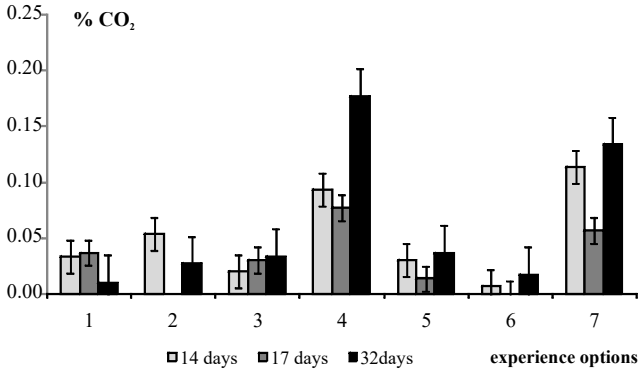

Fig. 5. The effect of ameliorants on the respiration rate of soils: 1) control; 2) dirty soil; 3) green earth; 4) sawdust; 5) Tamir; 6) hydrogel; 7) sawdust + Tamir

CONCLUSION

Keeping animals in a limited area of enclosures in a zoo can lead to a significant deterioration in the ecological condition of soils. To a large extent this applies to large ungulates, which compact the soil and pollute it with metabolic waste products. The use of ameliorants leads to the normalization of the bulk density, the water-air regime, and the improvement of soil respiration, which is an integral indicator of the biological activity of the soil. An increase in biological activity can contribute to the rapid neutralization of biogenic soil pollution of the zoo. The best land reclamation materials for the zoo are sawdust.

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REFERENCES

Birch HF 1964. Mineralisation of plant nitrogen following alternate wet and dry conditions. *Plant and Soil* **20**: 43-49.

Bünemann EK, Bongiorno G, Bai Z, Creamer RE, De Deyn G, Goede R, Fleskens L, Geissen V, Kuyper TW, Mäder P, Pulleman M, Sukke WI, Groenigen JW and Brussaard L 2018. Soil quality: A critical review. S*oil Biology and Biochemistry* **120**: 105-125.

Daoud RM, Kolesnikov SI and Kazeev K Sh 2019. Development of ecological regional maximum permissible concentrations of fuel oil in arid soils of South of Russia. *Indian Journal of Ecology* **46**(4): 740-744.

Ivanov AV, Braun M and Tataurov VA 2018. Seasonal and daily dynamics of the CO_2 emission from soils of pinus koraiensis forests in the South of the Sikhote-Alin Range. *Eurasian Soil Science* **51**(3): 290-295.

Karlen DL, Veum KS, Sudduth KA, Obrycki JF and Nunes MR 2019. Soil health assessment: Past accomplishments, current activities, and future opportunities. *Soil and Tillage Research* **195** 104365.

Kazeev KS, Kozun' YS and Kolesnikov SI 2015. Applying an integral index to evaluate the spatial differentiation of biological properties of oils along an aridity gradient in the South of Russia. *Contemporary Problems of Ecology* **8**(1): 91-98.

Kazeev K Sh, Zhadobin A V, Barbashev A I, Akimenko Y V and Kolesnikov SI 2018. Ecological State of the Soil at the Rostov-on-Don Zoo. *18th International Multidisciplinary Scientific GeoConference SGEM*. Conference Proceedings **18**: 119-126.

Kuzyakov Y 2006. Sources of CO_2 efflux from soil and review of partitioning methods. S*oil Biology and Biochemistry* **38**: 425-448.

Lopes de Gerenyu VO, Kurganova IN and Khoroshaev DA 2018. The effect of contrasting moistening regimes on CO_2 emission from the gray forest soil under a grass vegetation and bare fallow. *Eurasian Soil Science* **51**(10): 1200-1213.

Mellelo E, Samuilova EO, Denisov TS, Martynova DM and Olekhnovich RO 2019. Influence of the bentonite-containing acrylic humectant composite on the soil microflora. *Agronomy Research* **17**(5): 1960-1968.

Mordhorst A, Peth S and Horn R 2014. Influence of mechanical loading on static and dynamic CO_2 efflux on differently textured and managed Luvisols. *Geoderma* **219–220**, 1-13.

Odabashyan MY, Trushkov AV, Kazeev K Sh, and Kolesnikov SI 2019. Impact of wildfire on biological activity of sandy soil in the

South of Russia. *Indian Journal of Ecology* **46**(3): 648-653.

Oertel C, Matschullat J, Zurba K, Zimmermann F and Erasmi S 2016. Greenhouse gas emissions from soils: A review. *Chemie der Erde* **76**: 327-352.

Pal S, Panwar P, Loria N, Verma MR and Sharma NK 2020. Seasonal dynamics of soil microbial biomass carbon under different forests of north western Himalaya, India. *Indian Journal of Ecology* **47**(1): 164-170.

Zhadobin AV, Kazeev K Sh, Lesina AL, Aleksandrov AA, Kravtsova NE and Kolesnikov SI 2019. Assessment of the ecological condition of soils in Rostov zoo. *PNRPU. Applied ecology. Urban development* **1**: 131-141.

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Biochemical Analysis of Lead Induced Stress in Fodder Plants Pearl Millet (*Pennisetum glaucum* L.) and Alfalfa (*Medicago sativa* L.)

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Abstract: Heavy metals due to contamination of soil, water and air have imposed deleterious impact on both producers and consumers. An experiment was conducted to examine the effect of heavy metal i.e. lead on two edible plants i.e. pearl millet (*Pennisetum glaucum*) and alfalfa (*Medicago sativa*). Lead impact was induced by treating each set with different concentrations of lead nitrate ranging from 0 (control), 50, 100, 200 and 400 ppm. All seedling and plant growth parameters decreased in shoots and roots of both the plants with increasing concentrations of lead nitrate. Toxicity increased with increase in concentration of lead nitrate. Nevertheless, stress markers (MDA and Proline) were enhanced in pearl millet (*Pennisetum glaucum*) and alfalfa (*Medicago sativa*). This study highlighted that lead exerted harmful stress to the growth of *P. glaucum* and *M. sativa* upon uptake. Being edible plants entrance of lead in food chain and bio magnification at higher trophic level cannot be ignored. Therefore, immediate steps to mitigate lead pollution must be an urgent strategy for the sake of food safety.

Keywords: Heavy metal Pb, Pearl millet (*Pennisetum glaucum*), Alfalfa (*Medicago sativa*), Food chain, Bio magnification

One of the major prevalent problems worldwide due to anthropogenic activities heavy metals toxicity enhancement in natural resources which thereby affects plant growth in agro ecosystems. The heavy metals Pb, Cd, Cu, Zn, Ni, Co, Cr, and As are non-essential plant elements which adversely influence the plants at increased concentrations (Bharti et al 2019, Abdeldayem 2020). Not only this, bio magnification of Pb further exaggerated the problem of metal toxicity at higher trophic levels in a food chain. (Bhatti et al 2016, Yildirim et al 2019). The Pb reaches into the soil mostly due to anthropogenic activities, industrial effluents and vehicles etc. (Adamiec et al 2016). Besides, forest fire, volcano activity and seepage from rocks are also a cause (Sağlam 2013). In many parts of the world agricultural soils are contaminated slightly to moderately by heavy metal toxicity. This could be due to the long-term application of fertilizers, wastewater sludge, industrial waste and lead based products by human beings (Alimardan et al 2016, Ziarati et al 2016, Punia et al 2017). Research is in progress to develop stress tolerant crops (Rai et al 2011) which is also a safe method to combat such pollution. Production of reactive oxygen species (ROS) in response of increased levels of heavy metals is the first symptom of plant's reaction (Mithofer et al 2004). Other stress biomarkers are antioxidants, phenolic acids, protein and proline concentration (Aljahdali and Alhassan 2020). The effect of induced Pb content has been investigated on two edible crops i.e. pearl millet (*Pennisetum glaucum*) and alfalfa (*Medicago sativa*) in the present study. Growth in terms of morphometric and biochemical characteristics was considered for assessing the impact of lead on these two fodder crops of desert regions.

MATERIAL AND METHODS

Certified seeds of *Medicago sativa* L. and *Pennisetum glaucum* L. from Durgapura Research Station, Jaipur, Rajasthan were superficially sterilized for 3 min with 0.1 percent $HgCl_2$ solution, then thoroughly washed 3 times each for 5 min with distilled water and then dried with paper towel. Dry seeds were placed on a sheet of Whatman No. 1 filter paper in 90 mm diameter Petri dishes, and then moistened with 4 different concentrations of lead nitrate i.e. 50, 100, 200 and 400ppm and distilled water seeds also grown as in control. There were five treatments including control and replicated thrice. Each treatment has 30 seeds and total 150 seeds for each species were taken in this experiment (10 seeds/ petri plates). The Petri plates were kept under a photoperiod of 12 h, and room temperature (25±1°C) under normal light. Germination was observed for 7 days. The seedlings were harvested after two weeks. Growth parameters such as germination (%), root and shoot lengths and dry weight of seedlings were measured. Growth index, seed vigour index, relative stress injuries were computed. Further, biochemical markers of stress viz., proline, protein, lipid peroxidation contents were also determined in the dry matter of each treatment after 15 days using standard methods.

RESULTS AND DISCUSSION

Exposure to Pb produced deleterious effect on the

growth of seedlings of alfalfa and pearl millet. Germination per cent decreased to 73 and 67 % at 200 ppm and 67 and 60% in alfalfa and pearl millet at 400 ppm respectively. The shoot length and root length of alfalfa significantly decreased from 5.4 to 0.8cm and 6.7 to 1.2 cm at 400 ppm concentration of lead nitrate respectively. The same trend followed in pearl millet. With the elevation of Pb concentrations, the dry weights of alfalfa and pearl millet seedlings were significantly reduced from 0.169 g in control to 0.061g (Table 1) and 0.692 to 0.395 g at 400 ppm (Table 2). Seed vigour index significantly decreased from 11.72 to 2.58 at 200 and 1.34 at 400ppm in alfalfa and from 12.35 to 3.15 at 200 and 1.86 at 400ppm in pearl millet (Table 3). Growth Index also declined with increasing concentrations of lead.The relative stress injury (Table 3), proline concentrations (Table 4) and lipid peroxidation (Table 4) enhanced considerably from lower concentration to highest concentration of lead in the present study showing the sign of stress in the plant. However, protein content (Table 4) decreased with the increase in concentration of Pb in both the plants. The alfalfa and pearl millet both are edible fodder crops, the former is a medicinal plant whereas latter is important grain for human food and cattle feed. Absorption of Pb by fodder crop is harmful for cattle and others. Bio magnification has been documented (Zeng et al 2013). Pb has basically no role in plants metabolic processes (Tangahu et al 2011) hence accumulated in various parts (Zhou et al 2018). It is absorbed through roots (Fahr et al 2013).

The increased concentration of HMs in soil or water due to man-made is toxic to the growth of plants (Amari et al 2017). High concentration of HMs can diminish the protein pool (Chatterjee et al 2004, Garcia et al 2006,Piotrowska et al 2009) and certain amino acids, like proline, increase under lead stress (Qureshi et al 2007). Such proteins play a major role in the tolerance of the plant to lead and may defend the plant against lead stress (Gupta et al 2010), particularly for proteins involved in cell redox maintenance. The decrease in seed germination of pearl millet due to heavy metal treatment is in conformity with the findings of other workers (Turk and Tawaha 2003, Sharma and Agrawal 2005,Tian et al 2010, Sera et al 2010). General inhibition in physiological and biochemical processes along with plant's function has been

Table 1. Growth of alfalfa seedlings after two weeks of exposure to heavy metal (Pb)

Parameter	Control	50 ppm	100 ppm	200 ppm	400 ppm
Germination %	97±5	90±5**	83±4**	73±4**	67±2**
Shoot length (cm)	5.4±0.2	4.2±0.15**	2.5±0.20**	1.5±0.08**	0.8±0.06**
Root length (cm)	6.7±0.08	5.5±0.20**	3.7±0.1**	2±0.08**	1.2±0.08**
Seedling length (cm)	12.1±0.18	9.7±0.14**	6.2±0.08**	3.5±0.15**	2±0.15**
Dry weight(g)	0.169±0.01	0.114±0.01*	0.093±0.007**	0.069±0.001**	0.061±0.002**

Table 2. Growth of pearl millet seedlings after two weeks of exposure to HM (Pb)

Parameter	Control	50 ppm	100 ppm	200 ppm	400 ppm
Germination %	93±3	90±4**	77±2**	67±3**	60±2**
Shoot length, cm	7.6±0.14	5.7±0.08**	4.5±0.15**	2.5±0.08**	1.8±0.03**
Root length, cm	5.6±0.23	4.2±0.08**	3.9±0.06**	2.2±0.14**	1.3±0.03**
Seedling length, cm	13.2±0.23	9.9±0.16**	8.4±0.59**	4.7±0.20**	3.1±0.23**
Dry weight(g)	0.692±0.03	0.613±0.04**	0.595±0.03**	0.455±0.009**	0.395±0.004**

Table 3. Growth of seedlings after two weeks of exposure to HM (Pb)

Concn of lead nitrate	*P. glaucum*			*M. sativa*		
	Seed vigour index	Growth index	Relative stress injury	Seed vigour index	Growth index	Relative stress injury
Control	12.35±0.3	1±0.1	00±0.0	11.72±0.2	1±0.1	00±0.0
50 ppm	8.91±0.2**	0.74±0.03**	0.03±0.00**	8.73±0.2**	0.79±0.03**	0.06±0.00**
100 ppm	6.46±0.2**	0.63±0.03*	0.17±0.01**	5.19±0.2**	0.50±0.03*	0.13±0.01**
200 ppm	3.15±0.1**	0.35±0.02**	0.28±0.01*	2.58±0.1**	0.28±0.02**	0.24±0.02**
400 ppm	1.86±0.1**	0.23±0.02**	0.35±0.02**	1.34±0.1**	0.16±0.02**	0.31±0.02**

Table 4. Biochemical markers of HMs (Pb) stress in pearl millet and alfalfa seedlings after two weeks of exposure to Pb

Concn of lead nitrate	*P. glaucum*			*M. sativa*		
	Proline (mg/g of FW)	Protein (mg/g of FW)	MDA (µmole MDA/gm FW)	Proline (mg/g of FW)	Protein (mg/g of FW)	MDA (µmole MDA/gm FW)
Control	0.29±0.02	12.80±0.70	0.014±0.001	0.16±0.02	14.60±0.32	0.012±0.001
50 ppm	0.34±0.02*	9.00±0.70**	0.022±0.003**	0.18±0.01*	11.00±0.90**	0.019±0.002**
100 ppm	0.48±0.02**	7.00±0.26**	0.030±0.003**	0.24±0.02**	8.00±0.70**	0.024±0.001**
200 ppm	0.56±0.03**	3.00±0.15*	0.035±0.003**	0.36±0.02**	6.00±0.36**	0.036±0.004**
400 ppm	0.62±0.04**	2.60±0.30**	0.041±0.003**	0.54±0.04**	4.00±0.20**	0.042±0.004**

Mean±SE. *p< 0.05, **p<0.01. All columns of growth parameters are significantly compared with control using Tukey test

observed (Yildirim et al 2010). In the present study, both germination and growth are affected by the presence of heavy metals in both the crops. Heavy metals enter the food chain through grazing of contaminated crops and fodder (Kumar et al 2019). It reaches to human bodies through milk and fish in greater quantity as a result of bioaccumulation. Excess of HMs like Pb can seriously damage health of human and ecosystems (Ehya and Marbouti 2016). Use of Pb containing products should be minimized and remediation of soil and water encouraged at all levels to save from metal toxicity.

CONCLUSION

Heavy metal pollution in natural resources like soil, water and air has exerted heavy metal stress in plants. HM stress like Pb, deteriorated the growth of fodder plants alfalfa and pearl millet. It reduced germination, size, length and dry weight of both plants significantly. Not only this, the effect is evidenced from stress markers analyses. The proline content increased in fodder plants with increasing concentrations. Lipid peroxidation also increased due to the increased free oxygen radicles. While protein content decreased. All these stress markers showed the Pb toxicity in fodder plants. The study highlighted the presence of Pb in fodder plants which may be dangerous for health of cattle and further caused serious damage to food security.

REFERENCES

Abdeldayem RA 2020. Preliminary study of heavy metals pollution risk in water. *Applied Water Science* **10**(1): 1-4.

Adamiec E, Jarosz-Krzemińska E and Wieszała R 2016. Heavy metals from non-exhaust vehicle emissions in urban and motorway road dusts. *Environmental monitoring and Assessment* **188**(6): 369-372.

Alimardan M, Ziarati P and Jafari Moghadam R 2016. Adsorption of heavy metal ions from contaminated soil by *B. integerrima* barberry. *Biomedical & Pharmacology Journal* **9**(1): 169-175.

Aljahdali MO and Alhassan AB 2020. Metallic pollution and the use of antioxidant enzymes as biomarkers in Bellamyaunicolor [(Olivier, 1804) (Gastropoda: Bellamyinae)]. *Water* **12**(1): 202.

Amari T, Ghnaya T and Abdelly C 2017. Nickel, cadmium and lead phytotoxicity and potential of halophytic plants in heavy metal extraction. *South African Journal of Botany* **111**: 99-110.

Bharti V, Jain U, and Mohil P 2019. Effect of Heavy Metals on Physiology and Biochemical Profiling in *Cyamopsis tetragonoloba* L. *International Journal of Contemporary Research and Review* **10**(8): 20191-20202.

Bhatti SS, Sambyal V and Nagpal AK 2016. Heavy metals bioaccumulation in berseem (*Trifolium alexandrinum*) cultivated in areas under intensive agriculture, Punjab, India. *Springer Plus* **5**(1): 173.

Chatterjee C, Dube BK, Sinha P, Srivastava P 2004. Detrimental effects of lead phytotoxicity on growth, yield, and metabolism of rice. *Communications in Soil Science and Plant Analysis* **35**(1-2): 255-265.

Garcia JS, Gratão PL, Azevedo RA and Arruda MAZ 2006. Metal contamination effects on sunflower (*Helianthus annuus* L.) growth and protein expression in leaves during development. *Journal of Agricultural and Food Chemistry* **54**(22): 8623-8630.

Gupta D, Huang H, Yang X, Razafindrabe B and Inouhe M 2010. The detoxification of lead in *Sedum alfredii* H. is not related to hytochelatins but the glutathione. *Journal of Hazardous Materials* **177**(1-3): 437-444.

Helaoui S, Boughattas I, Hattab S, Mkhinini M, Alphonse V, Livet A, Bousserrhine N and Banni M 2020. Physiological, biochemical and transcriptomic responses of *Medicago sativa* to nickel exposure. *Chemosphere* **249**: 126-131.

Mithofer A, Schulze B and Boland W 2004. Biotic and heavy metal stress response in plants: evidence for common signals. *FEBS Letters* **566**: 1–5.

Piotrowska A, Bajguz A, Godlewska-Zylkiewicz B, Czerpak R and Kaminska M 2009. Jasmonic acid as modulator of lead toxicity in aquatic plant *Wolffia arrhiza* (Lemnaceae). *Environmental and Experimental Botany* **66**(3): 507-513.

Siddaiah NS and Singh SK 2017. Source and assessment of metal pollution at khetri copper mine tailings and neighboring soils, Rajasthan, India. *Bulletin of Environmental Contamination and Toxicology* **99**(5): 633-641.

Qureshi M, Abdin M, Qadir S and Iqbal M 2007. Lead-induced oxidative stress and metabolic alterations in *Cassia angustifolia* Vahl. *Biologia Plantarum* **51**(1):121-128.

Rai M, Kalia R, Singh R, Gangola MP and Dhawan A 2011. Developing stress tolerant plants through in vitro selection-An overview of the recent progress. *Environmental and Experimental Botany* **71**(1): 89-98.

Sağlam C 2013. Heavy metal accumulation in the edible parts of some cultivated plants and media samples from a volcanic region in Southern Turkey. *Ekoloji* **22**(86): 1-8.

Sera B, Spatenka P, Sery M, Vrchotova N and Hruskova I 2010. Influence of plasma treatment on wheat and oat germination and early growth. *IEEE Transactions on Plasma Science* **38**(10): 2963-2968.

Sharma RK and Agrawal M 2005. Biological effects of heavy metals: An overview. *Journal of Environmental Biology* **26**(2): 301-313.

Tangahu BV, Abdullah SRS, Basri H, Idris N, Anuar M and Mukhlisin M 2011. A review on heavy metals (As, Pb and Hg) uptake by plants through phytoremediation. *International Journal of Chemical Engineering* **2011**: 1-31.

Tian B, Xie B, Shi J, Wu J, Cai Y, Xu T, Xue S and Deng Q 2010. Physicochemical changes of oat seeds during germination. *Food Chemistry* **119**(3): 1195-1200.

Turk MA and Tawaha AM 2003. Allelopathic effect of black mustard (*Brassica nigra* L.) on germination and growth of wild oat (*Avena fatua* L.). *Crop Protection* **22**(4): 673-677.

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Zeng Y, Huang X, Gu B, Zhang D, Zhang X and YeF. 2013. Analysing biomagnification of heavy metals in food web from the Pearl River Estuary, South China by stable carbon and nitrogen isotopes. *Fresenius Environmental Bulletin* **22**: 1652-1658.

Zhou J, Zhang Z, Zhang Y, Wei Y and Jiang Z 2018. Effects of lead stress on the growth, physiology, and cellular structure of privet seedlings. *PLOS ONE* **13**(3): 1-17.

Ziarati P, Shokri F and Mousavi Z 2016. Removal of selected heavy metals from pharmaceutical effluent by *Aloe Vera* L. *Biomedical and Pharmacology Journal* **9**(2): 705-713.

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Appraisal of Soil Fertility Status in Vegetable Growing Soils of Outer Himalayan Region of Himachal Pradesh

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Abstract: The present investigation was carried out to assess the fertility status of soils under vegetable cultivation in Outer Himalayan region of Himachal Pradesh. Georeferenced surface soil samples (0-15 cm depth) from eighteen representative sites were collected from soils under vegetable based cropping sequences in Outer Himalayan region of Himachal Pradesh. The mean available N (kg ha^{-1}), P (kg ha^{-1}), K (kg ha^{-1}), Ca {cmol(p+) kg^{-1}}, Mg {cmol(p+) kg^{-1}}, S (kg ha^{-1}), Cu (mg kg^{-1}), Fe (mg kg^{-1}), Mn (mg kg^{-1}) and Zn (mg kg^{-1}) in these vegetable growing soils were 357, 10.8, 173, 3.9, 1.5, 23, 0.30, 7.9, 2.3 and 0.67, respectively. Out of total soil samples, 28, 39, 56 and 33 per cent soil samples were deficient in N, P, S and Zn, respectively. Such a spatial variation in soil fertility may be attributed to natural factors/processes as well as land management practices. Thus, soil test based balanced fertilizer recommendations or nutrient management can play a key role in enhancing vegetable production in the region.

***Keywords*:** Fertility status, Vegetable growing soils, Soil nutrient index, Himachal Pradesh

Soil is one of the most important components in human's total stock of natural resources which determines the food production and ultimate sustainability of any agricultural system. It has been described as a product of its environmental factors *viz.,* climate, vegetation/ organic matter, parent material, relief and time. The most important component of soil that virtually determines the productivity of agricultural system is soil fertility which may be defined as the inherent capacity of soil to supply essential nutrients to plants in adequate amount, in correct proportion at right-time for their optimum growth (Buol et al 2003). Soil fertility comprises not only the supply of nutrients but also their efficient management. Balanced plant nutrition plays a key role in sustainable agricultural production by increasing input use efficiency. Thus, assessment of nutritional status of soils can go a long way in developing economically viable alternatives for management of deficient nutrients in the soil. India is the second largest producer of vegetables in the world due to favorable agro-climatic conditions. In India, the area under vegetables was 10.26 million hectares with a production of 184.40 million tones during 2017-18 (Anonymous 2018). Vegetable cultivation is also gaining popularity among farmers in the hill state of Himachal Pradesh. The agro-climatic conditions are congenial for vegetable cultivation in the state. During 2018-19, vegetable production was 17.22 lakh tones in Himachal Pradesh (Anonymous 2019). The land holdings in the state are mostly marginal and small due to which there is limited scope for increasing income and employment from the production of traditional crops. Thus, the farmers who have irrigation facilities are diversifying their cropping systems through the introduction of vegetable crops for increasing their income. Outer Himalayas ("*Shivaliks*") which occupies 16.4 per cent of total geographical area of the Himachal Pradesh (55, 673 km^2) has greater significance for vegetable production. The region is spread over an area of 9.13 lakh hectares. The soils of this region are mainly belong to *Entisols* and *Inceptisols* (Sidhu et al 1997). Maintaining optimum soil nutrient levels is the key to a sustainable and productive vegetable production enterprise. The information on fertility status of vegetable growing soils in the Outer Himalayan region of Himachal Pradesh is lacking. Therefore, the present investigation was undertaken to assess the soil nutrient levels in vegetable growing *Entisols* and *Inceptisols* of Outer Himalayan region of Himachal Pradesh.

MATERIAL AND METHODS

Collection of soil samples*:* Eighteen (18) soil sampling sites representing major soils (*Entisols* and *Inceptisols*) under vegetable based cropping sequences were selected in Outer Himalayan region of Himachal Pradesh (Table 1). The composite surface soil samples (0-15 cm depth) were collected from selected vegetable growing sites.

Analysis of soil samples: All the collected soil samples were air dried in shade, crushed gently, sieved to obtain a uniform soil sample and stored in polythene bags for analysis. The soil samples were analyzed for available

nutrient status by using standard procedures. Available nitrogen (N) in soils was determined by alkaline potassium permanganate method described by Subbiah and Asija (1956). Available phosphorus (P) was estimated by using Olsen extractant (0.5 M $NaHCO_3$) (Olsen et al 1954). Available potassium (K) was extracted by using neutral normal ammonium acetate and the content was determined by aspirating the extract into flame photometer (Black 1965). Available calcium (Ca), magnesium (Mg) and sulphur (S) were determined as per the standard procedures (Jackson 1973). The method of Lindsay and Norvell (1978) was used for the estimation of available copper (Cu), iron (Fe), manganese (Mn) and zinc (Zn) in atomic absorption spectrophotometer (AAS) using DTPA extractant.

Available macro-and micro-nutrient status of soils was categorized as low, medium or high and sufficient or deficient, respectively by using the same limits as adopted by the State Soil Testing Laboratories (Table 2). Nutrient indices (NI) were worked out to depict the overall available status of each macro-nutrient in soils by using the formula proposed by Parker et al (1951) as given below:

$$\text{Nutrient Index (NI)} = \{(N_l \times 1) + (N_m \times 2) + (N_h \times 3)\} / N_t$$

where, N_l , N_m & N_h = Number of samples falling in low, medium and high category of nutrient status, respectively; N_t = Total number of samples analyzed for a nutrient in any given area.

Table 2. Critical limits used for classification of macro- and micro-nutrient status

Parameter	Critical limits
Available N	Low (< 280 kg ha^{-1}) Medium (280-560 kg ha^{-1}) High (> 560 kg ha^{-1})
Available P	Low (< 10 kg ha^{-1}) Medium (10-25 kg ha^{-1}) High (> 25 kg ha^{-1})
Available K	Low (< 118 kg ha^{-1}) Medium (118-280 kg ha^{-1}) High (> 280 kg ha^{-1})
Available Ca	Low (<1.5 cmol (p+) kg^{-1}) Medium (1.5 – 2.5 cmol (p+) kg^{-1}) High (>2.5 cmol (p+) kg^{-1})
Available Mg	Low (< 0.5 cmol (p+) kg^{-1}) Medium (0.5 to 1.0 cmol (p+) kg^{-1}) High (>1.0 cmol (p+) kg^{-1})
Available S	Low (<22.4 kg ha^{-1}) Medium (22.4 - 44.8 kg ha^{-1}) High (>44.8 kg ha^{-1})
Available Cu	Deficient (< 0.2 mg kg^{-1}) Sufficient (>0.2 mg kg^{-1})
Available Fe	Deficient (< 4.5 mg kg^{-1}) Sufficient (> 4.5 mg kg^{-1})
Available Mn	Deficient (< 1.0 mg kg^{-1}) Sufficient (> 1.0 mg kg^{-1})
Available Zn	Deficient (< 0.6 mg kg^{-1}) Sufficient (> 0.6 mg kg^{-1})

Table 1. A brief detail of soil sampling sites

Site	District	Location		Vegetables based cropping sequences
		Latitude	Longitude	
Entisols				
Fatehpur-I	Una	31°23'05"N	076°17'53"E	Sponge gourd/okra-wheat
Fatehpur-II	Una	31°23'06"N	076°17'53"E	Pumpkin-brinjal-raddish
Fatehpur-III	Una	31°23'08"N	076°18'04"E	Okra-potato-pea
Rainsary	Una	31°30'04"N	076°13'48"E	Okra-potato/cauliflower
Panoh	Una	31°31'48"N	076°12'07"E	Cauliflower-pea-frenchbean
Mogi Nand	Sirmaur	30°31'06"N	077°14'54"E	Colocasia/ginger-onion
Gangath	Kangra	32°13'36"N	075°49'27"E	Okra-cauliflower-onion
Ghera	Kangra	32°02'46"N	076°06'18"E	Summer squash-okra-radish
Thappal	Kangra	32°08'39"N	076°01'45"E	Okra-potato-wheat
Ghar Jarot	Kangra	32°05'06"N	076°04'00"E	Okra-potato-onion-coriander
Jarpal	Kangra	32°04'46"N	076°05'34"E	Bottle gourd-cauliflower-radish
Sasan	Bilaspur	31°24'51"N	076°33'28"E	Okra/chilli-wheat
Marura	Bilaspur	31°27'42"N	076°30'12"E	Bittergourd-cauliflower-radish
Inceptisols				
Dabhota	Solan	31°05'09"N	076°38'09"E	Turmeric/ginger-wheat
Khajurna	Sirmaur	30°32'20"N	077°17'49"E	Bottle gourd-spinach
Kolar	Sirmaur	30°29'58"N	077°26'13"E	Ginger-wheat
Spail	Kangra	32°05'09"N	076°06'46"E	Pumpkin-chilli/okra-radish
Bani	Kangra	31°48'21"N	076°13'12"E	Colocasia/turmeric-wheat

On the basis of NI, soil fertility level in respect of macro-nutrients was categorized as low (<1.67), medium (1.67 to 2.33) and high (>2.33).

RESULTS AND DISCUSSION

Available macro-nutrient status of soils

Primary nutrients (N, P & K): Mean available N, P and K in vegetable growing soils of Outer Himalayan region of Himachal Pradesh were 357, 10.8 and 173 kg ha^{-1}, respectively (Table 3). On the basis of NI, available N, P and K status in soils was medium (1.72), low (1.61) and medium (2.00), respectively. The 28 and 39 per cent of total soils were low in available N and P, respectively . Mean available N, P and K were 328, 9.9 and 160 kg ha^{-1} in *Entisols* and 432, 13.0 and 209 kg ha^{-1} in *Inceptisols*, respectively (Table 3). *Entisols* had lower mean values of available N, P and K as compared to *Inceptisols.* The NI values revealed that available N, P and K status was low (1.62), low (1.46) and medium (2.00) in *Entisols* and medium (2.00), medium (2.00) and medium (2.00) in *Inceptisols*, respectively. Similar observations were made by Kumar and Verma (2005) in soils of Palam valley of Himachal Pradesh and Annepu et al (2017) in mid Himalayan region of Himachal Pradesh.

Secondary nutrients (Ca, Mg & S): Mean available Ca {cmol(p+) kg^{-1}}, Mg {cmol(p+) kg^{-1}} and S (kg ha^{-1}) in the studied soils were 3.9, 1.5 and 23, respectively (Table 3). On the basis of NI, available Ca, Mg and S status in soils was high (2.89), high (2.83) and low (1.44), respectively. Of the total soils, 56 per cent soils were low in available S. Mean available Ca {cmol(p+) kg^{-1}}, Mg {cmol(p+) kg^{-1}} and S (kg ha^{-1}) were 3.6, 1.3 and 21 in *Entisols* and 4.7, 2.0 and 28 in *Inceptisols*, respectively (Table 3). *Entisols* had lower mean values of available Ca, Mg and S as compared to *Inceptisols.* The NI values revealed that available Ca, Mg and S status was high (2.85), high (2.77) and low (1.38) in *Entisols* and high (3.00), high (3.00) and low (1.60) in *Inceptisols*,

Table 3. Available nutrient status in vegetable growing soils of outer Himalayan region of Himachal Pradesh

Site	Available macronutrients						Available micronutrients			
	Primary nutrients			Secondary nutrients			Micro-nutrient cations			
	N	P	K	Ca	Mg	S	Cu	Fe	Mn	Zn
	(kg ha^{-1})			{cmol(p+) kg^{-1}}		(kg ha^{-1})	(mg kg^{-1})			
Entisols										
Fatehpur-I	178	6.4	124	2.5	1.0	13	0.20	4.7	1.6	0.40
Fatehpur-II	245	7.2	128	3.1	1.1	15	0.24	6.0	1.8	0.48
Fatehpur-III	163	6.6	124	2.4	0.8	12	0.18	4.5	1.6	0.32
Rainsary	257	7.8	132	3.2	1.2	17	0.24	5.6	1.8	0.44
Panoh	147	5.4	172	3.9	1.5	9	0.18	8.8	2.6	0.40
Mogi Nand	298	9.0	184	3.9	1.5	19	0.28	10.4	2.8	0.50
Gangath	316	7.9	124	3.1	1.1	20	0.28	5.4	1.6	0.60
Ghera	345	10.8	180	4.2	1.5	21	0.26	9.4	2.6	0.82
Thappal	440	12.4	180	4.2	1.4	27	0.34	8.4	2.4	0.88
GharJarot	514	15.0	230	5.0	2.2	37	0.40	10.2	2.8	0.72
Jarpal	410	11.8	196	4.2	1.5	23	0.30	9.8	2.8	0.92
Sasan	492	14.2	168	3.6	1.4	35	0.42	5.2	1.9	0.70
Marura	457	14.5	132	3.0	0.8	28	0.38	5.0	1.8	0.82
Mean ± SD	328±126.87	9.9±3.37	160±34.47	3.6±0.76	1.3±0.37	21±8.59	0.28±0.08	7.2±2.32	2.2±0.51	0.62±0.21
Inceptisols										
Dabhota	336	10.4	248	5.8	2.8	21	0.26	14.0	3.4	0.80
Khajurna	528	15.4	236	5.2	2.4	37	0.44	12.8	3.2	0.90
Kolar	457	14.0	154	3.6	1.3	27	0.36	5.2	1.6	0.60
Spail	514	15.0	236	4.8	2.0	36	0.44	8.8	2.4	0.80
Bani	325	10.2	172	3.9	1.4	19	0.28	8.6	2.2	0.90
Mean ± SD	432±96.48	13.0±2.52	209±42.93	4.7±0.91	2.0±0.64	28±8.31	0.36±0.09	9.9±3.54	2.6±0.74	0.80±0.12
Overall Mean ± SD	357±125.92	10.8±3.39	173±42.38	3.9±0.92	1.5±0.54	23±8.84	0.30±0.09	7.9±2.88	2.3±0.59	0.67±0.20

respectively. Similar observations were made by Suri et al (2019) in soils of Lesser Himalayan region of Himachal Pradesh and Annepu et al (2017) in mid Himalayan region of Himachal Pradesh.

Available micro-nutrient status of soils: Mean available Cu, Fe, Mn and Zn in vegetable growing soils of Outer Himalayan region of Himachal Pradesh were 0.30, 7.9, 2.3 and 0.67 mg kg^{-1}, respectively (Table 3). Available Cu, Fe and Mn were sufficient in all soils while available Zn was deficient in 33 per cent of total soils . Mean available Cu, Fe, Mn and Zn in soils were 0.28, 7.2, 2.2 and 0.62 mg kg^{-1} in *Entisols* and 0.36, 9.9, 2.6 and 0.80 mg kg^{-1} in *Inceptisols*, respectively. *Entisols* contained lower mean available Cu, Fe, Mn and Zn values than those *Inceptisols* (Table 3). Similar observations were made by Annepu et al (2017) in mid Himalayan region of Himachal Pradesh.

The soils under vegetable based cropping sequences in Outer Himalayan region of Himachal Pradesh varied considerably in available nutrient content/ status. This variation in nutrient content/status may be attributed to the differences in pedo-genesis (gains, losses, transformation and translocation of materials), soil management practices, land use types, plant nutrient recycling processes, etc. Soil forming factors/ processes and land management practices govern soil fertility of a particular area (Rattan et al 2015). In high rainfall areas, leaching of nutrients makes them unavailable to crops. Organic matter decomposition is faster in tropical and subtropical climates. Therefore, tropical and subtropical regions are less fertile as compared to temperate regions. *Inceptisols* have greater rate of soil development as compared to *Entisols*, thus high nutrient status is there in case of former (Sehgal 2009). Majority of the farmers in the study area adopt traditional management practices for growing different crops. They apply farmyard manure and fertilizers to almost all the crops, but at varying rates. Such a variation in cultural practices may also account for spatial variability of nutrient status of soils.

CONCLUSIONS

Soils under vegetable cultivation in Outer Himalayan region of Himachal Pradesh were medium in available N & K, low in available P & S, high in available Ca & Mg, sufficient in available Cu, Fe & Mn and deficient to sufficient in available Zn. The deficiency of four nutrients, *viz.,* N, P, S and Zn may impose threat to sustain the soil productivity for vegetable production in this region. Thus, soil test based balanced nutrient management can enhance vegetable production and ultimately the profitability of farmers in the region.

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REFERENCES

Annepu SK, Shirur M and Sharma VP 2017. Assessment of soil fertility status of Mid Himalayan Region, Himachal Pradesh. *Indian Journal of Ecology* **44**(2): 226-231.

Anonymous 2018. *Horticultural Statistics at a Glance*. Department of Agriculture, Cooperation & Farmers' Welfare, India. p 458.

Anonymous 2019. *Economic Survey of Himachal Pradesh*. Department of Economics & Statistics, Himachal Pradesh, Shimla. p 161.

Black CA 1965. *Methods of Soil Analysis. Part II. Chemical and mineralogical properties*. American society of Agronomy, Madison, Wisconsin, USA. p 1572.

Buol SW, Southard RJ, Graham RC and McDaniel PA 2003. *Soil Genesis and Classification*. 5th edition. Iowa State Press. Ames, Iowa. p 494.

Jackson ML 1973. *Soil Chemical Analysis*. Prentice Hall, India Private Limited, New Delhi. p 678.

Kumar P and Verma TS 2005. Characterization and classification of some rice growing soils of Palam valley of Himachal Pradesh. *Agropedology* **15**: 80-85.

Lindsay WL and Norwell WA 1978. Development of DTPA soil test for Zn, Cu, Fe and Mg. *Soil Science Society of America Journal* **42**: 421-428.

Olsen SR, Cole CV, Watanabe FS and Dean LA 1954. *Estimation of available phosphorus by extraction with sodium bicarbonate*. United States Department of Agriculture, Washington DC, Circular No. 939: p 19.

Parker FW, Nelson WL, Winters E and Miles IE 1951. The broad interpretation and application of soil test information. *Agronomy Journal* **43**: 105-112.

Rattan RK, Katyal JC, Dwivedi BS, Sarkar AK, Bhattacharyya T, Tarafdar JC and Kukal SS 2015. *Soil Science: An Introduction*. Indian Society of Soil Science, New Delhi. p 873.

Sehgal J 2009. *A Text Book of Pedology: Concepts and Applications*. Kalyani Publishers, Noida, India. p 516.

Sidhu GS, Rana KPC, Sehgal J and Velayutham M 1997. *Soils of Himachal Pradesh for optimizing land use*. National Bureau of Soil Survey and Land Use Planning, Nagpur, India. p 44.

Subbiah BV and Asija GL 1956. A rapid procedure for estimation of available nitrogen in soils. *Current Science* **25**: 259-260.

Suri D, Sharma VK, Nazir G, Anjali and Gill A 2019. Fertility status of soils under different land uses in Lesser Himalayan region of Himachal Pradesh. *Indian Journal of Ecology* **46**(4): 828-834.

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Effect of Seed Invigoration Treatment with Nitrate Salt on Seedling Growth of Maize (*Zea mays* L) Under Short Term Moisture Stress Induced by PEG-6000

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Abstract: A lab trial was conducted to assess the effect of seed invigoration treatment with Mg $(NO_3)_2$ salts over short term moisture induced by PEG-6000 on percent inhibition of germination, length, fresh and dry weight of shoot and root and increase and decrease of same over the range of moisture stress as compare to control. Elevated levels of PEG-6000 were applied to create a range of moisture stress viz. 1.5, 2.5, 3.5 and 4.5% alone and along with invigorated seed. Percent inhibition of germination increased along with increasing the level of moisture stress while the length of shoot and root (cm), fresh and dry weight of shoot and root and declined as the concentrations of PEG-6000 increased from 1.5% to 4.5% as compared to control. The ameliorative effect was observed very clearly while comparing the performance of control set with highest level of moisture stress (4.5% PEG-6000 alone) and control with highest level of moisture stress (4.5% PEG-6000 + nitrate invigorated seed) on various parameters i.e. length, fresh and dry weight of shoot and root of maize seed. These results indicate that the performance of maize seeds were improved while growing with seed invigoration treatment with Mg $(NO_3)_2$ under the various range of moisture stress.

Keywords: Germination, Mg $(NO_3)_2$, Maize, Moisture stress, PEG-6000, Seed invigoration

Maize (*Zea mays* L.) is one of the nutritious cereal crops having third rank next to wheat and rice grown under wide range of environment conditions around the world. Being a C_4 plant it requires quite low amount of water at early growth and development stages but gradually increase up to reproductive growth stage (Shah 2016, Bhat et al 2017). Among the abiotic stresses, moisture stress is one of the most critical environmental factors that inhibit the performance of all the growth, development and production of plants and ultimately under sever moisture stress condition it lead towards the death of plant (Xiong et al 2006, Staniak and Kocon 2015). Water stress affects almost every developmental stage of the plant. However, damaging effects of this moisture stress was more observed when it coincided with different growth stages like germination, length, fresh and dry weight of shoot and root (Rauf 2007, Fahad et al 2017). Water stress not only affects seed germination but also increases mean germination time in maize plants (Willanborb et al 2004). Crops are affected to the moisture conditions either limited amount of water supply to the root zone or the rate of transpiration is very high (Anjum et al 2011). The harshness of the damage caused by the moisture stress is mostly unpredictable because it is govern by various factors viz., rainfall patterns, water holding capacity of the soil and losses of water through evapotranspiration. Moisture stress intervenes with nutrient and water relations, Photosynthate partitioning, rate respiration and ultimately cause a significant hamper in yield of crop (Praba et al 2009, Zhao and Liu 2017). However, seed priming with nitrate salts not only help to stimulate the process of seed germination but also helping to give a better establishment of seedling by improving seed vigour, root shoot growth. Positive response of priming treatment with various salts like Mg (NO_3), KNO_3, Ca $(NO_3)_2$ and KH_2PO_4 has also been reported for various crop (Anaytullah and Bose 2007, Sathish et al 2012, Siddique and Kumar 2018). Keeping in view, present piece of work was conducted in lab to assess the adverse effect of moisture stress induced by PEG-6000.

MATERIAL AND METHODS

The seeds of maize (*Zea mays* L) variety SUNNY-NMH-777 was used to assess the effect of seed invigoration with Mg $(NO_3)_2$ against the various range of moisture stress induced by Polyethylene Glycol-6000. The experiment was rises in complete randomized design with three replications. In one sets only various range of moisture stress i.e. 1.5, 2.5, 3.5 and 4.5 % along normal seed (without invigorated) while second set have same range of moisture stress along with seed invigorated with Magnesium nitrate. The seeds were surface sterilized with $HgCl_2$ for two minutes and soaked for 15 hrs in particular solution and then after cleaning with distilled water, seeds were spread in well-arranged petridishes. All the petridishes were transferred in to plant

growth chamber (Model No.NU-151) under controlled conditions. The data regarding the seed germination was recorded at regular intervals of 24 hrs up to 240 hrs and percent germination was calculated. The percent inhibition of seed germination was calculated (Sundra and Pote, 1978)

$I = 100 - (E_2 X 100/E_1)$

Where, I = % inhibition, E_1= Response of control plant, E_2 = Response of treatment plant.

Length of root and shoot was measured and the fresh weight of root and shoot was recorded. The samples of root and shoot were kept for 12 hours in an oven pre-set at 80-85 ^{0}C. Thereafter, it was placed in an oven set at 60±2^{O}C till to get constant dry weight of root and shoot at 120 hrs and 240 hrs. Data was analyzed through SPSS 23.

RESULTS AND DISCUSSION

Percent inhibition of seed germination increased along with the elevated levels of PEG-6000 from 1.5 to 4.5% in both kinds of sets (i.e. PEG-6000 + untreated seed and PEG-6000 + invigorated seed). But rate of inhibition was greater in response of PEG-6000 + without invigorated seed set as compare to PEG-6000 + Invigorated seed at almost every concentration. The rate of % inhibition of germination was low at early stage i.e. 72 and 96 hrs of intervals and gradually increased up to 4.5 % of PEG-6000 result a high level of moisture stress. In second set where the range of moisture treatment was same as in the first set first + invigorated seed, the % inhibition of seed germination was less at all the levels of moisture stress as compare to rest of the treatment including control. Earlier workers observed that moisture stress adversely affected seed germination in barley, maize and rice (Anaytullah et al 2008, Yari et al 2010, Hellal et al 2018). Rate of seed germination affected by various factors in which water is one of them and it is ultimately responsible for initiating the germination process hormonal and enzymatic activities. Kadyam and Yagmur (2008), Pant and Bose (2016) who reported that germination decline at different levels of moisture stress because of the less water intake by the seed while seed priming with nitrate salts help to overcome the effect of moisture stress up to certain level.

The length, fresh and dry weight of shoot and root was gradually decrease as the level of short term moisture stress increased from low to high concentration (1.5 to 4.5%) along with and without treatment as compare to control at both the times of intervals (Fig. 3, a and b, 4 a and b). The initial effect of invigorated seed with magnesium nitrate was better than any other treatment including control also and gradually decreased as concentrations of PEG-6000 was increased. The effect of nitrate invigorated seed over a range of moisture stress on percent increase / decrease of length, fresh and dry weight of shoot and root of maize seed. The length of shoot and root was decreased 40 and 44.4% at moisture stress of 4.5% as compare to control. The effect of moisture was reduced up to 32.9 and 14.5% in invigorated seed at same intensity of moisture stress. The percent increase / decrease of fresh weight of shoot and root was compared among the peak intensity of moisture stress of both the set of treatments (T_4 and T_8) and found that minimum reduction was in T_8 (23.8, 31.5 and 33.6, 33.7%) as compared to control at both the time of intervals (120 and 240 hrs.) while the similar trend was also recorded for dry weight of shoot and root (19, 31.3 and 20, 29.1%). Elevated levels of moisture stress directly hinder the

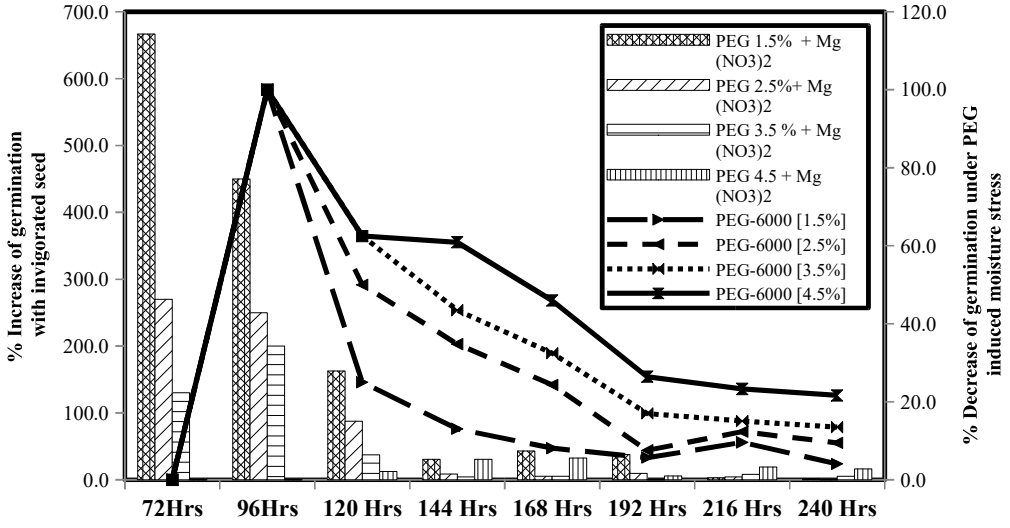
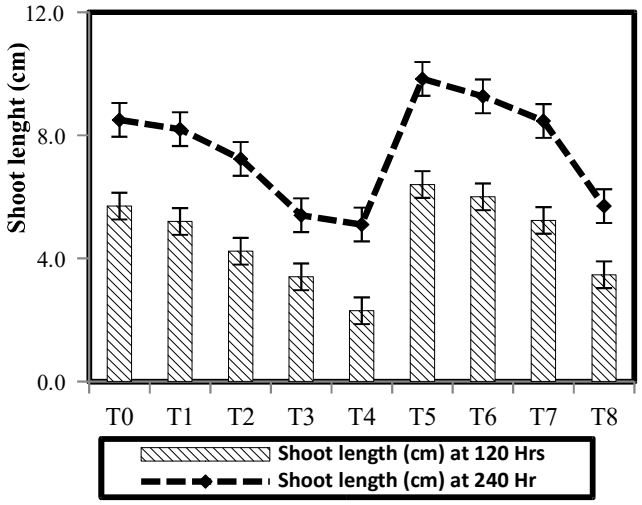
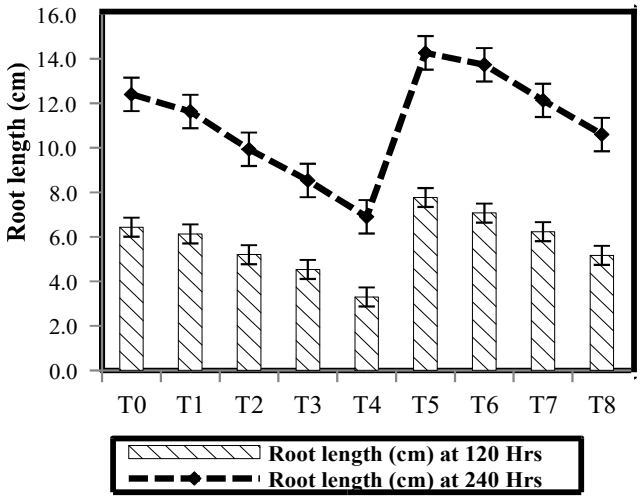


Fig. 1. Effect PEG-6000 induced moisture stress and seed invigoration treatment on % inhibition of seed germination interms of increase / decrease in maize

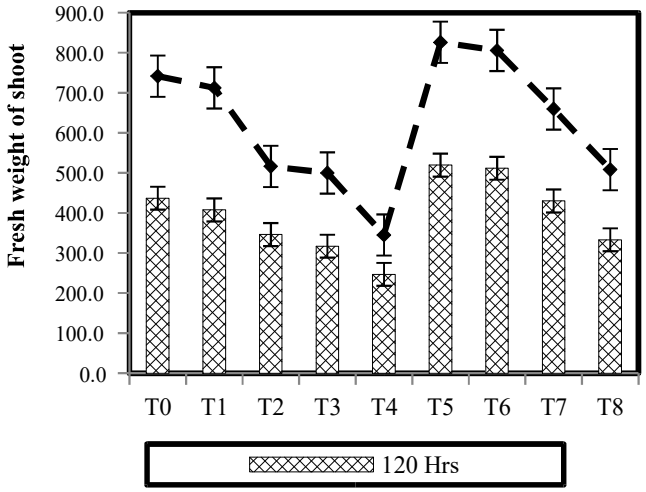




Note: T0 (Control), T1 (1.5 % of PEG-6000), T2 (2.5 % of PEG-6000), T3 (3.5% of PEG-6000), T4 (4.5 % PEG-6000), T5 (1.5 % PEG-6000 + Invigorated seed with Magnesium nitrate), T6 (2.5 % PEG-6000+ Invigorated seed with Magnesium nitrate), T7 (3.5 % PEG-6000+ Invigorated seed with Magnesium nitrate), T8 (4.5 % PEG-6000+ Invigorated seed with Magnesium nitrate)

Fig. 2a. Effect of seed invigoration treatment with Mg $(NO_3)_2$ on shoot length (cm) under PEG-6000 induced moinsture stress in maize

Fig. 2b. Effect of seed invigoration treatment with Mg $(NO_3)_2$ on root length (cm) under PEG-6000 induced moinsture stress in maize



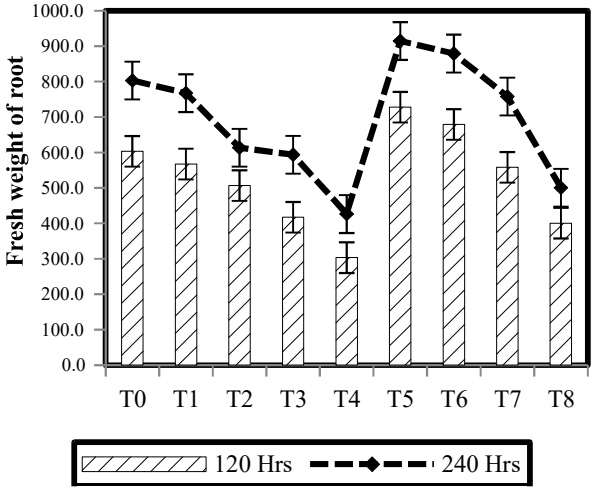


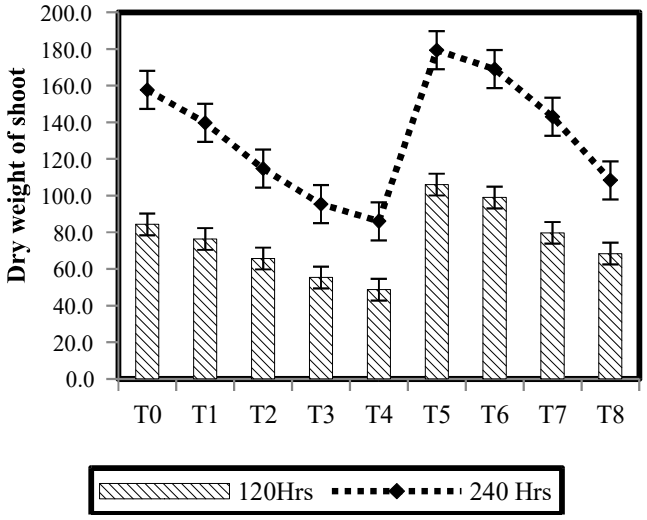
Fig. 3a. Effect of seed invigoration treatment with Mg(NO3)2 on fresh weight of shoot (mg) under PEG-6000 induced moinsture stress in maize

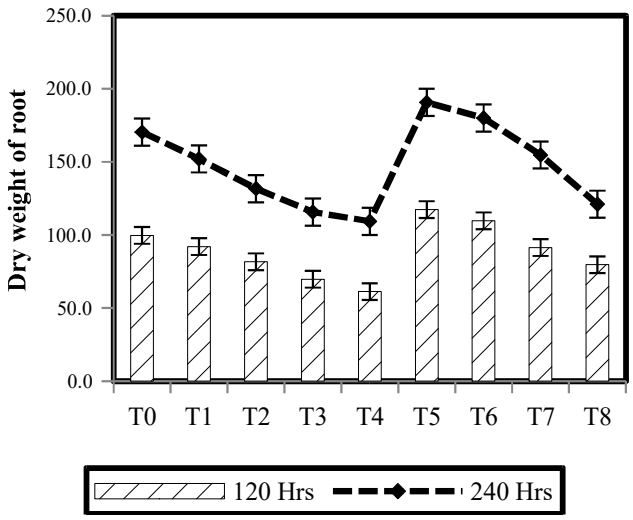
Fig. 3b. Effect of seed invigoration treatment with Mg(NO3)2 on fresh weight of root (mg) under PEG-6000 induced moinsture stress in maize

water intake process which leads to suppress not only the rate of imbibition process but also affect the various metabolic steps of respiration, hormonal changes and enzymatic process that ultimately suppress the breakdown of endospermic food material. Hence the supply of energy for cell division multiplication process get affected (Al-Karaki 2008, Singh et al 2012, Sevik and Cetin 2015, Pant and Bose 2015). Seed invigoration treatment counteract and trying to overcome the effect of moisture stress by improving seed germination and further establishment of healthy seedling (Merewitz 2016, Mohammad Abdel-Moneim Khafagy et al 2017). Furthermore, it help to protect cell membrane damage and also enhanced antioxidative process within the seed that alleviate the intensity of moisture stress and led the strong foundation for future plant growth (Moradi et al 2008, Hussain et al 2016).

CONCLUSIONS

Under elevated levels of moisture stress condition, rate of inhibition of germination was increased hence the length,





N: T0 (Control), T1 (1.5 % of PEG-6000), T2 (2.5 % of PEG-6000), T3 (3.5% of PEG-6000), T4 (4.5 % PEG-6000), T5 (1.5 % PEG-6000 + Invigorated seed with Magnesium nitrate), T6 (2.5 % PEG-6000+ Invigorated seed with Magnesium nitrate), T7 (3.5 % PEG-6000+ Invigorated seed with Magnesium nitrate), T8 (4.5 % PEG-6000+ Invigorated seed with Magnesium nitrate)

Fig. 4a. Effect of seed invigoration treatment with Mg(NO3)2 on dry weight of shoot (mg) under PEG-6000 induced moinsture stress in maize

Fig. 4b. Effect of seed invigoration treatment with Mg(NO3)2 on dry weight of root (mg) under PEG-6000 induced moinsture stress in maize

Table 1. Effect of seed invigoration treatment with Mg $(NO_3)_2$ salt to overcome the effect of PEG-6000 induced moisture stress on length, fresh and dry weight of shoot and root at 120 and 240 hrs. of intervals

Hours/ Treatments	Shoot length hours after		Root length hours after	
	120 hrs.	240 hrs.	120 hrs.	240 hrs.
% Increase / decrease of shoot and root length over control				
Control	5.7	8.5	6.4	12.4
T_4	2.3 [59.6]	5.1 [40.0]	3.3 [48.7]	6.9 [44.4]
T_8	3.5 [39.2]	5.7 [32.9]	5.2 [19.7]	10.6 [14.5]
% Increase/ decrease fresh weight of shoot and root over control				
Control	437	741.4	603.1	803.1
T_4	246.7 [43.5]	345.1 [53.5]	303.2 [49.7]	426.2 [46.9]
T_8	333.0 [23.8]	508.1 [31.5]	400.2 [33.6]	500.3 [37.7]
% Increase / decrease of dry weight of shoot and root over control				
Control	84.3	157.7	99.7	170.3
T_4	48.7 [42.3]	86.0 [45.5]	61.3 [38.5]	109.3 [35.8]
T_8	68.3 [19.0]	108.3 [31.3]	79.7 [20.1]	121.0 [29.0]

Note:

1- T_4 represent the levels of 4.5 % of PEG-6000 concentration along with normal seeds (without treated). T_5 represent the level of 4.5 % of PEG-6000 concentration along with invigorated seed with Mg $(NO_3)_2$.

2- Data in bracket shows % increase / decrease in respect to given treatments

fresh and dry weight of shoot and root of maize seedling were adversely affected. The present work also provide insight that seed invigorated with magnesium nitrate not only help to ameliorate the effect of moisture stress in respect to inhibition of germination but also help to improve the establishment of healthy seedling via improving the fresh and dry of shoot and root of maize seedling. It might also be possible that magnesium nitrate helps via improving water uptake.

REFERENCES

Al-Karaki GN 2008. Seed size and water potential effects on water uptake, germination and growth of lentil. *Journal Agronomy and Crop Science* **181**(4): 237-242.

Anaytullah, Ahmad A and Paswan VK 2008. Effect of water potential treatment on seed germination and seedling growth of some rice cultivars (*Oryza sativa* L.). *Indian Journal of Agricultural Research* **42**(1): 57-61.

Anaytullah and Bose B 2007. Nitrate hardened seeds increase germination, amylase activity and proline content in wheat seedlings at low temperature, *Physiology Molecular Biology of Plants* **13**(3&4): 199-207.

Anjum SA, Xie XY, Wang LC, Saleem MF, Man C and Lei W 2011. Morphological, physiological and biochemical responses of plants to drought stress. *African Journal of Agricultural Research* **6**(9): 2026-2032.

Bhat SA, Pandit BA, Khan JN, Kumar R and Jan R 2017. Water requirements and irrigation scheduling of maize crop using CROPWAT Model. *International Journal of Current Microbiology and Applied Science* **6**(11): 1662-1670.

Fahad S, Ali A, Nazir BU, Anjum SA, Farooq A, Zohaib A, Sadia A, Nasim W, Adkins S, Saud S, Ihsan MZ, Alharby H, Wu C, Wang D and Huang J 2017. Crop production under drought and heat

stress: Plant responses and management options. *Frontier in Plant Science* **8**: 1-16.

Hellal FA, El-Shabrawi HM, Abd El-Hady M, Khatab IA, El-Sayed SAA and Abdelly C 2018. Influence of PEG induced drought stress on molecular and biochemicalconstituents and seedling growth of Egyptian barley cultivars. *Journal of Genetic Engineering and Biotechnology* **16**(1)**:** 203-212.

Hussain S, Khan F, Cao W, Wu L and Geng M 2016. Seed priming alters the production and detoxification of reactive oxygen intermediates in rice seedlings grown under sub-optimal temperature and nutrient supply. *Frontiers in Plant Science* 7**:** 1-13.

Kaydan D and Yagmur M 2008. Germination, seedling growth and relative water content of shoot in different seed sizes of triticale under osmotic stress of water and NaCl. *African Journal of Biotechnology* **7**(16)**:** 2862-2868.

Mohammad Abdel-Moneim Khafagy, Zain Al-Abidin Abdul Hamid Mohamed, Saad Farouk and Hanan Khaleel Amrajaa 2017. Effect of pre-treatment of barley grain on germination and seedling growth under drought stress. *Advances in Applied Sciences* **2**(3): 33-42.

Merewit EB 2016. Chemical priming-induced drought stress tolerance in plants. In book: *Drought Stress Tolerance in Plants*. Vol **1**, DOI. 10.1007/978-3-319-28899-4_4.

Moradi P, Dezfuli F, Zadeh S and Janmohammadi M 2008. Influence of priming techniques on seed germination behavior of maize inbred lines (*Zea mays* L.). *ARPN J. Agricultural and Biological Sciences* **3**(3): 22-25.

Pant B and Bose B 2016. Mitigation of the influence of PEG-6000 imposed water stress on germination of halo primed rice seeds. *International Journal of Agriculture, Environment and Biotechnology* **9**(2): 275-281

Praba ML, Cairns JE, Babu RC and Lafitte HR 2009. Identification of physiological traits underlying cultivar differences in drought tolerance in rice and wheat. *Journal of Agronomy and Crop Science* **195**(1)**:** 30-46.

Rauf M, Munir M, Hassan MU, Ahmad M and Afzal M 2007. Performance of wheat genotypes under osmotic stress at germination and early seedling growth stage. *African Journal of Biotechnol*ogy **6**(8)**:** 971-975.

Sathish S, Sundareswaran S, Senthil N and Ganesan KN 2012. Biochemical changes due to seed priming in maize hybrid COH (M)-5. *Research Journal of Seed Science* **5**(3): 71-83.

Sevik H and Cetin M 2015. Effects of water stress on seed germination for select landscape plants. *Polish Journal of Environmental Studies* **24**(2): 689-693.

Shah SR 20016. Effect of seed priming on yield and yield components of maize. M.Sc. (Hons.) Thesis Department of Agronomy, KP Agricultural University Peshawar, Pakistan 2007; pp. 1-73.

Siddique A and Kumar P 2018. Physiological and biochemical basis of pre-sowing soaking seed treatment-an overview. *Plant Archives* **18**(2): 1933-1937.

Singh J, Sastry EVD and Singh V 2012. Effect of salinity on tomato (*Lycopersicon esculentum* mill.) during seed germination stage. *Physiology and Molecular Biology of Plants* **18**(1)**:**45-50.

Staniak M and Kocon A 2015. Forage grasses under drought stress in conditions of Poland. *Acta Physiologiae Plantarum* **37**(6)**:**116.

Sundra MP and Pote KB 1978. The allelopathic potentials of root exudates from different ages of *Celosia argenta* Linn. *Natural Academic Science Journal* **1**(2): 56-58.

Willanborb CJ, Gulden RH, Jhonson EN and Shirtliffe S J 2004. Germination characteristics of polymer-coated canola (*Brassica napus* L.) seeds subjected to moisture stress at different temperatures. *Agronomy Journal* **96**(3)**:** 786-791.

Yari Y, Aghaalikani M and Khazaei F 2010. Effect of seed priming duration and temperature on seed germination behavior of bread wheat (*Triticum aestivum* L.). *ARPN Journal of Agricultural and Biological Science* **5(**1): 1-6.

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Causes of Air Pollution in Kabul and its Effects on Health

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Abstract: The lack of air quality management capabilities from the Afghan government and standards for both indoor and outdoor air quality, air pollution remains a significant risk to human health and the quality of the environment. Air pollution is the second cause of deaths in Kabul based on air pollution assessments. Outdoor air pollution was responsible for more than 65% of human deaths. This paper compiles the main sources of air pollution along with contamination levels of major pollutants, and their relevant health effects in Kabul. The results indicated that particulate matter (PM) was the most serious air pollutant in Kabul followed by nitrogen dioxide (NO_2) and sulphur dioxide (SO_2). The levels of PM, SO_2, and NO_2were several times higher than the World Health Organization (WHO) air quality guidelines, whereas the concentrations of zone (O_3) and carbon monoxide (CO) were below the guidelines.

Keywords: Air pollution, Pollutants, Kabul, Health effects

Air pollution is one of the main health and environmental problems in the world, as it is estimated to contribute to 7.2 million premature deaths annually and 147 million disability-adjusted life years (Cohen et al 2017, WHO 2018). Considering the global trend of development, the least developed and developing countries in East Asia and the Pacific, South, and Western Asia and Sub-Saharan Africa bear much of the air pollution-related burdens (Cohen et al 2017). Air pollution can result from natural activities such as forest fires, volcano eruptions, dust storms, or methane emissions by cattle and other animals, or human-made air pollution activities such as burning woods, waste disposal, and transportation, etc (UNICEF 2016). During the past two centuries, air pollution created by humans has become the utmost issue, as it is responsible for 9% of deaths worldwide with 9 out of 10 people breathing contaminated air (WHO 2018). Air pollution is also attributed to climate change, global warming, and ozone depletion and is affecting the life on earth leading to extensive unfavorable health effects at different levels (Im et al 2018, Tiwary and Colls 2010). Decades of war in Afghanistan have caused environmental damage. Addressing environmental damage has always been a challenge for the Afghan government, which is plagued by problems such as insecurity, corruption, and a weak economy. In Afghanistan, environmental protection has never been a top priority and critical environmental problems such as air pollution are still not well understood by people and the government.

Although there are fewer official statistics on the number of deaths due to air pollution in Afghanistan, the Institute for Health Metrics and Evaluation has indicated that air pollution may have been responsible for the deaths of roughly 40,000 people in Afghanistan in 2017 (GBD 2017). The World Bank mentioned that air pollution caused 56,911 deaths in 2017, a number which is significantly higher than the previous estimates (WHO, 2018). At the same time, 26% of all deaths in Afghanistan are due to environmental risks, where indoor and outdoor air pollution caused over 27,000 and 11,000 deaths per year respectively (WHO, 2018). Kabul, which has always been known in modern Afghan history for its optimal climate, has now become the most polluted city of Afghanistan and one of the world's most polluted capitals (Popal 2017). Geographical and climatic factors along with high levels of man-made emissions such as excessive use of coal and low- quality fuels for heating, excessive population growth, old and smoky vehicles, factories that use low quality fossil fuels, lack of environmental protection infrastructures such as waste disposal technologies or water supply systems play a major role in influencing air pollution in the city (WHO 2018). The major air pollutants involved in different natural trends and projects are suspended particulate matter (PM 2.5 and PM10), sulphur dioxide (SO_2), and nitrogen dioxide (NO_2) which are parts of air quality monitoring (Saravanan et al 2018). The main objective of this study was to determine the sources and health effects of air pollution in Kabul. The results can be useful to increase public awareness about the fatal air pollution in Kabul, and also provide policy-makers with valuable information to take appropriate intervention measures.

MATERIAL AND METHODS

Kabul, the capital of Afghanistan is located in the eastern region of the country between 34°31′31″N and 69°10′42″E, has an area of 275 km^2 and an estimated population of 5,204,667 (NSIA 2020). Kabul is the most populous city of Afghanistan with more than 18% of the country's population (Taniwal 2017). Approximately 56% of Kabul territory is made up of mountains and rough terrain, while 38% is flat. Kabul has four dry seasons with maximum rain happening in February, March, and April. The highest annual rainfall reported in Kabul is approximately 400mm. The winter temperature ranges between -15°C and -20°C, while summer can range from 15°C to 39°C. For this study, five districts of Kabul (D2, D4, D6, D11, D17, D stands for the district) with an estimated total population of 1.1 million were selected as the main areas of study. The above districts were selected primarily due to the availability of reliable data, unbalanced population density, and a clear gap between the lifestyle of residents (in terms of income difference, house size, and kind of employer) in these districts. Evaluation of variations in the major air pollutants such as PM2.5, PM10, NO_2, SO_2, CO, and O_3 was conducted using ambient daily air measurements recorded by The National Environmental Protection Agency (NEPA) monitoring devices for one week (December 17-23, 2019). December was selected as data collection month because of the highest air pollution and energy consumption observed in that month.

Two surveys were also conducted – one with households and another with medical doctors. The first survey was conducted among households in all 22 districts of Kabul city using a questionnaire. It covered 294 households, with 32% in apartments and 68% in houses along with different living standards. The questionnaire focused on questions about energy sources for cooking/heating, being aware of air pollution, its negative effects and any air pollution-related health complications in family, form of transport being used, being aware of air quality in Kabul if attending any outdoor activities, and use of mask while being outdoors.

The second survey was conducted with 18 medical doctors in various hospitals in Kabul. The survey included questions about (most prevalent air pollution-related diseases in the city, the vulnerability of different age groups, the number of daily patients with respiratory problems, and the periodic mortality rate due to exposure, and seasonal variations of respiratory diseases in Kabul). The air pollution-related diseases and mortality rate in Kabul data were also procured from The Afghan Ministry of Public Health and eight leading Kabul hospitals (Indira Gandhi Child Care Hospital, Ataturk Child Care Hospital, Maiwand, Jamhoriat, Central Polytechnic, Wazir Akbar Khan, Khair Khana, and Sadri) for 2017 to 2019.

RESULTS AND DISCUSSION

The normalized concentrations of main air pollutants (PM2.5, PM10, NO_2, SO_2, CO, and O_3) in Kabul during the year 2019 are shown in (Fig. 1).

Particulate matter (PM2.5, PM10): The average PM2.5 concentration in Kabul was 92.2 µg m^{-3} (24 hours) which exceeded the WHO recommended limit of 25 µg m^{-3} (concentration measured in 24hour). Moreover, the average PM10 concentration in Kabul was 120.6 µg m^{-3} (24 hours) which exceeded the WHO recommended limit of 50 µg m^3 (concentration measured in 24 hour). The principal sources of particulate matter in Kabul are vehicular emissions, particularly from diesel vehicles, burning coal and wood, dust, thermal generators, and residential combustion processes. PM2.5 is considered to be more hazardous to human health than PM10.

Nitrogen dioxide (NO_2): The average NO_2 concentration in Kabul was 305.4 µg m^{-3} (1 hour) which exceeded the WHO recommended limit of 200 µg m^{-3} (concentration measured in 1 hour). NO_2 is produced by electric generators, combustion processes, but primarily from the vehicular exhaust. NO_2 level is higher in urban areas due to vehicle traffic. In addition, it is an important ingredient in the generation of smog which spreads in most areas of Kabul and has harmful effects such as damage to the upper respiratory system and lungs (Mohaqeq and Hajian 2013).

Sulfur dioxide (SO_2): The average daily SO_2 concentration in Kabul was 63.7 µg m^{-3} (concentration measured over 24 hours), which is 3 times the WHO recommended limit of 20 µg m^{-3} in (24 hours). Factors like an increase in population growth and the number of vehicles are responsible for raising the SO_2 levels (Fig. 2).

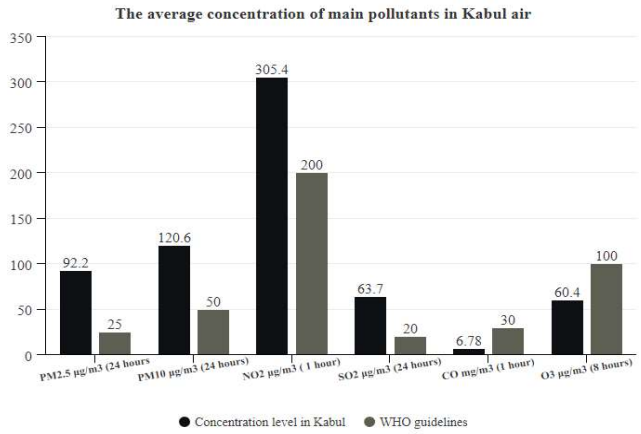
Ozone (O_3): The average O_3 concentration in Kabul was 60.4 µg m^{-3} (8 hours). Although O_3 is one of the pollutants in Kabul air, its concentration level has not exceeded the WHO recommended limit of 100 µg m^{-3} (concentration measured in 8 hours). The main sources of O_3 pollution in Kabul are old and smoky cars (cars with expired use date in country of origin and imported to Afghanistan) and power generators. An analysis of NEPA data indicates that the amount of O_3 in Kabul has increased by 20% since 2015.

Current pollution situation in Kabul

Old vehicles and low-quality fuel: The most important causes of air pollution in Kabul is the existence of more than 1 million illegally imported, very old, and poorly maintained vehicles accounted for more than 75 percent of the outdoor pollution in Kabul (Kabul Municipality Yearly Report 2019).

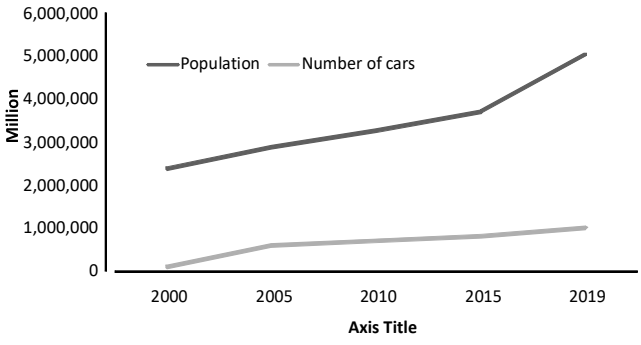
Vehicles in Kabul don't come with any pollution-related costs or ecological quality control norms. Annually, about 1.8 million tons of vehicle fuel is burnt in Kabul, 80 percent of which is low quality, and is mostly imported from Iran and Iraq without special quality control (Kabul Municipality Bulletin 2018).

Coal, charcoal, and wood fire: In Kabul, wood, charcoal, and coal are the main sources of heating homes during the cold seasons. November to February of 2019, every month approximately 97,000 tons of firewood and 3,10,000 tons of coal and charcoal were imported to Kabul (Kabul Municipality Bulletin 2018). Based on a survey carried out in all 22 districts of Kabul city in December 2019, 64 percent of households indicated that they use wood and charcoal as their main sources of cooking and heating, 23 percent stating wood and natural gas to be their primary sources of heating and cooling while remaining 13 percent pointing to using coal, wood or even electricity. The survey indicated that 73.9% of Kabul citizens are aware of the health and environmental dangers of using coal, charcoal, and wood in both indoor and outdoor environments.



Source: Author

Fig. 1. The average concentration of the major pollutants in Kabul air and their comparison with WHO guidelines



Sources: Afghanistan Statistical Yearbook 2019

Fig. 2. Population and number of cars in Kabul 2000 to 2019

Solid waste: Daily production and storing thousands of tons of garbage near the city poses a serious and intangible threat to Kabul's environment and residents. The city produces nearly 3,527 tons of solid waste per day, whereas the collection capacity is only 450 tons (Kabul Municipality Yearly Report 2018). Moreover, the lack of a solid waste disposal system, the poor drainage system, and limited access to sewage systems has complicated the situation. The collection and transportation of solid waste are not regularly maintained and different kinds of the waste get accumulated for extended periods. The knowledge about waste management and the impact of hazardous waste is low among the Kabul municipality staff and officials.

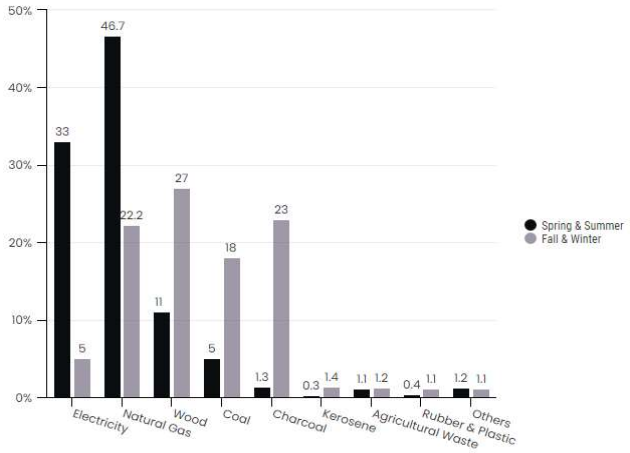
Rapid population growth and population density: In the early nineteen hundred, Kabul and its infrastructures had been planned for one million inhabitants (Cullather 2002). But in the last two decades, lack of work opportunities in the rest of the country and recent security issues have led to roughly 3 million people migrating from different parts of the country to this city. This has not only increased the population and pressure on the environment but also negatively affected the novel urbanization culture of Kabul. Kabul is one of the fastest-growing cities in the world, has witnessed an average annual population growth rate of 4.7 percent from 2006 to 2020 with population density doubling to 4,710 residents km^{-2} from that of 2002 (Safi 2019).

Energy crisis: More than 5.8 billion dollars have been spent on Afghanistan's energy from 2002-2018. But still, there are considerable deficiencies, especially in Kabul, which has seen 34 percent of the country's total energy investment (The Afghanistan Magazine 2017). In 2003, Kabul needed only 120 MW of electricity which was generated from domestic hydro sources and was normally used for all purposes including lighting, heating, and cooking. But in 2018, the electricity demand reached 650 MW while the supply remained around 330MW. Of this 330 MW, 235 MW was from Uzbekistan and Tajikistan, while the remaining 115 MW was generated in domestic hydropower plants (Afghan Ministry of Energy and Water Magazine, 2018). There is a gap of at least 200 MW between what Kabul residents need in terms of electricity and what the Afghan suppliers can provide. The wide gap between supply and demand means that Kabul is supplied low voltage electricity and residents are not able to use it as their main source of energy. Moreover, natural gas consumption has increased in Kabul since 2007, but hoarding, rapid price inflation during winter, and lack of stable access are the main obstacles to sustainable use and supply of natural gas as clean energy and replacement for wood,

coal, and charcoal. During the warm seasons, electricity and natural gas are the main sources of energy in Kabul, but in cold seasons, wood, coal, charcoal along with natural gas are the leading energy sources (Fig. 3). The valuation of air quality in Kabul for the last two years indicated an average PM2.5 concentration as 60 μg m^{-3}, which is 6 times the WHO recommended limit of 10 μg m^{-3}. The level of PM2.5 concentration was very high during the cold months mainly due to the extensive burning of coal, charcoal, wood, tires, and plastics (Fig. 4).

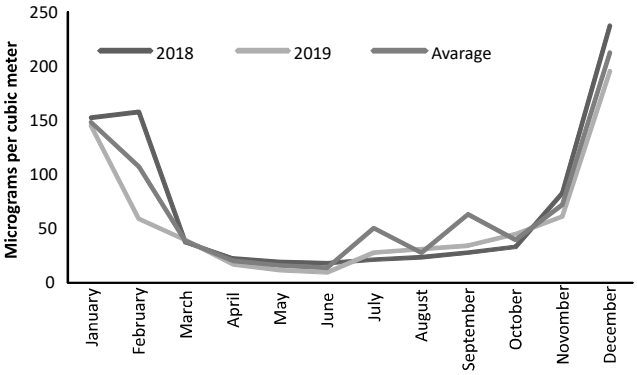
December was the most polluted month in both 2018 and 2019, followed by January and February. The PM2.5 concentration level for December 2018 and 2019 was 237.2, and 196 μg/m respectively that suggests a very unhealthy air condition for different groups. According to the Air Quality Index (AQI), the distribution of air quality status in 2019 was as follows: 25 days (7%) for good, 210 days (58%) for moderate, 48 days (11%) for unhealthy for sensitive groups, 40 days (10%) for unhealthy and 42 days (11%) for very unhealthy (Fig. 5). The winter is the most polluting season in Kabul. Blue and green colors represent good weather conditions whereas orange and red colors show polluted and unhealthy air quality (Fig. 5). Moreover, in 2018 and 2019, Kabul was among the top in the list of most polluted capitals in the world, just behind Delhi and Dhaka (Fig. 6). In 2019, outdoor air pollution was responsible for the increased mortality rate related to Ischemic Heart Disease (IHD), stroke, Acute Lower Respiratory Infection (ALRI), and other respiratory health problems in Kabul (Fig. 7). The number of children with asthma has doubled in Kabul since 2010 owing primarily to high-level exposure of PM, SO_2, and NO_2 pollutants.

The estimation of mortality rate attributed to indoor and outdoor air pollution (per 100,000 population) in Kabul from 1990 to 2020 indicates that from 1990 to 2000, the mortality rate related to indoor and outdoor air pollution was low specifically due to the immigration of more than 500,000 Kabul residents abroad and the low number of vehicles (Figure 8). Following the fall of the Taliban in 2001 to 2005, nearly 3.5 million Afghans returned to Afghanistan, in which around 1 million inhabited in Kabul. Rapid population inhabitation, lack of clean energy, and high numbers of imported old cars deteriorated the situation and increased both indoor and outdoor mortality rates during this period. Furthermore, the socio-economic study of multiple trends for Kabul city from 2006 to 2020 indicates that the mortality rate related to indoor pollution has decreased over time mainly due to improving energy sources such as natural gas and electricity among the households. Moreover, deaths from outdoor air pollution have increased significantly largely due



Source: Kabul Municipality 2019

Fig. 3. Percentage of energy consumption in Kabul for 2019



Source: World air quality report 2018-2019

Fig. 4. The estimation of PM 2.5 concentration (μg m^{-3}) in Kabul for 2018- 2019

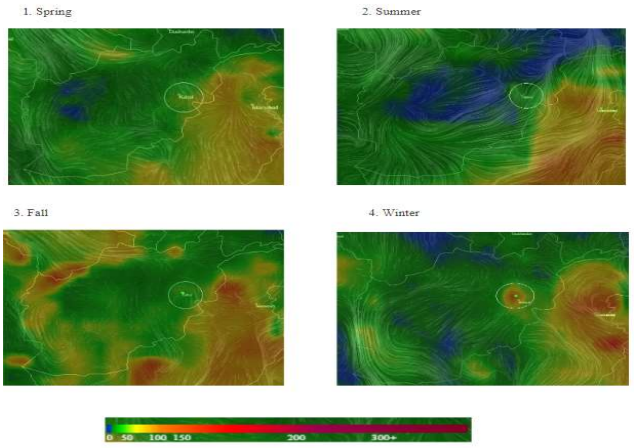


Fig. 5. Map of Afghanistan and surrounding area's air quality in 2018-2019 where Kabul is highlighted (IQAir Earth 2019)

to an increase in the number of old cars, overpopulation, and extensive use of coal and wood in brick kilns, public baths, and other sectors like wedding halls, hospitals, restaurants, etc.

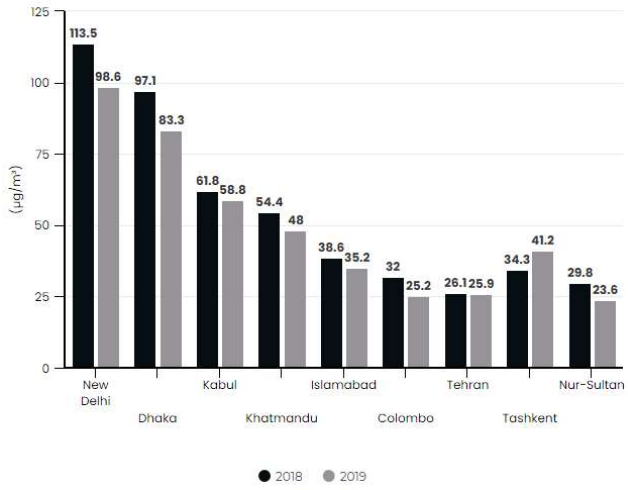
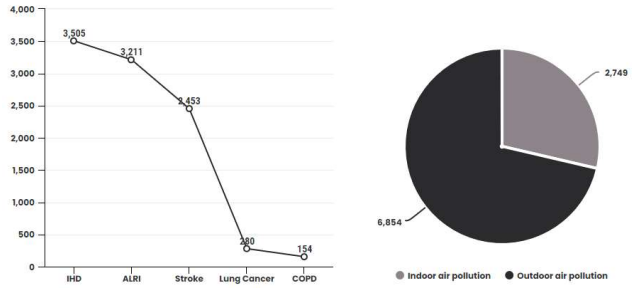


Fig. 6. Average yearly PM 2.5 concentration in South and Central Asian capitals in 2018 and 2019 (World Air Quality Report, 2019)



Source: Author

Fig. 7. The mortality rate due to indoor and outdoor air pollution relevant diseases in Kabul in 2019

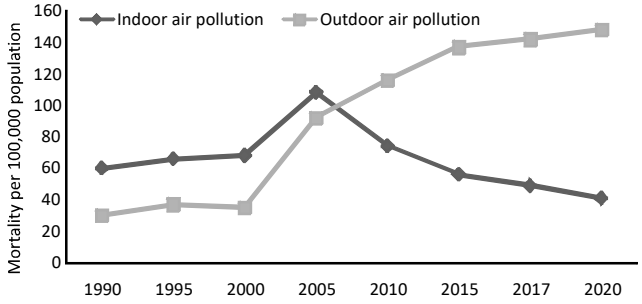


Fig. 8. Analysis of mortality rate attributed to indoor and outdoor air pollution (per 100,000 population) in Kabul from 1990 to 2020 (Afghanistan Ministry of Public Health 2020)

CONCLUSION

The situation of air pollution in Kabul has severely deteriorated over time and caused many fatal respiratory diseases. During the fall and winter seasons, the contamination levels of PM2.5 and PM10, NO_2, and SO_2 are much higher than the recommended WHO level primarily due to overpopulation, old and smoky cars, and lack of clean energy and it is considered to be the reason for most of the asthma cases. Supplying sustainable energy for heating and cooking has always been a challenge for the Afghan governments and their failure in ensuring stable and reliable energy sources, has forced people to burn energy sources such as coal, wood, charcoal, and plastic that are hazardous to human health and environment. Crucial pollution control measures should be taken into consideration to improve the devastating pollution scenario in Kabul.

REFERENCES

Afghanistan Breshna Sherkat 2017. Online Magazine No 69, 19.

Afghanistan Ministry of Energy and Water 2018. Magazine No 7, 27.

Afghanistan Ministry of Public Health 2020, Mortality Data Sheet/Kabul, 113.

ANEPA 2019. The Afghan National Environmental Protection Agency, Environmental Protection Report II, 16.

Cohen A, Braver M and Burnett R 2017. Estimates and 25-year trends of the global burden of disease attributable to ambient air pollution: an analysis of data from the Global Burden of Diseases Study 2015. *Lancet* **389**:1907-1918.

Cullather N 2005. Damming Afghanistan: Modernization in a buffer state. *The Journal of American History* (second edition) **89**(2): 512-537 (A special issue).

GBD Risk Factor Collaborators 2018. Risk Factor Collaborators. Global, regional, and national comparative risk assessment of 84 behavioral, environmental and occupational, and metabolic risks or clusters of risks for 195 countries and territories, 1990–2017: a systematic analysis for the Global Burden of Disease Study 2017. *Lancet* **392**: 1923-1994.

Im U, Brandt J, Geels C, Hansen K, Christensen M and Galmarini S 2018. Assessment and economic valuation of air pollution impacts on human health over Europe and the United States as calculated by a multi-model ensemble in the framework of AQMEII3. *Atmospheric Chemistry and Physics* **18**: 5967-5989.

IQAir Earth 2019 https://www.iqair.com/

Kabul Municipality 2018. Bulletin No 64, Action and Supervision "Our city is our home" 8.

Kabul Municipality 2019. Yearly Report, *Plans, and Development*, 34.

Kabul Municipality 2018. Yearly Report, *Supervision, and Achievements*, 12.

Mohaqeq S and Hajian M 2013. Sport and Air Pollution *NPM*. 3**:**237-249

National Statistics and Information Authority (NSIA) 2019. *Afghanistan Statistical Yearbook 2019*.

NSIA 2020. *Estimated Population of Afghanistan* 2020-21

Popal S A 2017. *The Urban Geography of Afghanistan*; Toward a new landscape, Haro Publications, 29.

Safi L 2019. *The Urban Geography of Afghanistan*, Saeed Press, Kabul 4-5.

Safi MS 2019. Air pollution in Kabul. *National conference for the prevention of air pollution*, pp. 45-56.

Saravanan P, Jegan J and Pushpa TB 2018. Air quality index for

environmental impact assessment of the port development at Beypore*, Indian Journal of Ecology* **45**(4): 768-773.

Taniwal Z and Haroon A 2012. *The General Geography of Afghanistan*, Sanati Press, 149**.**

Taniwal Z 2017. *Economic Geography of Afghanistan*, Azadi Press, 79.

Tiwary A, Williams I and Colls J 2019. *Air pollution: measurement, modeling, and mitigation* 4th edition. Routledge, Abingdon-on-Thames. CRC Press. ISBN 9781138503663.https://www.routledge.com/Air-Pollution-Measurement-Modelling-and-Mitigation -Fourth-Edition-4th/Tiwary-Williams/p/book/9781138503663.

World Air Quality Report 2018. Region & City PM2.5 Ranking. IQAir Air Visual.

World Air Quality Report 2019. Region & City PM2.5 Ranking. IQAir Air Visual.

WHO 2018. The burden of disease from the joint effects of household and ambient air pollution for 2016. World Health Organization, Geneva, Switzerland.

World Health Statistics 2018. *Monitoring health for the SDGs*, sustainable development goals. Geneva: World Health Organization; 2018.https://www.who.int/gho/publications/world_health_statistics/2018/en/

World Health Organization 2018. Non-communicable diseases country profiles. https://www.who.int/nmh/publications/ncd-profiles-2018/en/.

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Biodegradation of Pesticides in Soil Amended with Different Organic Matters

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Abstract: The biodegradation of pesticides is a vital process that controls pesticides' fate in soil. Organic matter has been proven to enhance biological activity in soil. The efficiency of microbial to degrade pesticides can be increased by adding organic matter to the soil. In this study, two types of organic matter (wheat straw and sheep residue) were added to soil to study the biodegradation of two types of pesticide (fungicide Topsan and herbicide Convidens) under different incubation periods. Results showed that the addition of organic matter increased the amount of CO_2 released. The CO_2 released from the treatments increased with increasing the incubation period. The incubation period of twenty one days recorded the highest amount of CO_2 release in all treatments. The number of bacteria and fungi in all treatments had significantly increased compared with the control treatment. Therefore, organic matter, especially wheat straw treatment, can be recommended in enhancing the degradation of pesticides in soils.

***Keywords*:** Organic matter, Pesticides, Biodegradation, CO_2 release, Soil contaminated

Pesticides are commonly used to prevent and control plant diseases (Dhawan et al 2013). Some pesticides may be non-toxic when the recommended concentration is used in the field, but repeated use of these pesticides for a long time may show a cumulative effect (Fenner et al 2013, Sharma et al 2013). These substances are distributed in agricultural products, soil, water, and air, thus causing serious damage to the environment and human health (Huang et al 2018). However, pesticides are susceptible to metabolism by microorganisms (e.g. bacteria) as essential nutrients and energy, as a result, would reduce their residual risk (Fenner et al 2013). Therefore, one of the most important processes that reduce and remove pesticide residues from the soil is microbial decomposition, which is capable of producing enzymes that have the ability to analyse decompose many types of pesticides (Sánchez 2010). Biodegradation of pesticides in the soil is influenced not only by the chemical composition of the pesticide and its toxicity but also by soil properties. Organic matter content of soil is one of these important properties (Prescott 2010). Organic matter can enhance soil properties (Abood et al 2013) and vary in terms of their tolerance to the decomposition process, that is, sugars and proteins are decomposed fast, cellulose and hemicellulose are decomposed slow and lignin is difficult to decompose (Adekunle and Okolie 2015). The degradation process of organic matter is mostly carried out outside the body of microorganisms via enzymes. The rate of decomposition varies according to the C:N ratio of the organic matter, wherein the decomposition process increases with the decrease of C:N (Yousif and Mubarak 2009,Walpola and Arunakumara 2010). Nitrogen-rich organic matter is faster to decompose than nitrogen-poor organic matter.

Microorganisms in nature could break down pesticide residues, are environmentally friendly, low-cost, and reduces pollution (Tapas et al 2017). However, their affectivity is slow (Singh, 2008, Huang et al 2018). Soil amended with organic matter would enhance microbial populations and their activity (El-sharouny 2015). Studies on the degradation of different pesticides in soil amended with different organic matter are limited. Therefore, our current study aims to evaluate the degradation of two types of pesticides, fungicide Topsan and herbicide Convidens, in soil amended with two types of organic matter (wheat straw and sheep residues) with different C:N ratio.

MATERIAL AND METHODS

Soil sampling and analysis: The soil sample was obtained from the surface horizon (0–30 cm depth) from the farm of the College of Agriculture, University of Diyala and were air-dried and passed with a 2 mm sieve. The physicochemical and biological properties of the soil sample. The pH and EC were determined in a 1:1 of soil to distill water using a glass electrode and EC meter, respectively. The organic matter content in soil was determined according to Walkley and Black method.

Incubation study: A factorial laboratory experiment was conducted in a completely randomized design to study the release of CO_2 from the decomposition of two organic matters (wheat straw and sheep residue) and two pesticides (fungicide Topsan and herbicide Convidens) mixed with the soil containing microorganisms (Table 1). Each treatment was replicated thrice. One g dry weight of wheat straw or sheep residue was mixed with 100 g of soil, and the mixture placed in airtight cans. Then, 2 g of fungicide Topsan or 2 ml of herbicide Convidens was mixed with the soils. The experiment included 36 unit treatments resulting from the overlap among treatments of organic matter, pesticides and four incubation periods (7, 14, 21, 28 days) at room temperature (30±2°C). Soil moisture was maintained at 80% field capacity. Thereafter 20 mL of NaOH was trapped in a small open tube and placed inside airtight cans. After each incubation period, drops of barium chloride solution were added to small cans containing 20 mL of NaOH, and titrations were done using HCl in the presence of phenolphthalein indicator to clarify the endpoint. The CO_2 reacted with NaOH and produced turbid sodium carbonate, which is deposited by adding drops of barium chloride solution as in the following equation.

$$Na_2OH + CO_2 \longrightarrow Na_2CO_3 + H_2O \quad \text{(turbid solution)}$$

$$Na_2CO_3 + BaCl_2 \longrightarrow 2\,NaCl + BaCO_3 \text{ (white precipitation)}$$

Soil-release CO_2 mg was estimated according to the following equation:

$$\text{mg } CO_2/100 \text{ gm Soil} = (B - V)\,NE$$

where *B* is the volume of acid consumed (mL) in control treatment, *V* is the volume of acid consumed (mL) in treatment, N is the normality of HCl and *E* is the equivalent weight of CO_2, which is equal to 22.

Carbon (C mg) was estimated according to the following equation:

$$C\ (mg) = \frac{CO_2\ (mg) \times 12}{44}$$

Number of bacteria and fungi: The total number of soil bacteria in treatments was calculated by using the method of dilution and plate counting using nutrient agar medium. The total number of soil fungi was estimated via dilution and plate counting method.

Statistical analysis: Statistical analysis was carried out using SPSS to determine significant differences in the amount of CO_2 release, carbon and the number of bacteria and fungi among treatments.

Table 1. The physiochemical and biological properties of the soil

Soil properties	Value
pH	7.9
EC (dsm^{-1})	4
Per cent of organic matter	1.8
Per cent of moisture content	15
Bacteria number (cfu g $soil^{-1}$)	$15^* 10^4$
Fungi number (cfu g $soil^{-1}$)	$2^* 10^3$

RESULTS AND DISCUSSION

All treatments amended with organic matter and pesticide had a significant increase the CO_2 release compared with the control at all incubation periods. The soil treated with wheat straw + fungicide Topsan had the highest CO_2 release (381.02 mg 100 g^{-1} soil), with a significant increase rate of 390.75% compared with the control (77.65 mg 100 g^{-1} soil). The treatment of sheep residue + fungicide Topsan (338.5 mg 100 g^{-1} soil) did not significantly differ with the wheat straw treatment. The CO_2 release significantly increased with increasing incubation periods, which were 158.35, 295.0, 315.03 and 340.6 mg 100 g^{-1} soil for 7, 14, 21 and 28 days, respectively. The 21-day incubation period had the highest CO_2 release with an increasing rate of 115.09% compared with the 7-day incubation period with the lowest CO_2 release. The periods of 7–21 days showed the first stage of CO_2 release, in which the maximum CO_2 release was recorded compared with the next period of 28 days. The wheat straw + fungicide Topsan for 21 days had the significantly higher CO_2 (461.9 mg 100g^{-1} soils) among all treatments and was followed by the wheat straw treatment that significantly differed with the treatment of fungicide Topsan + sheep residue with the same incubation period. However, the control treatment (7 days) was recorded with the lowest CO_2 release (70.4 mg 100 g^{-1} soil). In general, the two types of organic matter (wheat straw and sheep residue) treatments significantly exceeded the amount of CO_2 release compared with the two pesticides (fungicide Topsan and herbicide Convidens).

Increased CO_2 release at the period of 7–21 days may be due to the activity of microorganisms (bacteria and fungi) that decompose simple compounds, such as sugars and carbohydrates that come from organic matters added to the soil (Suheil and Fehmey 2009). Decreasing CO_2 release at the incubation period of 28 days may be due to the low biological activity of microorganisms caused by the low amount of simple compounds (Alamiri 2013). The increase in the amount of CO_2 released from organic matter and pesticide treatments compared with the control at the incubation period of 28 days may be due to the effectiveness of microorganisms and their enzymes in degrading complex molecules, such as cellulose and hemicellulose (Walpola and Arunakumara 2010, Ibrahim et al 2015). Moreover,

Huang et al (2018) stated that microbial degradation for pesticides was favoured because microbes decomposed pesticides into small molecules as main microbial nutrients, H_2O and CO_2. This action is known as an enzymatic reaction. It involves the entry of a compound into a microorganism's body via a series of physiological and biochemical reactions under the influence of different enzymes. In such process, pesticides would be completely decomposed into small molecular compounds that are less toxic or non-toxic.

The variation of organic matter sources in the amount of CO_2 released is due to their differences in the C:N ratio and their content of simple and complex substances (Al-Amiri 2013). Therefore, the treatment of fungicide Topsan + wheat was superior in CO_2 release due to its higher content of substances that are easy to decompose by microorganisms, as well as its high nitrogen content, which is necessary to grow microorganisms (Yousif and Mubarak 2009, Walpola and Arunakumara 2010).Organic matter that contains high nitrogen is fast to decompose. When nitrogen content is less than 1.5%, organic matter is slow to decompose. However, substances with more than 1.8% nitrogen are rapidly decomposing. Wheat straw is characterised by carbohydrates and 3.58% of nitrogen content (Suhal and Bader 2018). Semi-cellulose compounds decompose faster than cellulose and lignin in wheat straw due to their low polymerisation and amorphous nature (Ágoston-Szabó et al 2006, Shuai et al 2013).

The superiority of pesticide + organic matter treatments, especially the fungicide Topsan, in wheat straw and sheep residues in CO_2 released indicates that pesticides and organic matter have been degraded and degradation varied according to the type of materials. This superiority may be due to the availability of carbon in these substances, which is one of the main factors that determine the activity of heterotrophic microorganisms. Most soil microorganisms are heterotrophic, hence, their growth depends on the carbon and energy provided through their oxidation of organic compounds and pesticides in the soil. The process of decomposing pesticides depends on enzymes produced by soil microorganisms even though the number of bacteria or fungi is low. Pesticides usually appear to motivate soil bacteria when these pesticides are subject to degradation by bacteria, as well as the ability of fungi to decompose various types of waste by producing enzymes to obtain nutrients such as carbon and nitrogen for growth (Briceño et al 2007, Singh, 2008, Sánchez 2010, Fenner et al, 2013, Kumar et al 2018). Sánchez (2010) and Membrillo et al (2011) stated that microbial activity depends on the chemical composition of material waste and environmental conditions. The effect of pesticides on fungi is higher in the first days and then their effect starts to decrease until no effect occurs, and this observation may be due to the ability of fungus to destroy toxic substances and turn them into a non-toxic substance that the fungus metabolises from pesticides (Alwan and Lateef 2015).

All he treatments had a significant increase in carbon compared with the control treatment during all incubation times. The treatment of fungicide + wheat straw had the highest values (103.92 mg/100 g soil) with an increasing rate of 390.88% compared with the control treatment (21.17mg/100 gm soil) (Table 3). The treatments of fungicide + sheep residue (92.31 mg $100g^{-1}$ soil) did not significantly differ with the wheat treatment. The increase in incubation period from 7 days to 28 days led to a significant increase for carbon release 43.18, 80.44, 92.88, 85.91 mg10 0 g^{-1} soil for 7, 14, 21, 28 days), respectively. The highest values were

Table 2. Effect of addition pesticides and organic matter on the amount of CO_2 (mg100 g^{-1} of soil) released at different incubation periods

Treatments	Incubation periods (day)				Average
	7	14	21	28	
Control (soil only)	70.4c	75.0b	100.2y	65.0d	77.65h
Wheat straw	189.0u	348.7j	414.7b	398.2d	337.65b
sheep residue	163.9v	379.5fg	392.7e	376.2gh	328.07c
Convidens	136.4w	275.0r	323.4n	308.0o	260.7e
Convidens + Wheat straw	95.2z	330.0m	343.7k	334.4l	275.82d
Convidens + sheep residue	88.0a	281.8q	334.4l	309.1o	253.32f
Topsan	129.8x	259.6s	290.4p	290.0p	242.45g
Topsan + wheat straw	330.0m	358.6i	461.9a	373.6h	381.02a
Topsan + sheep residue	222.6t	346.8jk	404.0c	380.6f	338.5b
Average	158.3d	295.0c	a340.6	315.03b	

Different letters show significant differences (P<0.05) between the values

recorded at the period of 21 days with a significant increase rate of 115.09% compared with the period of 7 days, which gave the lowest value. The results of carbon were in line with the trend of CO_2 release for all treatments. The interaction treatments (organic matter, pesticides and different incubation periods) had a significant effect on the amount of carbon released. The increase of incubation periods resulted in a significant increase in the carbon released for all treatments. The 21-day incubation period had the highest values for all treatments. However, the lowest value was recorded in the control (19.2 mg/100 g soil) at the incubation period of 7 days. Moreover, the treatment of fungicide + wheat straw gave the significantly highest values (125.97 mg/100 g^{-1} soil) at the incubation period of 21 days, followed by the treatments of wheat straw and fungicide + sheep waste which did not significantly differ.

All treatments (pesticides and organic matters) showed a significant increase in the number of total bacteria compared with the control during all incubation periods (Table 4). The treatment Convidens + sheep residue had the significantly highest total bacteria number (5.92 * 10^5) cfu g^{-1} dry soil, with a significant increase rate (106.27%) compared with the control. The fungicide Topsan + wheat straw were followed with the value of total bacteria number (5.27 * 10^5) cfu g^{-1} dry soil. However, the control treatment gave the lowest total bacterial number (2.87 * 10^5) cfu g^{-1} dry soil. The increase of the incubation period from 7–21 days led to a significant increase in the number of total bacteria in the soil. The incubation period of 14 days had the highest number of total bacteria in the soil (5.51 * 10^5) cfu g^{-1} dry soil. However,

Table 3. Effect of adding some pesticides and organic matters to soil on the released carbon (mg/100 g soil) at different incubation periods

Treatments	Incubation periods (day)				Average
	7	14	21	28	
Control (soil only)	19.2tu	20.45t	27.32r	17.72u	21.17h
Wheat straw	51.54o	95.1g	113.1b	108.6cd	92.08b
sheep residue	44.7p	103.5e	107.1d	102.6e	89.47c
Convidens	37.2q	75.0l	88.2l	84.0J	71.1e
Convidens + wheat straw	25.96rs	90.0hi	93.73g	91.2h	75.21d
Convidens + sheep residue	24.0s	76.8l	91.2h	84.3J	69.07f
Topsan	35.4q	70.8m	79.2k	79.09k	66.12g
Topsan +wheat straw	90.0hi	97.8f	125.97a	101.94e	103.92a
Topsan + sheep residue	60.7n	94.58g	110.18c	103.8e	92.31b
Average	43.18d	80.44c	92.88a	85.91b	

Different letters show significant differences (P<0.05) between the values

Table 4. Effect of adding some pesticides and organic matter to soil on total bacteria number (cfu * 10^5 g^{-1} dry soil) at different incubation periods

Treatments	Incubation periods (day)				Average
	7	14	21	28	
Control (soil only)	2.45jk	3.7gh	2.85hij	2.5ijk	2.87g
Wheat straw	3.9fgh	5.1cdef	4.6efg	3.0hij	4.15de
Sheep residue	4.76efg	5.45cde	6.0bcd	2.0jkl	4.55cd
Convidens	5.36cde	6.65ab	5.6Bcde	1.6kl	4.80bc
Convidens + wheat straw	5.7bcde	6.8ab	4.8defg	3.8gh	5.27b
Convidens + sheep residue	6.7ab	7.8a	6.7ab	2.5ijk	5.92a
Topsan	3.65ghi	3.9fgh	5.06cdef	2.3jk	3.72ef
Topsan + wheat straw	3.8gh	4.0fgh	4.55efg	1.0l	3.33fg
Topsan + sheep residue	5.05cdef	6.25bc	3.65ghi	1.6kl	4.13de
Average	4.59b	5.51a	4.86b	2.25c	

Different letters show significant differences (P<0.05) between the values

the lowest values were recorded at the incubation period of 28 days (2.25 * 10^5) cfu g^{-1} dry soil. Moreover, the numbers of total bacteria at the 7- and 21-day incubation periods did not significantly differ. The interaction between the treatments (organic matters, pesticide and incubation periods) had significantly affected the number of the total bacterial population in the soil. The treatment herbicide Convidens + sheep residue with the incubation periods of 14 days had the highest total bacteria number in the soil (7.8 * 10^5) cfu g^{-1} dry soil. It was followed by herbicide Convidens + wheat straw at the same incubation periods (6.8 * 10^5) cfu g^{-1} dry soil. However, the incubation period of 28 days had the lowest total number of bacteria for all treatments among all periods. The treatment of fungicide Topsan + wheat straw at the incubation period of 28 days showed the lowest total number of bacteria (1.0 * 10^5) cfu g^{-1} dry soil.

The total number of fungi in the treatments (pesticides and organic matters) had significantly increased compared with the control during all incubation periods (Table 5). The treatment Convidens + Wheat straw had the significantly highest values (2.48 * 10^4 cfu g^{-1} dry soil) with a significant increase rate (892%) compared with the control t followed by Convidens + sheep residue (1.57 * 10^4 cfu g^{-1} dry soil). However, the control treatment had a significantly low number of soil fungi (0.25 * 10^4 cfu g^{-1} dry soil). The total number of fungi in all the treatments significantly increased with the increasing incubation periods from 7 to 21 days. The 14-day incubation period had the significantly highest total number of fungi (1.78 * 10^4 cfu g^{-1} dry soil). However, the incubation period of 7 days had the lowest total number of fungi (0.35 * 10^4 cfu g^{-1} dry soil).The interaction among treatments (pesticides, organic matters and different incubation periods) had significantly affected total number of fungi number in the soil. The treatment Convidens + Wheat straw at the incubation period of 14 days had the significantly highest total number of fungi (5.19 * 10^4 cfu g^{-1} dry soil) followed by Convidens + sheep residue at the same incubation period of 14 days (3.4*10^4 cfu g^{-1} dry soil). However, all treatments had the lowest total number of fungi at the incubation period of 7 days compared with other treatments. Moreover, the treatment of the fungicide Topsan or herbicide Convidens at the 7-day incubation period did not show any fungal growth, but only started to grow at the incubation periods of 14 and 21 days.

The increasing number of bacteria and fungi in soil treated with organic matters and pesticides was because the bacteria and fungi used pesticides as sources of carbon, phosphorous and energy. The decreasing number of bacteria during the 7-day incubation period was due to the lag phase of bacteria, which need time to adapt in new conditions and to build enzymes that can be used the contents of the new environment (Rolfe et al 2012). Then, the bacteria started to grow with the increase of the incubation period, indicating that the bacteria reached the Log phase, wherein enzymes are available and active. At this stage, bacteria began to degrade pesticides, reduce their toxicity, and use pesticides as a source of nutrients and energy, which led to an increase total number of bacteria at the 14-day incubation. The decrease in the total number of bacteria at the 21–28 days of incubation period indicates that the bacteria reached the death phase, wherein the number of dead bacteria exceed that of the live bacteria due to reduction in nutrients sources and the media become unsuitable for growth due to accumulating the toxic materials (Rolfe et al 2012). Suhal and Al-Samerria (2010) observed that bacterial growth increased with increasing incubation period. The 14-day incubation

Table 5. The effect of adding some pesticides and organic mattersto soil on total fungi number (cfu * 10^4 g^{-1} dry soil) at different incubation periods

Treatments	Incubation periods (day)				Average
	7	14	21	28	
Control (soil only)	0.2hij	0.4fghij	0.3ghij	0.1ij	0.25e
Wheat straw	0.3ghij	1.5cd	0.6fghij	1.0cdefg	0.85c
sheep residue	0.4fghij	1.6c	0.75efghi	0.5fghij	0.81c
Convidens	0J	1.35cde	1.1cdef	0.9defgh	0.83c
Convidens + Wheat straw	0.6fghij	5.19a	3.3b	0.85defgh	2.48a
Convidens + sheep residue	0.8efghi	3.4b	1.6c	0.5fghij	1.57b
fungicide Topsan	0J	0.9defgh	0.7efghij	0.2hij	0.45de
fungicide Topsan+ Wheat straw	0.35ghij	0.95cdefg	0.35ghij	0.95cdefg	0.65cd
fungicide Topsan+ sheep residue	0.55fghij	0.75efghi	0.3ghij	0.1ij	0.42de
Average	0.35d	1.78a	1.01 b	0.56 c	

Different letters show significant differences (P<0.05) between the values

period had the highest number of bacteria but eventually decreased, whereas the 21-day incubation period had the lowest number of bacteria. In the first period of incubation, fungi entered the lag phase and subsequently began to degrade pesticides and organic matter to use them as sources of energy. Al-Samerria and Al-Tamimi (2018) concluded that the total number of bacteria and fungi increased in soil treated with herbicide Convidens with increasing incubation periods of 1, 3 and 9 days. The increase in microbial community when soil is amended with organic matter indicated that microbial activity increases with the presence of organic substances (El-sharouny 2015).

CONCLUSIONS

Soil treated with organic matter and pesticides showed a significant amount of CO_2 release. The incubation period of 21 days showed the highest CO_2 release. The number of bacteria and fungi increased with soil treated with organic matter and pesticides, as well as with increasing incubation periods. Therefore, soil amended with wheat straw or sheep residue is recommended to enhance the biodegradation of pesticides (fungicide Topsan and herbicide Convidens) in soil.

REFERENCES

Abood MA, Jasim AA, Fahmi AH and Badawi TK 2013. Effect of Sulfur and Organic Fertilizers on Growth and Yield of Garlic *Allium sativum* L. *International Journal of Agricultural Science and Research* **3**: 25-32.

Adekunle KF and Okolie JA 2015. A review of biochemical process of anaerobic digestion. *Advances in Bioscience and Biotechnology* **6**(3)*:* 205-212.

Al-Amiri A H F2013. The effect of gypsum and limestone soils on the decomposition of organic materials different. *Diyala Journal of Agricultural Sciences* **5**(2): 133-143.

Alwan SAZJA and Lateef S 2015. Effect of two species of Aspergillus in the analysis of some chemical pesticides in soils and various organic fertilizers. *Kufa Journal of Agriculture Science* **7:** 90-111.

Briceño G, Palma G and Durán N 2007. Influence of organic amendment on the biodegradation and movement of pesticides. *Critical Reviews in Environmental Science and Technology* **37:** 233-271.

Dhawan AK, Vijay Kumar and Shera PS 2013. Ecological Perspectives in Pest Management for Sustainable IPM. *Indian Journal of Ecology* **40**(2): 167-77.

Ágoston-Szabó, Edit, Mária Dinka, László Némedi, and Gábor Horváth 2006. Decomposition of Phragmites australis rhizome in a shallow lake.*Aquatic Botany* **85**: 309-316.

El-sharouny EE 2015. Effect of different soil amendments on the microbial count correlated with resistance of apple plants towards pathogenic Rhizoctonia solani AG-5. *Biotechnology Andiotechnological Equipment* **29:** 463-469.

Faris M Suhal and Basem BR 2018. Effect of different local agricultural media on the productivity of Pleurotus florida and its content of nitrogen, potassium and protein. *Journal of Kirkuk University Agriculture Science* **22:** 618-624.

Faris M Suhal and Ismail Khalil Al-Samerria 2010. Effect of different level herbecides in growth and number of Azotobacter chroococcum under different incubation periods. *Diyala Journal of Pure Science* **6:** 192-208.

Fenner K, Canonica S, Wackett LP and Elsner M 2013. Evaluating pesticide degradation in the environment: Blind spots and emerging opportunities. S*cience* **341**: 752-758.

Huang Y, Xiao L, Li F, Xiao M, Lin D, Long X and Wu Z 2018. Microbial degradation of pesticide residues and an emphasis on the degradation of cypermethrin and 3-phenoxy benzoic acid: A review. *Molecules* **23**.

Ibrahim M, Cao CG, Zhan M, Li CF and Iqbal J 2015. Changes of CO_2 emission and labile organic carbon as influenced by rice straw and different water regimes. *International journal of Environmental Science and Technology* **12**: 263-274.

Ismeal KH Al-Samerria and Faris M Al-Tamimi 2018. *Concepts and applied of soil microbiology*. Ministry of Higher Education and scientific Research- University of Diyala.

Kumar S, Kaushik G, Dar M A, Nimesh S, Lopez-Chuken UJ and Villarreal-Chiu JF 2018. Microbial degradation of organophosphate pesticides: A review. *Pedosphere* **28**: 190-208.

Membrillo I, Sánchez C, Meneses M, Favela E and Loera O 2011. Particle geometry affects differentially substrate composition and enzyme profiles by Pleurotus ostreatus growing on sugar cane bagasse. *Bioresource Technology* **102**: 1581-1586.

Sánchez C2010. Cultivation of Pleurotus ostreatus and other edible mushrooms. *Applied Microbiology and Biotechnology* **85:** 1321-1337.

Ortiz-Hernández ML and Sánchez-Salinas E 2010. Biodegradation of the organophosphate pesticide tetrachlorvinphos by bacteria isolated from agricultural soils in México. *Ambient Revista internacional de contaminación ambiental* **26**: 27-38.

Prescott CE 2010. Litter decomposition: what controls it and how can we alter it to sequester more carbon in forest soils.*Biogeochemist* **101**: 133-149.

Rolfe Matthew D, Christopher J Rice, Sacha Lucchini, Carmen Pin, Arthur Thompson, Andrew DS Cameron and Mark Alston 2012. Lag phase is a distinct growth phase that prepares bacteria for exponential growth and involves transient metal accumulation. *Journal of bacteriology* **194**: 686-701.

Sharma S, Sangha J K and Singh B 2013. Pesticide Residues in Food Items: A Study of Organized and Unorganized Retail Outlets in Ludhiana District. *Indian Ecological Society* **40**(1): 96-99.

Shuai L, Ni CX and Dong WX 2013. Changes of the components and energy of corn stalk during decomposition process in cropland with different fertility. *African Journal of Agricultural Research* **8:** 1411-1417.

Singh DK 2008. Biodegradation and bioremediation of pesticide in soil : Concept , method and recent developments. *Indian Journal of Microbiology* **48:** 35-40.

Suheil FM and Fehmey A H2009. Determination of minimum inhibitory concentration from chemical pesticides on bacteria Azotobacter numbers with period of incubation diffrant. *Diyala Agricultural Sciences Journal* **1**(1): 33-38.

Tapas C, Ravindra S and Sharma GL 2017. Effective eco-friendly micro-flora for early degradation of herbicide and enhancing chickpea productivity. *Indian Journal of Ecology* **44**: 7-11.

Walpola BC and Arunakumara KKIU 2010. Effect of salt stress on decomposition of organic matter and nitrogen mineralization in animal manure amended soils. *Journal of Agricultural Sciences–Sri Lanka* **5**(1): 21-27

Yousif AM and Mubarak AR 2009. Variations in nitrogen mineralization from different manures in semi-arid tropics of Sudan with reference to salt-affected soils. *International Journal of Agriculture and Biology* (Pakistan) **11**(5); 39-45.

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Dynamics of Traditional Information of Medicinal Plants from Hilly Terrains of Ramban (J&K) India

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Abstract: A study was conducted in hill station of District Ramban (J&K) in order to check the present status of medicinal plants diversity their abundance and for suggested utilization measures for residential peoples of the area. During the field survey, medicinal plants used via the local community were ranged from 68 to 79 plant species, specifically 46 to 55 herbs, 13 to 15 trees, and 08 to 09 shrubs from selected sampling zones for treating various diseases and disorder. These florae are disbursed in 38 families with Asteraceae was dominant in all sampling zones.

Keywords: Traditional information, Dynamics, Medicinal plant, Ramban, J&K

Ethnomedicine plays very significant role in human health care since time immemorial. According to WHO, about 80% of the people in developing countries still depend on local medicinal plants to fulfil their primary health needs. Ethnobotanical surveys have been found to be one of the reliable approaches to drug discovery (Kalaichelvi and Swaminathan 2009, Saha 2016, Debnath and Das 2019, Singh and Sahoo 2019). India is fortunate to have tremendous and varied medicinal plants resources distributed broadly in the vivid forest ecosystem. Many studies have been carried out from time to time to document the ethnomedicinal information from different districts of Jammu and Kashmir, India (Sharma et al 2012, Sharma et al 2019). Therefore, in the present study, an effort has been made to document some locally available medicinal plants used by the local community of district Ramban, for curing various diseases. The present data has its importance because recorded for the first time.

MATERIAL AND METHODS

Description about study area: The study area was divided into three sampling zones and every zone has further three stations for the collection of medicinal plants.

Sampling strategy: The study was conducted on monthly basis for the period of one year during 2019-2020. The sampling process was completed in three days every month and two sites were covered in one day.

Collection of Medicinal plants: The collection and identification of specimen has been done by flowering/fruiting to facilitate the process of identification covering all the sampling month. In case of trees and shrubs, branches of suitable size in flowering or fruiting stages were taken. Field number for each collected sample was assigned and preserved for identification. Identification was done with the help of Floras of the Himalaya, Flora Britannica and Flora of J&K. The technique for collection of plants was the same as suggested by (Jain and Rao 1978).

Identification of Medicinal plants: The plants were identified with the help of flora (Raizada and Saxena 1978). The identified medicinal plants were confirmed by consulting the herbaria of different standards keys in Department of Plant Sciences, Central University of Himachal Pradesh and Department of Botany and Microbiology, Gurukula Kangri Vishwavidyalaya, Haridwar.

Documentation of local traditional knowledge: Local uses of medicinal plants of the sampling area, their local names, parts used, purpose for which it is used, method of administration were recorded through talks and conversation with elderly persons, and rural women in villages.

RESULTS AND DISCUSSION

The total number of 79 medicinal plant species belonging to 38 families had been collected and identified from the selected sampling zones (Table 1). Total 35 families of medicinal plants were from sampling zone 1 in which Asteraceae family was most dominant family (10 species) followed by Lamiaceae (6 species), Rosaceae, Ranunculaceae. *Pinus wallichiana* was dominant species (7%) followed by *Juglans regia* (6%), *Cedrus deodara* (5%), due to the uniform sunlight exposure and low human interferences. Total 3 types of medicinal plants were collected (Fig. 1) herb (50 number) followed by tree (13

Table 1. Medicinal plants recorded from selected sampling zones along with family, habit, plant part used and their various uses

Botanical Name	Zone 1	Zone 2	Zone 3	Family	Habit	Parts used	Uses
Achilliea millefolium	P	P	A	Asteraceae	Herb	Leaves, flower	Diuretic, simulative, haemostatic tonic
Adiantum venustum	P	P	P	Pteridaceae	Herb	Fronds	Expectorant, diuretic, in scorpion-sting
Asparagus filicinus	P	P	P	Asparagaceae	Herb	Root	Tonic, astringent
Aesculus indica	A	P	P	Sapindaceae	Tree	Roots, bark	Leucorrhoea; dislocated joints
Agrimonia pilosa	P	P	P	Rosaceae	Herb	Roots, leaves	Diuretic
Ainsliaea aptera DC.	A	P	P	Asteraceae	Herb	Roots	Stomach-ache, diuretic
Amaranthus spinosus	P	P	P	Amaranthaceae	Herb	Whole plan	Sudorific fevers, snake-bite; eczema, boils, burns, gonorrhoea
Anaphalis contorta	A	P	P	Asteraceae	Herb	Whole plan	Healing wounds, prevents bleeding
Anemone vitifolia	P	P	P	Ranunculaceae	Herb	Whole plant	Pathogenic fungi
Angelica glauca	P	P	P	Apiaceae	Herb	Whole plant	Dyspepsia, constipation, condiment,
Arctium lappa Linn	P	P	P	Asteraceae	Herb	Roots, seeds	Diuretic, diaphoretic, depurative,
Artemisia vestita	P	P	P	Asteraceae	Herb	Leaves	Haemostatic
Berberis aristata	P	P	P	Berberidaceae	Herb	Root bark,	Menorrhagia, diarrhoea, jaundice,
Berberis lycium	P	P	P	Berberidaceae	Herb	Roots	Febrifuge, menorrhagia, diarrhoea, piles, ophthalmia, jaundice
Bergenia ciliata	P	P	P	Saxifragaceae	Herb	Rhizomes	Diarrhoea, fever, spleen enlargement
Bergenia stracheyi	P	P	A	Saxifragaceae	Herb	Rhizomes	Menorrhagia, urinary troubles
Betula utilis	P	P	P	Betulaceae	Tree	Bark	Anaemia, cough, obesity
Bidens pilosa Linn.	P	P	P	Asteraceae	Herb	Whole plant	Leprosy, tumour, skin problem
Bidense tripartita	P	P	P	Asteraceae	Herb	Whole plant	Chronic dysentery, eczema
Bistorta amplexicaulis	P	P	A	Polygonaceae	Herb	Root-stock	Unani medicine
Bupleurum falcatum	P	P	A	Apiaceae	Herb	Whole plant	Liver problems
Cannabis sativa	P	P	P	Cannabaceae	Herb	Leaves, flower,	Sedative, analgesic, narcotic
Capsella bursapastoris	P	P	P	Brassicaceae	Herb	Herb	Diuretic, febrifuge, haemostatic
Cedrus deodara	P	P	P	Pinaceae	Tree	Bark	Fevers, diarrhoea, dysentery
Celtis australis	P	P	P	Cannabaceae	Tree	Fruit	Amenorrhoea
Corylus colurna	P	P	P	Betulaceae	Tree	Nuts, leaves	Treatment of injuries
Cotoneaster	P	P	P	Rosaceae	Shrub	Stolon	Astringent
Cuscuta reflexa	P	P	P	Convolvulaceae	Herb	Whole plant	Liver complaints, itch, fevers
Cynoglossum	P	P	A	Boraginaceae	Herb	Roots	Vomiting
Datura stramonium	P	P	P	Solanaceae	Herb	Seeds, flowers	Ear ache, scalp, falling hair
Delphinium denudatum	P	P	P	Ranunculaceae	Herb	Roots	Adulterant for aconite
Dioscorea deltoidea	P	P	P	Dioscoreaceae	Herb	Tubers	Washing silk, wool, hair
Elaeagnus umbellata	P	P	P	Elaeagnaceae	Shrub	Flowers, seeds	Stimulant, cardiac, astringent
Elsholtzia fruticosa	P	P	P	Lamiaceae	Shrub	Fruits, leaves	Fruiting, leaves yield essential oil
Fagopyrum cymosum	P	P	P	Polygonaceae	Herb	Seeds	Choleraic diarrhoea, fluxes
Geranium wallichianum	P	P	P	Geraniaceae	Herb	Whole plant	Cure for tooth ache, eye- troubles
Hypericum perforatum	P	P	P	Hypericaceae	Herb	Whole plant	Wounds, ulcers, swellings
Jasminum humile	P	P	P	Oleaceae	Shrub	Flowers, roots,	Oil perfumery, ringworm
Juglans regia	P	P	P	Juglandaceae	Tree	Leaves, bark,	Anthelmintic, detergent, rheumatism
Juniperus recurva	P	P	P	Cupressaceae	Tree	Wood, leaves,	Incense, alcohol extract
Lamium album	P	P	P	Lamiaceae	Herb	Whole plant	Haemorrhages of uterus, nose
Leonurus cardiaca	P	P	P	Lamiaceae	Herb	Leaves	Diuretic, emmenagogue

Cont....

Continues Table 1

Botanical Name	Zone 1	Zone 2	Zone 3	Family	Habit	Parts used	Uses
Mentha longifolia	P	P	P	Lamiaceae	Herb	Whole plant	Carminative, antiseptic
Nasturtium officinale	A	P	P	Brassicaceae	Herb	Whole plan	Vermifuge, diuretic
Ocimum basilicum	P	P	P	Lamiaceae	Herb	Whole plant	Stomachic, alexipharmac, ringworm,
Origanum vulgare	P	P	P	Lamiaceae	Herb	Whole plant	Stomachic, diuretic, diaphoretic
Phytolacca acinosa	P	P	A	Phytolaccaceae	Herb	Whole plant	Pain in joints
Pinus wallichiana	P	P	P	PInaceae	Tree	Resin, needles	Liniment for healing of the cuts, wounds
Plantago lanceolata	P	P	P	Plantaginaceae	Herb	Whole plant	Cough, asthma, pulmonary diseases
Plantago major	P	P	P	Plantaginaceae	Herb	Seeds	Gastric complaints, stomach disorders
Podophyllum hexandrum Royle	P	P	P	Berberidaceae	Herb		Effective vermifuge
Polygonum hydropiper	P	P	P	Polygonaceae	Herb	Whole plan	Skin affections
Populus ciliata	P	P	P	Salicaceae	Tree	Bark	Blood purifier
Prunus armeniaca	P	P	P	Rosaceae	Tree	Kernels	Pharmaceutical, cosmetic industry
P. persica	P	P	P	Rosaceae	Tree	Kernels, leaves,	Cough, anthelmintic
Punica granatum	P	P	P	Lythraceae	Shrub	Bark, fruits,	Diarrhoea, dysentery, bronchitis
Ranunculus laetus	P	P	P	Ranunculaceae	Herb	Herb	Toxic properties
Rhododendron arboreum	P	P	P	Ericaceae	Tree	Bark, petals	Diarrhoea, dysentery
Robinia pseudoacacia	A	P	A	Fabaceae	Tree	Leaves, flowers	Digestive disorders
Rosa brunonii	P	P	P	Rosaceae	Shrub	Flowers, roots	Eye troubles
Rumex nepalensis	P	P	P	Polygonaceae	Herb	Leaves	Syphilitic ulcers
Salix babylonica	P	P	P	Salicaceae	Tree		Rheumatism
Selinum vaginatum	P	P	P	Apiaceae	Herb	Roots	Sedative, analgesic properties
Siegesbeckia orientalis	A	P	A	Asteraceae	Herb	Whole plant	Ulcers. Sores, skin diseases
Skimmia laureola	P	P	A	Rutaceae	Shrub	Leaves	Small-pox
Solanum nigrum	P	P	P	Solanaceae	Herb	Whole plant	Fevers, diarrhoea, eye troubles
Solidago virgaaurea	P	P	P	Asteraceae	Herb	Aerial part	Kidney, bladder stone
Sonchus asper	P	P	A	Asteraceae	Herb	Herb	Wounds, boils treatment
Tagetes minuta	P	P	P	Asteraceae	Herb	Herb	Stomachic, aperient
Taraxacum officinale	P	P	P	Asteraceae	Herb	Rhizomes,	Stomachic, hepatic stimulant
Taxus baccata	P	P	P	Taxaceae	Tree	Leaves, fruits	Coldness of extremities, diarrhoea
Thalicturm foliolosum	A	P	A	Ranunculaceae	Herb	Roots	Extremities, diarrhoea
Thymus serpyllum	P	P	P	Lamiacae	Shrub	Leaves roots,	Expectorant, carminative
Trifolium repens	P	P	P	Fabaceae	Herb	Leaves, flowers	Detergent, depurative
Urtica dioica	P	P	P	Urticaea	Herb	Whole plan	Chronic hepatitis, habitual constipation
Valeriana jatamansi	P	P	P	Valerianaceae	Herb	Roots	Hysteria, nervous unrest, urinary troubles
Verbascum thapsus	P	P	P	Scrophulriaceae	Herb	Whole plant	Heart stimulant
Xanthium strumarium	P	P	P	Asteraceae	Herb	Whole plant	Chronic malaria, urinogenital diseases
Zizyphus mauritiana	P	P	P	Rhamnaceae	Shrub	Fruits	Sedative, soporific, to stop vomiting
Total	72	79	68				

Sampling zones	Name of sampling zones		Geo-coordinates	
			Longitude "E"	Latitude "N"
Zones 1	Pogal Valley (Sarvadhar to Omnagar)	Sarvadhar	75°20'04.08	33°21'16.99
		Omnagar	75°25'51.41	33°20'01.96
Zones 2	Omnagar Valley (Omnagar to Neel)	Neel	75°25'30.08	33°25'20.03
Zones 3	Sanasar Valley (Sanasar to Nathatop)	Sanasar	74°79'73.71	34°08'36.56
		Nathatop	75°19'36.88	33°07'77.78

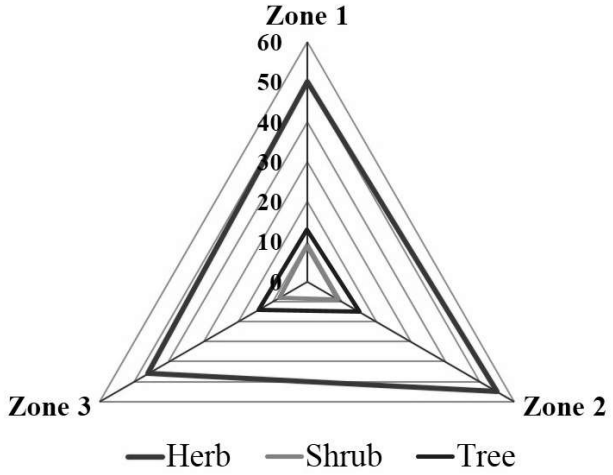

Fig. 1. Number of medicinal plant along habit type from selected zones

number) and shrub (9 number). Ethnomedicinal uses of 10 species belonging to 7 families from Pulwama District was reported by Chak et al (2009). Total 38 families were recorded from sampling zone 2 in which Asteraceae family was dominant family (13 species) followed by Lamiaceae (6 species), Rosaceae (5 species). Higher number of plant species may be due to the lower elevation which imply the climate adaption by plant species. *Pinus wallichiana* was dominant species (6%) followed by *Juglans regia* (5%), *Cedrus deodara* (4%). Total 3 types of medicinal plant were collected (Fig. 1) herb (55 number) followed by tree (09 number) and shrub (15 number). Uniyal (2003) documented 24 medicinal plant from Wildlife Sanctuary. Singh (2004) counted 90 medicinal plant of Western Himalayas. Singh and Chauhan (2005) recorded the medicinal plant habit of 43 plant belonging to 25 families. Total 35 families from sampling zone 3 in which Asteraceae (11 species) followed by Lamiaceae (6 species), Rosaceae (5 species). *Juglans regia* was dominant species (7%) followed by *Capsella bursapastoris* (5%), *Cedrus deodara* (5%). Total 3 types of medicinal plant were collected (Fig. 1) herb (46 number) followed by tree (08 number) and shrub (16 number). *Juglans regia* was dominant species because of prolonged winter season, which is more significant climate factor for sustainable establishment of various types of medicinal plants. There is evidence that primarily climatic factors are responsible for spread of *Juglans regia*. Climatic change in the environment causes huge impacts on plant species their communities and also on forest ecosystems. Bisht and Pundir (2008) reported 67 medicinal plants from Western Himalayas, Uttarakhand. Sixty-five medicinal plants were identified in different areas of Manipur (Nizar et al 2015, Srivastav et al 2009).

CONCLUSIONS

From the present study it may be concluded that the traditional knowledge system about the medicinal uses of native plants several parts in India is rapidly diminishing day by day. Therefore, it is vital necessity to register and document all ethnobotanical information among the diverse ethnic and local communities before the traditional cultures are completely lost. So, attempt had been done to survey and study the ethnomedicinal plants present in the area and document the traditional knowledge of the ethnic peoples. It has been found that there is rich diversity of medicinal plant wealth in all the selected sampling zones.

REFERENCES

Bisht DS, and Pundir YPS 2008. Wild medicinal plants of Jaunsar-Bawar (Western Himalayas), Uttarakh, - II. *The Indian Forester* **134**(5): 674-686.

Chak I, Agarwal RK and Khan AM 2009. Ethno medicinal study of important plants the treatment of hair & boils in District Pulwama of Kashmir. *Annals of Forester* **17**: 101-107.

Debnath N and Das AK 2019. Ethnomedicinal plants used by the Halam Tribe of North Tripura, Northeast India. *Indian Journal of Ecology* **46**(2): 437-443.

Jain SK and Rao RR 1978. *A Handbook of Field and Herbarium Methods*. Today and Tomorrow Publ. New Delhi.

Kalaichelvi K and Swaminathan AA 2009. Alternate L, use through cultivation of medicinal and aromatic: A review. *Indian Journal of Agricultural Research* **30**(3): 176-183.

Nizar KM, Gopakumar S, Kumar V and Ajeesh R 2015. Indigenous ethnomedicines and victuals of Malayans: An indigenous population of Peechi-Vazhani wildlife sanctuary, Western Ghats, India. *Indian Journal of Ecology* **42**(421) :9-15.

Raizada MB and Saxena H 1978. *Flora of Mussorie*. Bishen Singh Mahendra Pal Singh, Dehradun.

Saha SK 2016. Parashi (*Cleistanthus collinus* Roxb.): A multipurpose plant of ethno-botanical importance in south west Bengal of India. *Indian Journal of Ecology* **43**(1): 426-430.

Sharma AK, Malik DS, Kumar D and Bargali H 2019. Ichtyotoxic plants used for collection of fishes in India: A review. *Latest Trends in Zoology and Entomology Sciences,* AkiNik Publications. New Delhi **5**: 27-52.

Sharma MM, Verma RN, Jamal SM, Batra A and Rao DV 2012. An anti-asthmatic plant: *Tylophora indica burm.* F. Merill – A Review. *Indian Journal of Agricultural Research* **33**(3): *192-201*.

Singh SL and Sahoo UK 2019. Shift in phenology of some dominant tree species due to climate change in Mizoram, North-East India. *Indian Journal of Ecology* **46**: 132-136.

Singh GS 2004. Ethnobiological and biomedicinal wealth of Western Himalayas, India. *Journal of Medicinal and Aromatic Plant Science* **26**(3): 517-526.

Singh V and Chauhan NS 2005. Traditional practices of herbal medicines in the Lahual valley, Himachal Himalayas. *Indian Journal of Traditional Knowledge* **4**(2): 208-220.

Srivastav PK, Singh NI and Singh ST 2009. Medicinal food plants of Manipur. *Annals of Forestry* **17**(2): 269-292.

Uniyal B 2003. Utilization of medicinal plants by the rural women of Akola, Maharashtra. Indian *Journal of traditional Knowledge* **2**(4): 336-370.

Verma JS 2006. Insect pest problem in medicinal plants: A review. *Indian Journal of Agricultural Research* **27**(2): 130 – 136.

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Comparative Study on Diversity of Trees and Shrubs in Protected Areas - Vansda National Park and Ratanmahal Sanctuary of Gujarat State, India

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Abstract: This study deals with comparative floral inventory in two Protected Areas (PAs)-Vansda National Park (VNP) and Ratanmahal Sanctuary (RS) of Gujarat state. During the study, transect and quadrat methods have been applied to achieve qualitative and quantitative information of flora in which the quadrat size varied for the trees and shrubs, respectively. The analysis of the plant inventory study shows that RS harbors a total of 99 trees and 32 shrubs species whereas VNP harbors a total of 93 trees and 21 shrubs species. The plant inventory study also revealed that VNP has less species diversity than RS. However, in quadrat study, more diversity of tree species has been recorded in VNP than RS. Furthermore, Simpson and Shannon indices were calculated to know sustainability of plant species which shows that VNP has more tree diversity than RS whereas the shrub species showed decline of its richness and evenness. The similarity and dissimilarity indices of trees and shrubs have been calculated between two PAs. The similarity has been found to be 75 % and 64 % for trees and shrubs, respectively and dissimilarity have been found to be 25 % and 36 % for trees and shrubs, respectively.

Keywords: Comparative, Diversity, Trees, Shrubs, VNP, RS

India is a tropical country with the geographical area of 2.4 % of the world, but it houses 8% of the biodiversity of the world. It is located at the junction of three realms namely, Agro tropical, Indo-Malayan and Paleo- arctic (Tadvi 2013). There are a total of 10 biogeographical zones in India, out of which, 4 biogeographical zones, viz. 3B- Desert Kachchh, 4B-Arid Gujarat Rajwara, 5A/5B- Western Ghat and 10A-West Coast are represented in Gujarat state (Yadav et al 2018). Every biogeographical zone has its unique or diverse floristic composition in all Protected Areas (PAs) of Gujarat state. The Protected Area (PAs) is a repository of numerous plants and animals which may be a rare, endangered, vulnerable or critically endangered types as per International Union for Conservation of Nature (IUCN) category. Gujarat state has 28 Protected Areas (PAs) i.e., 4 National Park, 23 Sanctuaries and 1 Conservation Reserve, covering a total of 2888.85 km^2, which comprises 13.3% of a total forest area of the state (GFD 2016). The floral diversity of the state varies due to differences in sunlight intensity, temperature, humidity as well as other factors such as geology, climate and topography. Mostert (2014) discribed that at the local scale, the terrestrial plant diversity is driven by height, slope, feature, soil condition, human and animals in a particular area. The dissimilarity and resemblance of floristic composition of any area may be of great ecological importance, attracting our attention to the vegetation of any region. Plant species diversity in any particular area is a key feature to know the community like trees and shrubs which are correlated with environmental conditions (Nabi et al 2016). The diversity and species richness of trees are main foundation of other forest species diversity, because it provide habitat to other minor species such as climbers and herbaceous vegetation (Arya et al 2017). As is evident known, India being a tropical country, has tropical vegetation mostly dominated by angiospermic trees and shrubs which play an important role in providing shade and shelter to herbaceous and others flora in the particular region (Bora and Bhattacharya 2017). Keeping the aforementioned facts in view, an attempt has been made to investigate comparative diversity status of tree and shrub between two protected areas i.e. Vansda National Park (VNP) and Ratanmahal Sanctuary (RS) of Gujarat State.

MATERIAL AND METHODS

Study area: Vansda National Park (VNP) falls in 5B-Western Ghat - agro climatic zone. It is located between 20°51'16" N and 21°21'22" N latitudes and between 73°20'30" E and 73°31'20" E longitudes and area is spread over 23.99 km^2. Another Protected Area (PAs) Ratanmahals Sanctuary (RS) falls in 4B-Arid Gujarat *Rajwara* - agroclimatic zone and has a relatively larger area, i.e., 55.65 km^2 than VNP. It is located between 22°35'10" N and 22°30'41" N latitudes and between 74°03'16" E and 74°11' 27" E. Both of these PAs have two different types of

agroclimatic zone as shown in the map of Gujarat given below. Therefore, perhaps both PAs will have different floristic diversity in their jurisdictions.

Sampling procedure: The study was undertaken for enumeration of tree and shrub species available in two protected areas (PAs) i.e., RS and VNP during May and December, 2017, respectively. The transect and quadrats are two ecological tools quantify plants in the selected area, therefore, this methodology was employed. Total of 43 and 29 quadrats were laid down on set transects in two PAs i.e., RS and VNP, respectively. The size of quadrats was 20 ×20m for trees and 10m × 10m for shrubs, respectively as describe by Yadav et al (2018). Further, longitudes and latitudes were also recorded for each of the quadrats laid in the area by using GPS (Global Positioning System). Apart from quadrate survey, transects were also laid out for plant inventory study.

Data analysis: All collected data have been analysed using various formulas of common measurable attributes such as density, frequency, abundance and species composition. Lastly, The Simpson Diversity Index and Shannon's Weiner diversity indices were calculated to know species diversity status, richness and evenness of plant species in the study area. Sorenson coefficient was calcualted for estimation of similarity of all encountered species in two protected areas.

RESULTS AND DISCUSSION

The systematic survey and inventory of flora of two Protected Areas (PAs) showed a considerable variation qualitatively and quantitatively.

Qualitative assessment: In the current plant inventory, a total of 99 tree species and 32 shrub species were noted in RS on the transect while in VNP a total of 93 and 21 species of trees and shrubs, respectively were recorded. The study showed RS has more species diversity or species richness than VNP.

Quantitative assessment: The *Tectona grandis* L.f. have shown maximum floristic density, abundance, frequency and composition in VNP whereas in RS, the *T. grandis* L.f.., showed maximum floristic density, abundance and composition bearing species but maximum frequency was in *Terminalia crenulata* Roth (Table 1). Both PAs show that *T. grandis* L.f. species having maximum density of individuals which is common for both of the regions. These variations

Table 1. Comparative quantitative analysis of tree species found in two PAs

Scientific name	English name	Family	Sanctuary	Density (ind/ha)		Abundance (ind/ha)		Frequency (%)		Composition (%)	
				VNP	RS	VNP	RS	VNP	RS	VNP	RS
Acacia chundra Wild.	Red cutch tree	Mimosaceae	VNP	7.8	NA	1.3	NA	24.1	NA	2.7	NA
Acacia ferruginea DC.	Rusty acacia	Mimosaceae	VNP	0.9	NA	1.0	NA	3.4	NA	0.3	NA
Acacia catechu (L.f.) Willd.	Black cutch tree	Mimosaceae	RS	NA	1.2	NA	1.0	NA	4.7	NA	0.2
Adina cordifolia (Roxb.) Bth. and Hk.	Yellow teak	Rubiaceae	Both	1.7	1.7	2.0	1.0	3.4	7.0	0.6	0.3
Alangium salviifolium (L) Wang.	Stone Mmngo	Alangiaceae	RS	NA	7.6	NA	3.3	NA	9.3	NA	1.2
Albizia lebbeck (L.) Bth.	Women's tongue tree	Mimosaceae	Both	3.4	1.2	1.3	2.0	10.3	2.3	1.2	0.2
Albizia procera (Roxb.) Bth.	White Siris	Mimosaceae	Both	4.3	0.6	2.5	1.0	6.9	2.3	1.5	0.1
Anogeissus latifolia Wall. ex. Bedd.	Axle Wood Tree	Combretaceae	Both	3.4	14.5	2.0	2.3	6.9	25.6	1.2	2.3
Bauhinia lawii Baker	Pore leaved bauhinia	Caesalpiniaceae	VNP	4.3	NA	1.7	NA	10.3	NA	1.5	NA
Bombax ceiba L.	Silk cotton tree	Bombacaceae	VNP	2.6	NA	1.0	NA	10.3	NA	0.9	NA
Borassus flabellifer L.	Palmayra palm	Arecaceae	RS	NA	0.6	NA	1.0	NA	2.3	NA	0.1
Bridelia retusa (L.) Spr.	Spinous kino tree	Euphorbiaceae	Both	5.2	18.0	2.0	2.1	10.3	34.9	1.8	2.8
Buchanania lanzan Spr.	Chironi tree	Anacardiaceae	Both	0.9	16.3	1.0	2.5	3.4	25.6	0.3	2.6
Butea monosperma (Lam.) Taub.	Flame of the forest	Fabaceae	Both	17.2	29.7	1.3	4.6	55.2	25.6	6.0	4.7
Careya arborea Roxb.	Wild Gguava	Lecythidaceae	RS	NA	8.7	NA	3.8	NA	9.3	NA	1.4
Casearia elliptica Willd.	Sano bethe	Flacourtiaceae	RS	NA	2.3	NA	1.3	NA	7.0	NA	0.4
Cassia fistula L.	Amaltas	Caesalpiniaceae	Both	0.9	1.2	1.0	1.0	3.4	4.7	0.3	0.2
Cassine glauca (Rottb.) O. Ktze.	Ceylon tea	Celastraceae	RS	NA	8.1	NA	2.3	NA	14.0	NA	1.3
Dalbergia lanceolaria L.f.	East Indian rosewood	Fabaceae	RS	NA	0.6	NA	1.0	NA	2.3	NA	0.1

Cont...

Continues Table 1

Scientific name	English name	Family	Sanctuary	Density (ind/ha)		Abundance (ind/ha)		Frequency (%)		Composition (%)	
				VNP	RS	VNP	RS	VNP	RS	VNP	RS
Dalbergia latifolia Roxb.	Black Rosewood	Fabaceae	Both	6.0	4.7	1.2	1.3	20.7	14.0	2.1	0.7
Dalbergia paniculata Roxb.	Indian Rosewood	Fabaceae	Both	6.9	2.9	1.3	1.3	20.7	9.3	2.4	0.5
Derris indica (Lam.) Bennet	Pongame oil tree	Fabaceae	RS	NA	0.6	NA	1.0	NA	2.3	NA	0.1
Diospyros melanoxylon Roxb.	Coromandel ebony	Ebenaceae	Both	13.8	34.3	1.6	2.6	34.5	53.5	4.8	5.4
Phyllanthus emblica L.	Indian gooseberry	Euphorbiaceae	VNP	0.9	NA	1.0	NA	3.4	NA	0.3	NA
Erythrina suberosa Roxb.	Corky coral tree	Fabaceae	VNP	0.9	NA	1.0	NA	3.4	NA	0.3	NA
Ficus asperrima Roxb.	Brahma's banyan	Moraceae	VNP	0.9	NA	1.0	NA	3.4	NA	0.3	NA
Ficus racemosa L.	Cluster fig	Moraceae	RS	NA	1.7	NA	3.0	NA	2.3	NA	0.3
Ficus religiosa L.	Sacred fig	Moraceae	VNP	1.7	NA	1.0	NA	6.9	NA	0.6	NA
Garuga pinnata Roxb	Garuga	Burseraceae	Both	13.8	27.3	2.0	2.8	27.6	39.5	4.8	4.3
*Grewia tiliaefolia*Vahl	Dhaman	Tiliaceae	VNP	3.4	NA	1.3	NA	10.3	NA	1.2	NA
Heterophragma quadriloculare (Roth) K.Schum.	Waras	Bignoniaceae	VNP	0.9	NA	1.0	NA	3.4	NA	0.3	NA
Hymenodictyon excelsum (Roxb.) Wall.	Bridal Ccouch tree	Rubiaceae	VNP	0.9	NA	1.0	NA	3.4	NA	0.3	NA
Lagerstroemia parviflora Roxb.	Small flowered crape myetle	Lythraceae	Both	2.6	29.1	1.5	4.2	6.9	27.9	0.9	4.6
Lannea coromandelica (Houtt) Herrill	Indian ash tree	Anacardiaceae	Both	12.1	7.6	1.4	1.9	34.5	16.3	4.2	1.2
Madhuca indica J. F. Gmel.	Mahua	Sapotaceae	RS	6.0	9.3	1.8	1.6	13.8	23.3	2.1	1.5
Meyna laxiflora Robyns.	Muyna	Rubiaceae	VNP	2.6	NA	1.5	NA	6.9	NA	0.9	NA
Miliusa tomentosa (Roxb.) Sinclair	Hoom	Annonaceae	Both	5.2	32.0	2.0	3.2	10.3	39.5	1.8	5.0
Mitragyna parvifolia (Roxb.) Korth.	Kaim	Rubiaceae	Both	6.0	4.1	1.0	1.0	24.1	16.3	2.1	0.6
Morinda tomentosa (Heyne ex Roth) Hk. f.	India mulberry	Rubiaceae	RS	NA	1.2	NA	2.0	NA	2.3	NA	0.2
Ougeinia oojeinensis (Roxb.) Hochreut.	Ujjain desmodium tree	Fabaceae	Both	3.4	2.3	1.3	4.0	10.3	2.3	1.2	0.4
Pterocarpus marsupium Roxb.	Indian kino tree	Fabaceae	Both	5.2	1.2	1.2	2.0	17.2	2.3	1.8	0.2
Schleichera oleosa (Lour.) Oken	Ceylon oak	Sapindaceae	Both	9.5	12.2	1.2	2.1	31.0	23.3	3.3	1.9
Soymida febrifuga (Roxb.) A. Juss.	Indian redwood	Meliaceae	Both	1.7	1.2	1.0	2.0	6.9	2.3	0.6	0.2
Sterculia urens Roxb.	Gum karaya	Sterculiaceae	VNP	3.4	NA	2.0	NA	6.9	NA	1.2	NA
Sterculia villosa Roxb.	Hairy Sterculia	Sterculiaceae	RS	NA	0.6	NA	1.0	NA	2.3	NA	0.1
Syzygium cumini (L.) Skeels	Jamun	Myrtaceae	RS	NA	1.2	NA	2.0	NA	2.3	NA	0.2
Tamarindus indica L.	Tamarind	Caesalpiniaceae	RS	NA	1.7	NA	1.5	NA	4.7	NA	0.3
Tectona grandis L.f.	Teak	Verbenaceae	Both	69.8	155.2	3.2	10.3	86.2	60.5	24.5	24.4
Terminalia bellirica (Gaertn.) Roxb.	Bedda nut tree	Combretaceae	Both	3.4	1.2	2.0	1.0	6.9	4.7	1.2	0.2
Terminalia crenulata Roth.	Laurel	Combretaceae	Both	42.2	116.9	2.5	6.3	69.0	74.4	14.8	18.3
Wrightia tinctoria R. Br.	Sweet indrajao	Apocynaceae	Both	9.5	43.6	1.8	4.4	20.7	39.5	3.3	6.8
Wrightia tomentosa R. & S.	Wolly dyeing rosebay	Apocynaceae	RS	NA	31.4	NA	4.2	NA	30.2	NA	4.9
Xeromphis spinosa (Thunb.) Keay	Mountain pomegranate	Rubiaceae	RS	NA	1.2	NA	2.0	NA	2.3	NA	0.2

NA- Not Available, **ind**-Individuals

may be due to the subtropical arid and tropical climate in RS and VNP, respectively which becomes humid during monsoon season.

The density, frequency, abundance and composition of different plant show very huge variation in their value for both of the PAs (Table 2). The *Carvia callosa* (Nees) Bremek. shows maximum density, abundance, frequency and composition in VNP while in RS, the *Helicteres isora* L. shows maximum density, abundance, frequency and composition among all shown species. Both PAs have many similar species also in their jurisdiction but many other species showed very huge variation in density, frequency, abundance and floristic composition.

Comparison of species diversity indices: The tree species shows a lower value of the Simpson index in VNP (0.09) than RS (0.11) while, the shrub species show higher value of the Simpson index in VNP (0.44) than RS (0.22). The Simpson index value reflects that the VNP has more diversity of tree than RS while RS has more diversity of shrub than VNP because if the Simpson index increases, the tree diversity decreases. The present Simpson index value was compared to a research study done by Yadav et al (2018) in other Protected Areas i.e. Purna Wildlife Sanctuary (PWS) and Jessore Wildlife Sanctuary (JWS) of Gujarat state in which they have reported the indices of 0.16 to 0.26 and 0.33 to 0.45 for tree and shrub species, respectively. These values of Simpson indices in both protected areas were in the range of standard value of 0-1 as provided by Anon (2017). An analysis of Shannon-Weiner indices of trees were noted to be 2.90 and 2.67, respectively for VNP and RS. Likewise, in the shrub species the Shannon-Weiner indices were noted to be 1.15 and 1.53, respectively for VN and RS (Table 3). The current value of Shannon index was found less than the range of 1.85-2.05 as reported by Panda et al (2013). The present value of Shannon-Weiner index of tree species was between in standard range of 1.5 to 3.5 (Anonymous 2017**).** However, the shrub species diversity value in VNP was less than of standard range indicates the species richness and evenness decreased in the VNP (Table 3).

Similarity and dissimilarity indices: The analysis of similarity and dissimilarity of the current study revealed that 75 % of tree species are common in both of the PAs, which means only 25 % of tree species showed dissimilarity. Similarly, in shrub species, a total of 64 % species showed similarity and remaining 36 % of the species showed dissimilarity.

Table 2. Comparative quantitative analysis of shrub species found in two PAs

Scientific name	English name	Family	Sanctuary	Density (ind/ha)		Abundance (ind/ha)		Frequency (%)		Composition (%)	
				VNP	RS	VNP	RS	VNP	RS	VNP	RS
Calotropis procera (Ait) R.Br	Rubber bush	Asclepiadaceae	VNP	6.9	11.6	1.0	2.5	6.9	4.7	2.2	3.0
Carissa congesta Wight.	Wild karanda	Apocynaceae	VNP	62.1	NA	3.6	NA	17.2	NA	20.2	NA
Carvia callosa (Nees) Bremek.	Karvy	Acanthaceae	Both	193.1	34.9	5.6	5.0	34.5	7.0	62.9	8.9
Euphorbia nivulia Buch-Ham.	Leafy milk hedge	Euphorbiaceae	VNP	27.6	NA	2.7	NA	10.3	NA	9.0	NA
Helicteres isora L.	East Indian screw	Sterculiaceae	Both	3.4	176.7	1.0	12.7	3.4	14.0	1.1	45.2
Jatropha curcas L.	Physic Nut	Euphorbiaceae	Both	3.4	4.7	1.0	2.0	3.4	2.3	1.1	1.2
Ziziphus nummularia (Burm.f.) W.&A.	Jhar beri	Rhamnaceae	Both	3.4	9.3	1.0	4.0	3.4	2.3	1.1	2.4
Ziziphus xylopyrus (Retz.) Willd.	Jujab	Rhamnaceae	Both	6.9	16.3	1.0	2.3	6.9	7.0	2.2	4.2
Holarrhena antidysenterica (Heyne ex Roth) Wall	Tellycherry bark	Fabaceae	RS	NA	95.3	NA	8.2	NA	11.6	NA	24.4
Lantana camara L.	Lantana	Verbenaceae	RS	NA	41.9	NA	3.0	NA	14.0	NA	10.7

NA- Not Available, **ind**-Individuals

Table 3. Comparative tree and shrub species richness and evenness in two PAs

Habit	Simpson index		Shannon-Weiner index		Species richness		Species evenness	
	VNP	RS	VNP	RS	VNP	RS	VNP	RS
Tree	0.09	0.11	2.90	2.67	2.08	1.23	0.79	0.72
Shrub	0.44	0.28	1.15	1.53	0.84	0.61	0.59	0.73

CONCLUSION

Considerable variation in qualitative floristic diversity in both Protected Areas (PAs) i.e. RS and VNP of Gujarat state was observed. The quantitative assessment of VNP and RS showed that the *Tectona grandis* L.f.. has maximum density, abundance, frequency and floristic composition but maximum frequency was found of *Terminalia crenulata* Roth. The Simpson diversity index and Shannon-Weiner index revealed that the VNP has more diversity of trees than RS while RS has more diversity of shrub than VNP. The shrub species need to improved their richness and evenness in VNP for sustainable management of the VNP forest area. The change in quantitative attributes of few tree and shrub species between both Protected Areas may be due to various ecological or environmental adaptability of species.

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REFERENCES

Anonymous 2017. *http://www.countrysideinfo.co.uk/simpsons.htm.* Retrieved from http://www. countrysideinfo.co.uk.

Arya V, Kumar B and Rawat JS 2017. Tree species diversity, community composition and distribuition across six forest statnd of Uttarakhand, Central Himalaya India. *Indian Journal of Ecology* **44**(4): 722-728.

Bora A and Bhattacharya D 2017. Phytodiversity of barail wildlife sanctuary, Assam, India: Field based observation- I. Tree and Lianas. *Check list* **13**(6): 1037-1053.

GFD 2016. *https://forests.gujarat.gov.in/forest-area-information.htm#table2*. Retrieved from https://forests.gujarat.gov.in.

Mostert T 2014. *Vegetation and Woodland Deliniation of Prority Habitats in Transnet Capital Projects Rechards Bay Port Expantion Project.* Cruz Environmental, Durban, p 107.

Nabi S, Quaisar KN, Rather SA, Khan PA and Nabi B 2016 . Plant diversity in horti-agricultural system of District Budgam, Kashmir valley: Seasonal varriation in structure, compostion and vegetation indices. *The Ecoscan* **10**(4): 543-551.

Panda PC, Mahapatra AK, Acharya PK and Debata AK 2013. Plant diversity in tropical decidous forest of estern ghats, India: A landscape level assesmemnt. *International Journal of Biodiversity and Conservation* **5**(10): 625-639.

Tadvi DS 2013. *Floristic Diversity of Dangs Gujarat.* Ph.D. Disserataion, Department of Botany, The Maharaja Sayajirao University, Vadodara, India.

Yadav RS, Suthar A and Kamboj RD 2018. Comparative study of wooded angispermic diversity of the two protected areas (Purna Wildlife Sanctuary and Jessor Wildlife Sanctuary) in two biogegraphic region of Gujarat, India. *Indian Forester* **144**(7): 639-645.

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Composition and Diversity of Riparian Forest in Region of Tlemcen (Western Algeria)

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Abstract: The objective of this study is to highlight the great diversity of these ecosystems and to evaluate their specific richness. For this purpose, an inventory of the vegetation was carried out, including 110 riparian species, belonging to 90 genera and 44 families, with an identification of the biological and morphological types in order to determine the structure of the different ecological spectra. Initial findings reveal that floristic diversity varies systematically with environmental factors such as exposure and altitude.

Keywords: Riparian forests, Species richness, Diversity, Index, Tlemcen (Algeria)

Demographic pressure, anthropogenic actions and climatic hazards have a considerable influence on ecosystems. Biodiversity decreases with increasing deforestation and bare soil (Maranz 2009). Riaparian forests are highly complex, diverse and productive ecosystems although they survive as fragments (Natta 2003, Ceperley et al 2010, Naiman et al 2010). These forests are ecological zones that improve biodiversity in the ecosystem and protect the quality of water. In the Mediterranean region, these hydro systems are no longer considered as homeostatic systems showing equilibrium conditions, but rather as highly dynamic and open ecosystems (Ward et al 2002), because they are traversed by flows of a stochastic nature. The objective of this study is to determine the variation in the diversity, composition and the specific richness of these ecosystems, in two stations, bordering the Wadi Tafna in the region of Tlemcen.

MATERIAL AND METHODS

The study was carried out in the Tafna watershed, in the region of Tlemcen, located in the north-west of the Algerian territory. The selected stations are located, one at the upstream of Béni-Bahdal dam, on the south of Tlemcen, and the other at the mouth of Rechgoun beach, in the north (Fig. 1).

The annual rainfall varies between 326 mm at Béni-Bahdal dam and 371 mm at Rechgoun. The annual temperatures vary between 16.7°C at Béni-Bahdal and 18°C at Rechgoun. For the new periods from POWER Data Access site, the annual rainfall is 355.9 mm at Béni-Bahdal dam and 570.4 at Rechgoun. The annual temperatures vary between 16°C at Béni-Bahdal and 15.6°C at Rechgoun. This type of climate influences both the vegetation cover and the anthropozoogenic action (fires, overgrazing and extensive agriculture). Sampling of the flora was done during their flowering period (March and October 2017). In each of the two selected stations, several floristic surveys were carried out and for the survey area, the method of Braun-Blanquet was used. This inventory is based on a stratified sampling, show the maximum of ecological situations. The flora collected has been identified in the laboratory, and a determination of biological and morphological types.to measure and compare the diversity of flora, used index of diversity. Shannon's diversity index (H), Piélou's equitability (E_H) (Dajoz 2003, Frontier et al 2008), Simpson's reciprocal index (I_s), Simpson's equitability (E_S) and Margalef index (D). Equitability (E_H) results from the ration of the Shannon's diversity index (H) or actual diversity and the maximum theoretical value (Hmax).

Shannon diversity index:

$$H = -\sum_{i=1}^{s} pi\ In\ Pi$$

With s = the total number of species in the stand, pi = the relative abundance of a given species. The ratio pi = ni/N expresses the probability of encountering species i in the total effective population N where ni = number of individuals of the given species, N = total number of individuals. This index varies from 0 (one species very largely dominating all the others) to ln S (when all species have the same abundance).

Equitability (E_H): This corresponds to relative diversity and is defined by the following formula:

E = H / H max = H / In s

Equitability (EH) varies from 0 to 1: It tends to 0, means dominance of one of the species. It is equal to 1, an

equidistribution of individuals in species.

Simpson reciprocal index:

$$I_s = 1 / \sum_{i=1}^{s} Pi^2$$

It is between 1 and the maximum:1 = (to indicate the minimum of diversity),The maximum = indicate the maximum diversity.

Simpson's equitability:

$E_s = I_s - 1 / S - 1$

Varies from 0 to 1:O = the different abundances of individuals between species are strong, 1 = the different abundances of individuals between species are same.

Margalef diversity index:

$D = S - 1 / \ln N$

Varies from 0 = all individuals belong to the same species, D maximum = each individual belong to a different species.The degree of floristic affinity between ecosystems was estimated using Sorensen's similarity coefficient (1948):

$CS = 2j / 2j + a + b$

Where a = number of species from station 1, b = number of species from station 2 and j = number of species common to both stations. This coefficient varies between 0 and 1, when the value is close to 1, it indicates a greater similarity and therefore a low diversity (Magurran, 2004).

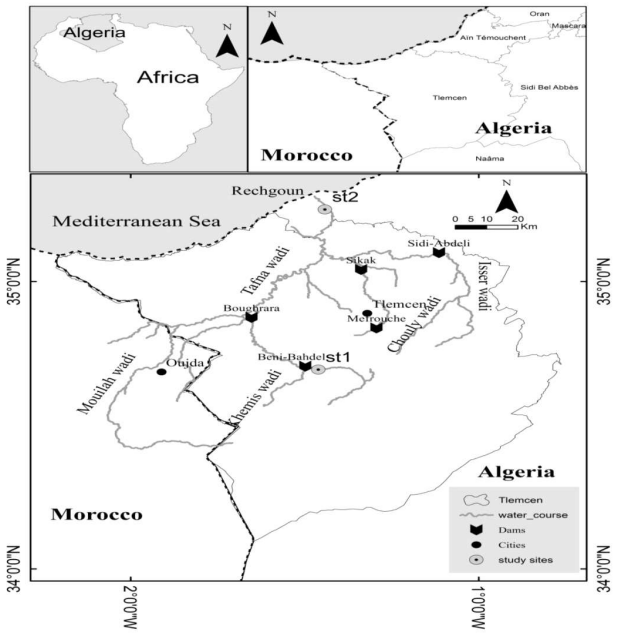

Fig. 1. Location map

RESULTS AND DISCUSSION

The study area has more than 110 species in 90 genera and 44 families. The 67 species were recorded in the Béni-Bahdal dam station, represented by 60 genera and 28 families and 61 species in the Rechgoun station, represented in 49 genera and 33 families (Table 2). The greatest specific wealth was in the southern resort of Tlemcen, the Rechgoun station (north of Tlemcen) is less rich. The most commonly encountered species are *Nerium oleander* L., *Anacyclus valentinus* L., *Erigeron sumatrensis* Retz., *Dittrichia viscosa* (L.) Greuter, *Calendula arvensis* (Vaill.) L., *Xanthium strumarium* L., *Cynodon dactylon* L., *Cyperus longus*L., *Juncus acutus*L., *Malva parviflora* L. and *Tamarix Africana* Poir. The latter species are present at both stations with a fairly high abundance. The most dominant families are Asteraceae, Poaceae, and Amaranthaceae (Fig. 2 and Fig. 3).

The biological type of the flora in the first station was predominantly dominated by the Therophytes and Hemicryptophytes with 52 and 24%, which means the annual herbaceous plants (AH) and the perennial herbs (PH) with regard to the morphological type (52 and 34%).Geophytes are at the third place with 10%. Then come the perennial woody trees (WP) with 14%, including Chamaephytes (9%) and Phanerophytes (5%) (Fig. 4). The vegetation of the Béni-Bahdal station is heterogeneous: Th>He> Ge>Ch>Ph.

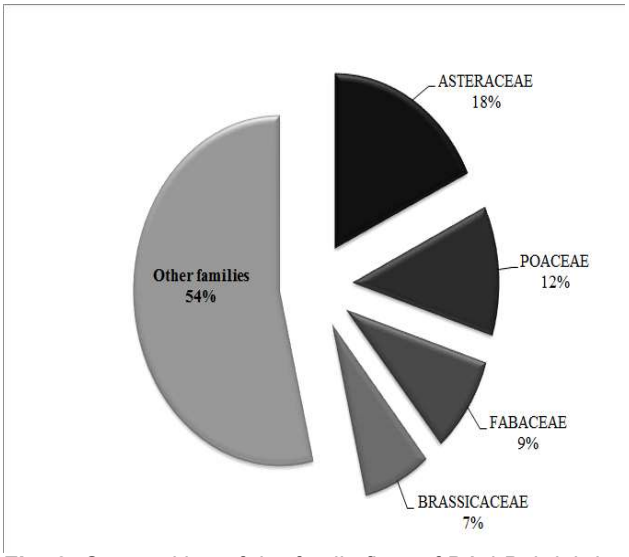

Fig. 2. Composition of the family flora of Béni-Bahdal dam station

Table 1. Stationary features

Study sites	Latitude (N)	Longitude (O)	Altitude (m)	Slope (%)	Recovery (%)
St1 : Upstream of Béni-Bahdal dam	34°41'	1°27'	675	20	15
St2 : Rechgoun	35°17'	1°28'	10	5	20

Table 2. Taxa list

Taxa list of station 1 (upstream of Béni-Bahdal dam)				Taxa list of station 2 (Rechgoun)			
Families	Taxa	Bt	Mt	Families	Taxa	Bt	Mt
Amaranthaceae	*Beta vulgaris* L.	Ge	PH	Amaranthaceae	*Amaranthus albus* L.	Th	AH
Apiaceae	*Thapsia garganica* L.	He	PH		*Atriplex tornabenei* Tineo	Th	AH
	Apium graveolens L.	He	PH		*Atriplex chenopodioides* Batt.	Th	AH
Apocynaceae	*Nerium oleander* L.	Ch	WP		*Atriplex halimus* L.	Ch	WP
Arecaceae	*Chamaerops humilis* L.	Ch	WP		*Atriplex prostrata* DC.	Th	AH
Boraginaceae	*Cynoglossum creticum* Mill.	He	PH		*Chenopodium murale* L.	Th	AH
	Cynoglossum cheirifolium L.	Th	AH		*Beta vulgaris* L.	Ge	PH
Brassicaceae	*Rorippa nasturtium-aquaticum* (L.) Hayek	Th	AH		*Chenopodium album* L.	Th	AH
	Alyssum simplex Rudolphi	Th	AH		*Arthrocnemum macrostachym* (Moric.) K.Koch	Ch	WP
	Matthiola maroccana Coss.	Th	AH		*Salsola kali* L.	Th	AH
	Sinapis arvensis L.	Th	AH	Anacardiaceae	*Schinus molle* L.	Ph	WP
	Capsella bursa-pastoris (L.) Medik	Th	AH	Apiaceae	*Eryngium maritimum* L.	He	PH
Caryophylaceae	*Paronychia argentea* Lam.	Th	AH		*Smyrnium olusatrum* L.	Th	PH
	Stellaria media(L.) Vill.	Th	AH		*Pseudorlaya pumila* (L.) Grande	Th	AH
Cistaceae	*Helianthemum syriacum* (Jacq.) Dum.Cours.	Ch	WP	Apocynaceae	*Nerium oleander* L.	Ph	WP
Asteraceae	*Anacyclus valentinus* L.	He	PH	Boraginaceae	*Cynoglossum creticum* Mill.	He	PH
	Bellis annua L.	Th	AH		*Echium sabulicolm* Pomel	Th	PH
	Calendula arvensis (Vaill.) L.	Th	AH		*Echium vulgare* L.	He	PH
	Centaurea calcitrapa L.	He	AH	Brassicaceae	*Sinapis alba* L.	Th	AH
	Cladanthus arabicus (L.) Coss.	Th	AH		*Raphanus rhaphanistrum* L.	Th	AH
	Erigeron sumatrensis Retz.	Th	AH		*Cakile maritima* Scop.	Th	AH
	Filago pyramidata L.	Th	AH		*Lepidium didymum* L.	Th	PH
	Dittrichia viscosa (L.) Greuter	He	PH	Caryophylaceae	*Stellaria media* (L.) Vill.	Th	AH
	Onopordum macracanthum Schousb.	He	PH	Asteraceae	*Dittrichia viscosa* (L.) Greuter	He	PH
	Scolymus hispanicus L.	He	PH		*Limbarda crithmoides* (L.) Dumort	He	PH
	Senecio lividus L.	Th	AH		*Anacyclus valentinus* L.	He	PH
	Xanthium strumarium L.	Th	AH		*Senecio leucanthemifolius* Poir.	Th	AH
Crassulaceae	*Sedum nevadense*Coss.	Th	AH		*Heteranthemis viscidehirta* Schott	Th	AH
Cyperaceae	*Cyperus fuscus*L.	Th	AH		*Glebionis coronaria* (L.) Spach	Th	AH
	*Cyperus longus*L.	Ge	PH		*Calendula arvensis* (Vaill.) L.	Th	AH
Fabaceae	*Calicotome intermedia* C. Presl	Ch	WP		*Erigeron sumatrensis* Retz.	Th	AH
	Lotus glinoides Delile	Th	AH		*Xanthium spinosum* L.	Th	AH
	Medicago minima (L.) L.	Th	AH		*Xanthium strumarium* L.	Th	AH
	Melilotus macrocarpus Coss. Et Durieu	Th	AH		*Sonchus maritimus* L.	Th	AH
	Ononis biflora Desf.	Th	AH		*Sonchus asper* (L.) Hill	Th	AH
	Trifolium tomentosum L.	Th	AH		*Centaurea pullata* L.	Th	AH

Cont...

Continues Table 2

Taxa list of station 1 (upstream of Béni-Bahdal dam)				Taxa list of station 2 (Rechgoun)			
Families	Taxa	Bt	Mt	Families	Taxa	Bt	Mt
Geraniaceae	*Geranium molle* L.	He	PH		*Silybum marianum* (L.) Gaertn.	Th	PH
	Erodium moschatum (L.) L'Hér.	He	PH		*Scolymus hispanicus* L.	He	PH
Juncaceae	*Juncus acutus* L.	Ge	PH		*Reichardia tingitana* (L.) Roth	Th	PH
	Juncus maritimus Lam.	Ge	PH	Convolvulaceae	*Convolvulus humilis* Jacq.	Th	AH
Lamiaceae	*Ballota hirsuta* Benth.	He	PH	Euphorbiaceae	*Ricinus communis* L.	Ph	WP
	Mentha suaveolens Ehrh.	He	PH	Fabaceae	*Ononis natrix* L.	Ch	WP
	Lamium amplexicaule L.	Th	AH		*Ulex parviflorus* Pourr.	Ch	WP
Linaceae	*Linum strictum* L.	Ch	WP	Juncaceae	*Juncus acutus* L.	Ge	PH
Malvaceae	*Malva parviflora* L.	Th	AH	Lamiaceae	*Ballota hirsuta* Benth.	He	PH
	Malva sylvestris L.	Th	AH	Malvaceae	*Malva parviflora* L.	Th	AH
Oleaceae	*Olea europea* L.	Pe	WP		*Malva sylvestris* L.	Th	AH
Plantaginaceae	*Plantago lagopus* L.	He	PH	Plantaginaceae	*Plantago lagopus* L.	He	PH
	Plantago major L.	He	PH		*Plantago serraria* L.	He	PH
Poaceae	*Trachynia distachya* (L.)	Th	AH	Poaceae	*Cynodon dactylon* (L.) Pers.	Ge	PH
	Brachypodium sylvaticum (Huds.) P. Beauv.	Ge	PH		*Anisantha madritensis* (L.) Nevski	Th	AH
	Anisantha rubens (L.) Nevski	Th	AH		*Hordeum murinum* L.	Th	AH
	Schedonorus arundinaceus(Schreb.)	Ge	PH		*Hordeum vulgare* L.	Th	AH
	Cynodon dactylon (L.) Pers.	Ge	PH		*Phramites australis* (Cav.) Steud.	Ge	PH
	Echinaria capitata (L.) Desf.	Th	AH	Polygonaceae	*Rumex pulcher* L.	He	PH
	Gastridium scabrum C. Presl	Th	AH		*Polygonum maritimum* L.	Ch	WP
	Piptatherum miliaceum (L.) Coss.	Ch	WP	Solanaceae	*Nicotiana glauca* Graham	Ph	WP
Polygonaceae	*Fallopia convolvulus* (L.) A.	Th	AH		*Datura stramonium* L.	Th	PH
	Polygonum equisetiforme Sibth. &Sm.	Th	AH		*Solanum nigrum* L.	Th	AH
	Persicaria desipiens (R. Br.) K. L. Wilson	Th	AH	Tamaricaceae	*Tamarix africana* Poir.	Ph	WP
Primulaceae	*Lysimachia arvensis* (L.) U. Manns & Anderb.	Th	AH	Urticaceae	*Urtica pilulifera* L.	Th	AH
Resedaceae	*Reseda alba* L.	Th	AH				
Salicaceae	*Populus alba* L.	Ph	WP				
Scrofulariaceae	*Verbascum sinuatum* L.	He	PH				
Solanaceae	*Solanum nigrum* L.	Th	AH				
Tamaricaceae	*Tamarix africana* Poir.	Ph	WP				
Valerianaceae	*Valeriana tuberosa* L.	He	PH				

Biological types (Bt)
Th : Therophyte, He : Hemicryptophyte,Ge : Geophyte,Ch : Chamaephyte,Ph : Phanerophyte
Morphological types (Mt)
AH : Annual herbaceous,PH : Perennial herbs,WP : Perennial woody

Table 3. The different calculated diversity index

Study site	D	H	E_H	I_s	E_s	C_s
St1 : upstream of Béni-Bahdal dam S = 28 et N = 67	6.43	4.28	0.88	13.52	0.46	0,2
St2 : Rechgoun S = 21 et N = 61	4.86	3.73	0,85	8.63	0.38	

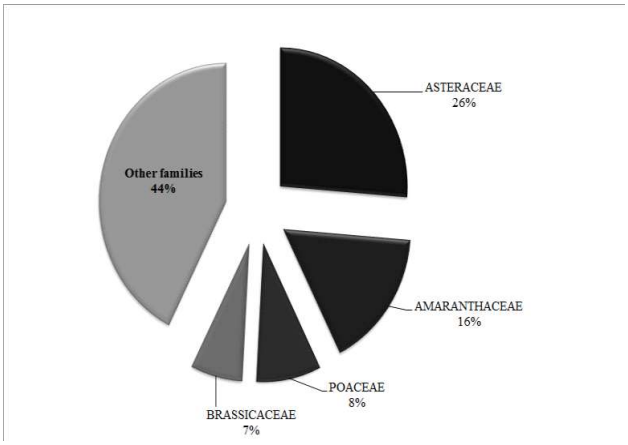

Fig. 3. Composition of the family flora of the Rechgoun station

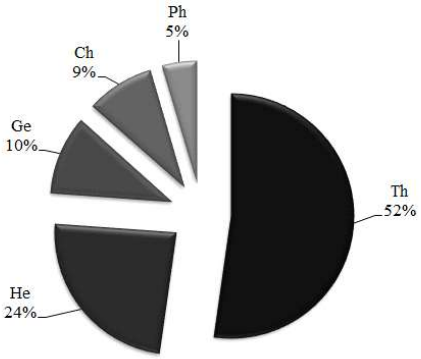

Fig. 4. Biological types of the Béni-Bahdal dam station

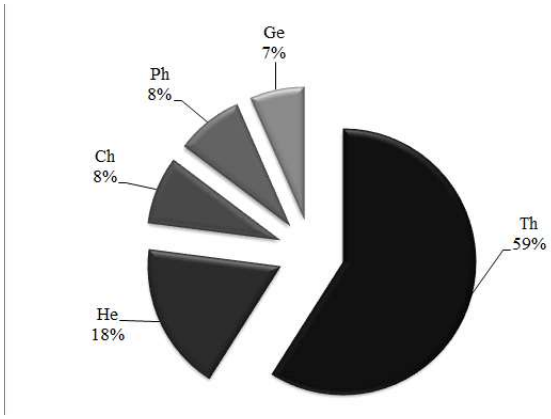

Fig. 5. Biological types of the Rechgoun station

In the second station, concerning the biological type the flora was dominated by the Therophytes and Hemicryptophytes with 59 and 18%, followed by Chamaephytes and Phanerophytes (8%) indicating that Geophytes come last with 7% (Fig. 5). The morphological type is dominated by the annual herbaceous plants (AH) in the first with 49% then the perennial herbs (PH) with 35% and 16% for the perennial woody trees (WP). The vegetation of Rechgoun station is: TH > HEMI > CH >PH >GEO. The vegetation of both stations is : AH>PH > WP.

The integral specific diversity can be related to the intensity of the floods, the variations of the topography, the variations of the climate and the disturbance regimes by the environment of the highlands (Suzuki et al 2002, Naiman et al 2008). Environmental heterogeneity and resource diversity have a major effect on species richness (Koponen et al 2004), a mosaic of habitats is created by these forces, allowing species to coexist. The diversity index, Margalef index, Shannon diversity index, Simpson reciprocal index, Piélou and Simpson equitabilities vary significantly between the two stations. The number of species (N) and the number of families (S) are different. This as S decreases, the calculated index decrease. ß-diversity is represented by Sorensen's resemblance coefficient (Cs) was also calculated, it reveals a weak similarity between the stations (Table 3).

CONCLUSION

Calculated index of diversity allowed to conclude that sites are rich and diversified, especially that of Béni-Bahdal, due to certain ecological parameters. Almost the majority of species have the same abundance, with an almost equal distribution of species. The resemblance coefficient confirms the reability of the results by indicating a negligible resemblance, which means a great diversity between the stations. Species richness, taxonomic composition and its diversity with stand structure are generally influenced by geographic position, anthropogenic disturbances, climatic variations and water regime of streams.

REFERENCES

Ceperley N, Montagnini F and Natta A 2010. Importance of sacred sites for the conservation of gallery forests in central Benin. *Tropical Timber and Forests* **303** (1): 5-23.

Koponen P Nygren P Sabatier D Rousteau A and Saur E 2004. Tree species diversity and forest structure in relation to microtopography in a tropical freshwater forest swamp forest in French Quiana. *Plant Ecology* **173**: 17-32.

Magurran AE 2004. *Measuring biological diversity*. Oxford and Victoria: Blackwell Publishing, Malden, p. 256.

Maranz S 2009. Tree mortality in the African Sahel indicated an anthropogenic ecosystem displaced by climate change. *Journal of Biography* **36**: 1181-1193.

Naiman RJ Latterell JJ Pettit NE and Olden JD 2008. Flow variability and the biophysical vitality of river systems. *R. Geoscience* **340**: 629-643.

Natta AK 2003. *Ecological assessment of riparian forests in Benin*: Phytodiversity, Netherlands, p. 230.

Suzuki W Osumi K Masaki T Takahachi K Daimaru H and Hoshizaki K 2002. Kanimazawa riparian research forest, Northern Japan, Kanimazawa riparian forest. *Forest Ecology and Management* **157**: 285-301.

Stolnack SA and Naiman RJ 2010. Patern of conifer establishment and vigor on montane river floodplains on Olympic National Park Washington, USA. *Canadian Journal of Research* **40**: 410-422.

Ward JV Tockner K Arscott DB and Claret C 2010. Riverine landscape diversity. *Freshwater Biology* **47**: 517-539

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Growth, Proximate Composition and Condition Coefficient of *Labeo rohita* Fingerlings Reared in Insitu and Exsitu Biofloc System

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Abstract: The present study is a preliminary work on the comparison of insitu and exsitu biofloc technology in the culture of fingerlings of *Labeo rohita*. The investigation was done to study the growth pattern, proximate composition and condition factor of fingerlings of *L. rohita* cultured in insitu and exsitu biofloc systems. During the study period of 90 days, three diets used were: artificial feed (control), insitu bioflocs (Treatment 1) and exsitu bioflocs (Treatment 2). Results revealed that net length gain and net weight gain was maximum in Treatment 1 followed by Treatment 2 and control. Proximate composition and condition factor were calculated at the start and end of culture period. An increase in protein and lipid content with a decrease in moisture and ash content was observed in all the treatment units whereas the muscle protein and lipid content of fishes was maximum in Treatment 1. The condition factor was above 1 in all the experimental units which indicated that fishes were in good condition during the experiment.

Keywords: Growth pattern, Condition factor, *Labeo rohita*, Fingerlings

Bioflocs are a kind of fast growing microbial mixed culture in which the waste nitrogen is recycled to young cells and application of biofloc technology (BFT) facilitates the effective utilisation of microbial food web by cultured organisms. Implementation of biofloc technology in the culture of *Labeo rohita* offers several advantages including better growth and improved water quality. Two biofloc technology systems are considered for fish and shrimp culture. The first is in-situ biofloc system, wherein bioflocs are grown along with culture species and second is ex-situ biofloc system, in which the waste water from aquaculture pond is used for the culture of bioflocs and these are then used as a feed ingredient. Biofloc is a consortium of microorganisms, micro/macro invertebrates, filamentous organisms, extracellular polymers, and uneaten feed. This nutritious mixture has often proven to be beneficial in fish culture. In-situ biofloc system is more popular among farmers as in this culture system ammonia is assimilated directly into microbial proteins, thereby preventing the accumulation of inorganic nitrogen species i.e. ammonia, nitrate and nitrite. Moreover, insitu bioflocs provide nutrition directly to the culture species and is available all the time. Feeding is a vital factor that affect the nutritional quality of fish in an intensive culture system. The nutritional value of fish obviously depends on their biochemical composition (Prado et al 2009). Nutritional quality of fish is however, not uniform and varies a lot among different fish species even within species when cultured under environments and different culture systems (Iqbal et al 2014). Proximate body composition is thus analysed for moisture, crude fat, crude protein, ash and carbohydrate contents of fish. Percentage of moisture content in fish muscles is good indicator of its relative contents of energy, crude proteins and fat. Lower the percentage of moisture, greater the crude fat and protein contents and higher the energy density of the fish meat (Dempson et al 2004).

Feeding the fish using different diets affect the growth of fishes in different ways. Different fishes grow with different rates depending upon their genetic makeup, food resources available and the environment conditions in which they live and grow (Khajuria et al 2014). The condition factor is an indicator of the health of an organism. Variations in a fish's coefficient of condition primarily reflect state of sexual maturity and degree of nourishment (William 2000). Therefore condition factor can be used to determine whether it is making good use of its feeding source (Lizama and Ambrosia 2002, Gomiero et al 2008). Keeping in view all the above mentioned concerns the present study is planned to find out the effect of insitu and exsitu bioflocs on growth, proximate composition and condition of *Labeo rohita*.

MATERIAL AND METHODS

The study was conducted at University of Jammu. Fingerlings of *Labeo rohita* were brought from the Gho-Manhasan fish farm and acclimatized for one week under laboratory conditions. These were then stocked in three troughs of 70l capacity each with one replica at a density of 20 fingerlings per trough. Culture was maintained for a period of 90 days with zero water exchange.

Experimental diets: The three dietary treatments tested were: Control: containing only artificial diet with 30% protein, T1 comprised of insitu bioflocs and T 2 with exsitu bioflocs.

Water quality analysis: To analyze variations in physiochemical parameters of water during the experiment, weekly analysis of pH using digital pH meter, water temperature, dissolved oxygen (DO) following Winkler method (APHA 1985) was done. Ammonia, nitrate and nitrite were analysed spectrophotometrically (APHA 1985).

Growth parameters: The length and weight of fingerlings was recorded fortnightly and various yield parameters were calculated:

Weight gain (WG) = Final weight (W_F) - Initial weight (W_I)

Length gain (LG) = Final length (mm) - Initial length (mm)

Mean weight gain (MWG) = Final weight (W_F) - Initial weight (W_I)/100

Percent weight gain = Final weight (W_F)- Initial weight (W_I)/Initial weight (W_I) x 100 pecific growth rate (SGR) (% body weight/ day) = 100 × ln (Final weight - Initial weight)/culture period (days)

Survival rate (SR) = N_t x 100 ÷ N_0. (N_0, initial number of fish in each replicate and N_t, final number of fish in each replicate).

Proximate analysis: The experimental animals were analysed for protein (Lowry et al 1951), lipid (Folch et al 1957), moisture and ash (AOAC 1999).

Condition factor: The wet body weight (after blot-drying excess water on body) and total length (from the tip of snout to distal end of the caudal fin ray) of each fish was recorded. The condition factor (k) was established (Le Cren 1951).

$K = 100\ W/L^3$

Where W = weight of fish, L = total length

100 = factor to bring the value near to unity.

RESULTS AND DISCUSSION

Water quality analysis: Average water temperature was 20.6^{0}C, 20.8^{0}C and 21.0^{0}C in control, T1 and T $_2$ respectively (Table 1). Temperature in all the experimental units remained within the biokinetics range (optimal range) of the fish 18.3^{0}C and 37.8^{0}C (Jhingran 1978). pH ranged between 7.4 and 7.8 and was in the optimum range for the growth of fish and also for growth of insitu biofloc in T1. Mahanand et al (2013) observed desirable limit for optimum biofloc is 6.94 to 8.65 but after the addition of molasses for insitu biofloc growth in T 1, pH declined upto 5.8 and it was maintained above 7 by the addition of sodium bicarbonate. Azim et al (2008) reported that biofloc system lose buffering capacity and therefore require frequent addition of $NaHCO_3$. The dissolved oxygen (DO) did not vary among treatments (5.4-5.6 mg/l). Water quality parameters must be within the recommended range and play an important role in the culture of Indian major carps (Ojha et al 2019).

Average ammonia level was 0.69, 0.56 and 0.60 mg/l, nitrate level was 0.41, 0.19 and 0.25 mg/l and nitrite level was 0.078, 0.035 , 0.050 mg/l in control, T I and T 2 ,respectively. The inorganic nitrogen i.e. ammonia, nitrate and nitrite level was higher in control. This may be due the accumulation of uneaten feed and excretal waste and the conversion of excess ammonia into nitrate and nitrite. Insitu biofloc culture system showed least ammonia, nitrate and nitrite level because of the conversion of ammonia into bacterial protein by heterotrophic bacteria and thereby become unavailable for nitrification process. Exsitu biofloc system showed slightly higher concentration of inorganic nitrogen species than insitu culture system. This may be attributed to the external addition of biofloc suspension that converts some of the ammonia into bacterial biomass.

Fish growth analysis: The net weight gain was 3.69 , 4.8 and 4.05 g and net length gain was 2.12 , 3.5 and 2.45 cm in control, T 1 and T 2 , respectively (Table 2, Fig. 1 and 2). Gain in length was significantly higher in T 2 followed by T 1 and control whereas there was non-significant relationship in gain in weight. The growth parameters differed between control and biofloc treatments. Mean weight gain was significantly higher in T 1 than T 2 and control. Percent weight gain and specific growth rate were not significantly different between control and biofloc treatments. However, survival was 100% in control as well as both the biofloc treatments.

Table 1. Water quality parameters recorded during the culture period (Mean±SD)

Parameters/ Treatment	Control	T 1	T 2
Temperature (^{0}C)	20.6±0.098	20.8±0.023	21.0±0.061
pH	7.8±0.037	7.4±0.052	7.5±0.021
DO (mg l^{-1})	5.6±0.158	5.4±0.130	5.4±0.085
Ammonia (mg l^{-1})	0.69±0.008	0.56±0.012	0.60±.0.098
Nitrates (mg l^{-1})	0.41±0.093	0.19±0.100	0.25±0.088
Nitrites (mg l^{-1})	0.078 ±0.056	0.035±0.002	0.050±0.013

Table 2. Growth parameters during the culture period (Mean±SD)

Parameters	Control	T 1	T 2
Net Gain in weight (g)	3.69±0.251	4.8±0.706	4.05±0.110
Net Gain in length (cm)	2.13±0.152	3.5±0.270	2.45±0.126
Mean weight gain (g $fish^{-1}$)	0.037±0.001	0.048±0.007	0.040±0.001
Percent weight gain (% of initial)	96.85±3.185	133.70±30.691	104.92±3.24
Specific growth rate (SGR)	4.1±0.310	5.33±0.787	4.5±0.121
Survival (%)	100	100	100

This indicated that insitu biofloc system is an efficient culture system for the growth of fishes. The possible reasons may be: the continuous recycling of inorganic nitrogenous waste into bacterial biomass that otherwise affect the growth of fishes, continuous availability of a source of protein in the form of bacteria and associated planktonic organisms that remain suspended in the water column and fingerlings were fed upto proper satiation (Silva et al 2013). Azim and Little (2008) also recorded improved growth of Nile tilapia in biofloc system as compared to control. Xu et al (2012) observed that biofloc is a source of abundant natural microbes and bioactive compounds that could exert a positive effect on the physiological health and improved the digestibility of cultured shrimp. In exsitu biofloc system fishes were fed twice with biofloc suspension cultured in separate unit. These flocs settled after some time and remained unavailable to the fingerlings and also lead to the formation of ammonia pockets and the feed is not all the time available.

Proximate composition of fish muscle: The protein content of fingerlings was higher in Treatment 1 (13.95%) followed by treatment 2 (12.10%) and control (11.32%) and the lipid content was also higher in T1 (1.32%) than in control (1.18%) and Tt 2 (1.10%). Muscle moisture content was higher in control (72.10%) as compared to T 1 (69.12%) and T 2 (67.98%). Similarly ash content was higher in control (2.35%) followed by T 2 (2.05%) and T1 (1.89%). Maximum weight attained by fingerlings in Treatment 1 support the maximum value of protein and lipid. Breck (2014) reported that protein and lipids are known to increase with increase in fish size Sutton et al (2000) postulated that when the weight of fish increases, the amount of nutrients (protein, lipid and carbohydrates) in the fish body also increases.

Moisture and ash content in the fish muscle decreased over the period of 90 days in all the experimental units. Correlation of different body components (moisture, protein, lipid and ash) in *Labeo rohita* fingerlings revealed that moisture showed a negative correlation with protein and lipid and positive correlation with ash. Similar results were recorded by Iverson et al (2002), Bakhtiyar et al (2011). Daramola et al (2007) also corroborated the present results that small size fish species show higher ash content due to higher bone to flesh ratio.

Condition factor: Condition factor calculated at the 1st day of culture period was maximum in control (2.3) followed by T 1 (2.2) and minimum condition factor was recorded in T 2 (1.8) whereas at 90th day of experimental period, it was 1.7, 1.2 and 1.3 in control, T 1 and T 2 respectively. The condition factor showed a decrease with increase in length and weight. Naeem and Salam (2004) also reported that the condition factor may vary with increasing length when average weight of fish does not increase in direct proportion to the cube of its length. If the weight increase more rapidly than cube of length, the K would increase with increase in length. When weight increases less than the cube of length, K would tend to decrease with the growth of the fish (Naeem et al 2000). The condition factor of fingerlings was above 1 indicated their good growth and absence of any stress factor. Crab et al (2009) while working on tilapia in extreme winters observed a uniform condition factor of 2.2 which indicate that that the fish were in good condition with minimal stress symptoms.

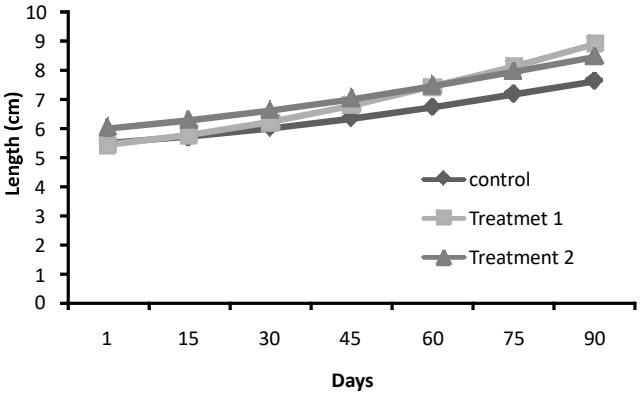

Fig. 1. Fortnightly variation in length of fingerlings of *Labeo rohita*

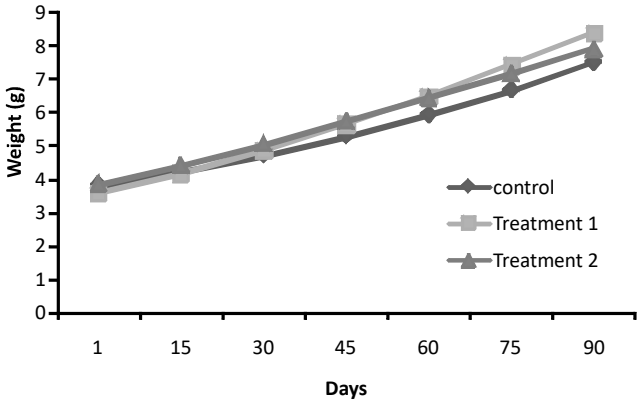

Fig. 2. Fortnightly recorded variation in weight of fingerlings of *Labeo rohita*

Table 3. Proximate composition analysis of fish muscle during start and end of experiment

Composition (%)	Control		T 1		T 2	
	1st	90th	1st	90th	1st	90th
Moisture	76.10	72.10	79.12	69.12	72.10	67.98
Protein	8.76	11.32	8.13	13.95	8.90	12.10
Lipid	1.07	1.18	0.98	1.32	1.00	1.10
Ash	2.47	2.35	2.05	1.89	2.13	2.05

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REFERENCES

AOAC 1999. *Official methods of the Association of Official Analytical Chemists*. p 1298.

APHA 1985. *Standard Methods for the Examination of Water and Waste Water,* 16th Edition, American Public Health Association. American Water Works Association and Water Pollution Control federation, Washington DC. p 1134.

Azim ME, Little DC and Bron JE 2008. Microbial protein production in activated suspension tanks manipulating C: N ratio in feed and the implications for fish culture. *Bioresource Technology* **99:** 3590-3599.

Azim ME and Little DC 2008. The biofloc technology (BFT) in indoor tanks: Water quality, biofloc composition, and growth and welfare of Nile tilapia (*Oreochromis niloticus*). *Aquaculture* **283:** 29-35.

Bakhtiyar Y, Langer S, Karlopia SK and Ahmed I 2011. Growth, survival and proximate body composition of Labeo rohita larvae fed artificial food and natural food organisms under laboratory condition. *International Journal of Fisheries and Aquaculture* **3** (6): 114-117.

Breck JE 2014. Body composition in fishes: Body size matters. *Aquaculture* **433**: 4049.

Crab R, Kochva M, Verstraete W and Avnimelech Y 2009. Bio-flocs technology application in over-wintering of tilapia. *Aquaculture Engineering* **40:** 105-112.

Daramola JA, Fasakin EO and Adeparusi EO 2007. Changes in physicochemical and sensory characteristics of smoke- dried fish species stored at ambient temperature. *African Journal of Food and Agriculture, Nutrition and Development* **7**(6): 169-18.

Dempson IB, Schwarz CJ, Shears M and Furey G 2004. Comparative proximate body composition of Atlantic salmon with emphasis on parr from fluvial and lacustrine habitats. *Journal of Fish Biology* **64:** 1257-1271.

Folch J, Less M and Stanley GHS 1957. A simple method for the isolation and purification of total lipids from animal tissues. *Journal of Biological Chemistry* **226**: 497-509.

Gomiero LM and Braga FMS 2003. Relação pesocomprimento e fator de condição para Cichla cf. ocellaris e Cichla monoculus (Perciformes, Cichlidae) no reservatório de Volta Grande, rio Grande - MG/SP. *Acta Scientiarum Biological Sci* **25:** 79-86

Iqbal Z, Ijaz N and Chaudhary JA 2014. Effect of ammonia on growth of fingerlings of a freshwater fish, *Cirrhinus mrigala* (H.). *European Journal of Veterinary Medicine* **2**(3): 163-170.

Iverson SJ, Frost KJ and Lang SLC 2002. Fat content and fatty acid composition of forage fish and invertebrates in Prince William Sound, Alaska: Factors contributing to among and within species variability. *Marine Ecology Progress Series* **241:** 161-181.

Jhingran VG 1978. *Fish and Fisheries of India*. Hindustan Publishing Corporation, Delhi, India. I-XV: 1-954.

Khajuria B, Langer S and Sharma R 2014. Length weight relationship and condition factor of Tor putitora from Jhajjar stream. *International Journal of Scientific & Engineering Research* **5**(2): 567-572.

Le Cren ED 1951. The length-weight relationship and seasonal cycle in the gonad weight and condition in the perch (*Perca fluviatilis*). *Journal of Animal Ecology* **20**: 201-219.

Lizama MAP and Ambrósia AM 2002. Condition factor in nine species of fish of the Characidae family in the upper Paraná River floodplain. *Brazilian Journal of Biology* **62:** 113-124.

Lowry OH, Rosenbrough N, Fair AC and Randall RJ 1951. Protein measurement with folin phenol reagent. *Journal of Biological Chemistry* **193**: 265-275.

Mahanand SS, Moulick S and Rao PS 2013. Optimum formulation of feed for rohu, *Labeo rohita* (Hamilton) with biofloc as a component. *Aquaculture International* **21:** 347-360.

Naeem M and Salam A 2004. Morphometric studies on *Oreochromis nilotica* (Male) in relation to body size from Islamabad, Pakistan. *Punjab University Journal of Zoology* **19:** 73-81.

Naeem M, Salam A and Bhatti MN 2000. Morphometric studies of cold water fish rainbow trout *Oncorhynchus mykiss* in relation to body size. *Pakistan Journal of Fish* **1(**1): 55-62.

Ojha ML, Suman AK, Saini VP and Surnar SR 2019. Effect of physico-chemical and biological parameters on Growth of Indian major carps in micro watershed of Southern Rajasthan. *Indian Journal of Ecology* **46**(3): 657-661.

Prado R, Rioboo C, Herrero C and Cid A 2009. The herbicide paraquat induces alterations in the elemental and biochemical composition of nontarget microalgal species. *Chemosphere* **76**: 1440-1444.

Silva KR, Wasielesky W and Abreu P C 2013. Nitrogen and phosphorus dynamics in the biofloc production of the pacific white shrimp, *Litopenaeus vannamei*. *Journal of the World Aquaculture Society* **44**(1): 30-41.

Sutton SG, Bult, TP and Haedrich RL 2000. Relationships among fat weight, body weight, water weight and condition factors in wild Atlantic salmon parr. *Trans American Fish Society* **129:** 527–538.

Williams JE 2000. The coefficient of condition of fish. chapter 13. In. Schneider, JC (ed.) *Manual of Fisheries Survey Methods II*. Michigam Department of Natural resources, Fisheries special report 25.

Xu WJ, Pan LQ, Zhao DH and Huang J 2012. Preliminary investigation into the contribution of biofloc on protein nutrition of *Litopenaeus vannamei* fed with different dietary protein levels in zero-water exchange culture tanks. *Aquaculture* **350**: 147-153.

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Phenological Patterns of Selected Tree Species in Dry Deciduous Forests of Sri Lankamalleswara Wildlife Sanctuary in Southern Eastern Ghats, Andhra Pradesh, India

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Abstract: The study observed the leafing, flowering and fruiting phenological events of twenty seven tree species in the dry deciduous forest of Sri Lankamalleswara wildlife sanctuary. A total of ten individuals (>30cm gbh), for each of the selected twenty seven tree species, were observed at fifteen days interval during 2017-19 to record the leafing, flowering and fruiting phenological patterns. Leaf flushing initiated in March and reached peak in April and got completed before the onset of monsoon. Leaf expansion peak was recorded in June. Leaf fall started in December and reached peak in February before the intense dry period. Flowering peak was observed in April/May and majority of tree species revealed synchronous flowering with leaf flushing. Fruit bud initiation occurred in February and reached peak in June. Majority of tree species featured large fruit maturation period. The results indicate that leafing and flowering events occur during the dry period before the onset of first rains and fruit maturation period is large and fruit fall timing is in consequence to utilize the rains. Thus seasonal rains (soil moisture availability) and extent of deciduous period (photoperiod) influence the leafing and reproductive phenological events in this dry deciduous forest.

Tropical dry forests comprise of tree communities growing in climates with marked pronounced dry and wet periods in an annual period (Singh and Kushwaha 2006). These forests constitute high variations in vegetative and reproductive phenological patterns at both large and small scales (Nanda et al 2014). The seasonal changing events such as availability of soil moisture, stem water status, photoperiod, changes in temperature and irradiance (Singh and Sahoo 2019) and biotic factors like pollinators attraction, competition for seed dispersers and avoidance of herbivory have been proposed to influence the varied phenological patterns in tropical dry forests (Singh and Kushwaha 2005. Thus phenological patterns should be evaluated by both abiotic factors and plant functional traits to achieve an integrative understanding of tree community (Saha 2007). Phenological patterns of plants are the outcome of the evolutionary plant responses to prevailing environmental conditions and the quantitative phenological studies helps in understanding the implications of global climate change factors on plant responses at local level. Few community wide studies on phenology in dry forests were carried out (Singh and Kushwaha 2005, Nanda et al 2014). But only few seasonality based phenological studies in dry deciduous forests of southern Eastern Ghats in Andhra Pradesh were carried out. Hence the study was undertaken with an objective to examine the variations in flowering and fruiting periods in reference to the extent of leafing phenology among the deciduous tree species in a dry deciduous forest.

MATERIAL AND METHODS

Study site: The study site is Sri Lankamallaswera wildlife sanctuary that lies in elevation range from 160-620m. The mean annual rain fall across a ten years period 2009 to 2019 was 688.8 mm. It extends between 14^{0}28'and 14^{0}44'N and 78^{0} 54' to78^{0}59' E in southern Eastern Ghats of Andhra Pradesh. The hill ranges support dry deciduous forest type with a tree assemblage of *Pterocarpus santalinus-Hardwickia binata-Anogeissus latifolia* (Mastan et al 2020). The area experiences tropical monsoon climate with three seasons in a year, namely, summer (April-mid-June), rainy (mid June-September) and winter (November-February). The climate is wet and windy during the monsoon and hot and dry during summer with a temperature range from 28^{0}C-46^{0}C.

A total of 27 tree species were observed for vegetative and reproductive phenological features in Sri Lankamallaswera wildlife sanctuary. The vegetative phenology events such as leaf fall, leaf less period, leaf initiation, leaf mature period were recorded and reproductive phenology events such as flower initiation, fruit bud initiation, fruit maturation periods were recorded. A total of ten marked individuals (>30cm gbh) for each of the selected 27 tree species were observed at 15 days interval during 2017-19. Further, the phenological events were categorized in to brief (less than 30 days) and extended periods (greater than 30

days) based on the duration of a particular phenological event in the forest (Yadav and Yadav 2008).

RESULTS AND DISCUSSION

Among the selected 27 tree species, emergence of fresh leaves was initiated in March in four species (15%) and reached a peak in April (12 species; 44%) and continued up to May (9 species 33%) and June (2 species, 7%, Table 1, Fig. 1). Majority of tree species (18 species, 67%) featured brief leaf flushing activity and nine species showed extended leaf initiation period. In the whole forest, *Schleichera oleasa* has produced first new set of leaves and *Cochlospermum religiousm* the last new set of leaves. The relatively higher proportion of trees featuring leaf flushing activity in hot summer period indicate increase in temperature and day length photo period are the triggering factors for leaf initiation in these dry forests as also observed in Vindhyan dry forests (Singh and Kushwaha 2006). The observations indicated that all the tree species completed their leaf expansion by July with a peak in May/June (74%). The leaf fall got started before the onset of dry period in December (three species, 11%) lasted in January (species, 26%) and reached peak in February (17 species, 63%) and the leaf fall was completed in March from where the total forest will be in leafless condition. The first tree to start the leaf fall in the forest is *Gyrocarpus americanus* followed by *Sterculia urens* and *Cassia fistula* in December. All the observed 27 trees showed certain and varied extent of leaf less period (deciduousness) like *Boswellia serrata, Gyrocarpus americanus, Lannea coromandelica* and *Cochlospermum religiosum* had large period (4-5 months; 121-144 days), nine species had 2-4 months (58 to 105 days) and 14 species had<2 months leaf less period in the range of 21-50 days; Table 1, Fig. 1). Species with high deciduous period have shed their leaves in brief period, with a range of 22-30 days and those with lower deciduous period also have shed their leaves remarkably well before the onset of dry period. These observations suggest that the initiation of leaf fall is periodic and concurred mainly with low temperature dry period after the post North-East monsoon rains that prevail in this region.

Flowering phenology: Flower bud breaking started in January (two species, 7%), lasted in February (two species, 7%), May (four species, 15%), reached peak in April/March (14 species, 52%) and continued up to June (four species, 15%). In the forest the species which produce flowers early is *Gyrocarpus americanus* followed by *Sterculia urens* and *Anogeissus latifolia* is the only tree species that produced flowers after the onset of monsoon rains in September. Species specific initiation of flowering in relation to leaf phenology was observed; five species produced flowers

Table 1. Leafing and flowering phenological events of tree species (2017-2019)

Name of the tree species	Leaf fall initiation	Leaf emergence	Flowering initiation
4 species>4 months deciduous period			
Boswellia serrata	January 24(Br)	May 10(Br)	February 21(Br)
Cochlospermum religiosum	January 30 (Ext)	June 16(Br)	March 22(Br)
Gyrocarpus americanus	January 27 (Br)	May 15(Br)	January 20(Br)
Lannea coromandelica	February 22 (Br)	June 22(Br)	April 62(Ext)
9 species (2-4 months deciduous period)			
Chloroxylon swietenia	January 42(Ext)	June 15(Br)	March 30(Br)
Dalbergia paniculata	February 30 (Ext)	May 17(Br)	May 31(Ext)
Gardenia resinifera	February 18 (Br)	April 15(Ext)	May 36(Ext)
Givotia moluccana	January 28(Br)	May 30(Br)	June 28(Br)
Holoptelea integrifolia	February 20(Br)	May 20(Br)	March 19(Br)
Ochna obtusata	February 15 (Br)	May 20(Br)	April 30(Br)
Sterculia urens	January 36(Ext)	May 20(Br)	January 22(Br)
Terminalia alata	February 16(Br)	May 29(Br)	June 17(Br)
Ziziphus xylopyrus	January 24 (Br)	April 18(Br)	May 37(Ext)
14 species <2months deciduous period			
Cleistanthus collinus	February 14 (Br)	April 34(Ext)	April 40(Ext)
Anogeissus latifolia	January 34(Ext)	April 30(Ext)	Sep 34(Ext)
Bauhinia racemosa	February 16(Br)	April 33(Ext)	April 30(Br)
Buchanania axillaris	February 30(Ext)	April 45(Ext)	May 45(Ext)
Cassia fistula	Dec 60(Ext)	April 30(Ext)	March 120(Ext)
Diospyros chloroxylon	February 14(Br)	April 37(Ext)	April 74(Ext)
Diospyros montana	February 30(Ext)	March 18(Br)	April 30(Br)
Dolichandrone atrovirens	February 33(Ext)	April 31(Br)	June 45(Ext)
Morinda pubescens	February 30(Ext)	April 30(Ext)	June 45(Ext)
Polyalthia cerasoides	Dec 60(Ext)	April 30(Ext)	February 75(Ext)
Pterocarpus santalinus	January 24(Br)	March 15(Br)	March 45(Ext)
Schleichera oleosa	February 16(Br)	March 27(Br)	March 15(Br)
Strychnos nux-vomica	February 15(Br)	March 29(Br)	March 45(Ext)
Wrightia tinctoria	February 14(Br)	April 23(Br)	April 60(Ext)

Br: Brief phenological period (<30 days) and Ext: Extended phenological period (>30 days)

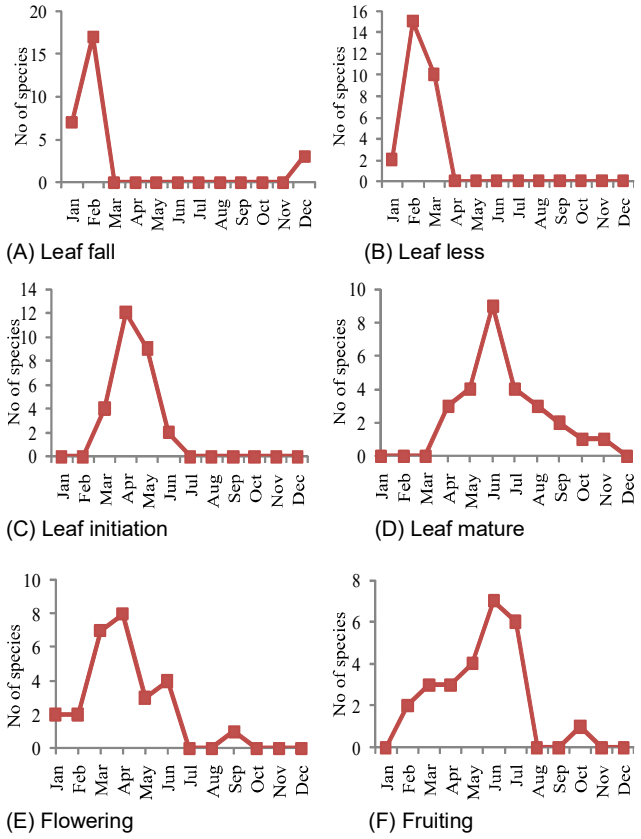

Fig. 1. Number of species with a specific phenological feature (2017-19)

immediately after leaf fall indicating rehydration of stems as the trigger point, five species promulgated flowering during leafless period and nine species produced flowers and leaves simultaneously suggesting increase in day length period and temperature as the triggering points. While eight species produced flowers after leaf maturation indicating the first rains as the triggering feature. Thus both leafing and flowering activities occurred mainly during the dry period as also observed in dry deciduous forests of Bhadra wildlife sanctuary (Nanda et al 2014). The pattern indicates that flowering activity is dependent on leafless period to a certain extent and deciduousness form an important factor in deciding the phenology of deciduous tree species as suggested by Singh and Kushwaha (2005) in dry deciduous forests. In addition flowering during leafless period makes flowers more visible to the specific pollinators, as 12 species (44%) had brief flowering period and 15 species (56%) produced flowering with greater than 30 days flowering phenophase.

Fruiting initiated in February (two species, 7%), lasted in March/April/May (11 species, 41%) reached peak in June/July (13 species, 48%) and *Anogeissus latifolia* produced fruits in October. Nearly half of the recorded species (13 species, 48%) produced fruit buds in the dry season and in 14 species (52%) the fruit bud initiated after the onset of rains. *Cochlospermum religiosum* only had < 30 days fruit maturation period and it is the first tree to produce mature fruit in the forest, eight species had 2-4 months fruit maturation period and 18 tree species (67%) had >4 months fruit maturation period which include prominent species like *Pterocapus santlinus, Terminalaia alata, Anogeissus latifolia, Dalbergia paniculata*. Thus, in majority of tree species, the fruit maturation period is long for about 4-7 months and this pattern is in line with other dry forest studies (Nanda et al 2014). Among the 27 species, ten species (37%) have completed their seed dispersal before the onset of rains. These species are found to comprise of exclusive wind dispersal syndromes. While among 17 species that have initiated seed dispersal after September, eight species possessed both autochory and zoochory but not the wind dispersal syndromes and another nine species had wind dispersal syndromes. The seed dispersal timing and the respective dispersal mechanisms have to be understood in the context of regeneration mechanisms like seed bank formation and rapid seed germination rates that prevail in the dry forest trees (Teketey 2005).

CONCLUSION

The dry months have featured immense phenological activities in these dry deciduous forests. In majority of trees, leaf initiation occurred in the dry period and leaf expansion was after the monsoon rains. Flowering phenology peaked in summer period and got synchronized with leaf flushing activity. Fruit bud breaking occurred after the first rains and fruit fall was observed after the rains got reduced. The seasonal observations reveal variations in phenological patterns among the selected tree species and soil moisture availability and photoperiod seem to be the prominent triggers exhibited in the dry deciduous forest. The long term studies should be conducted to understand the typical variations and their relationship with environment factors.

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REFERENCES

Mastan T, Ankalaiah C, VenkataRamana C and Reddy MS 2020. Assessment of tree diversity in Nithyapoojakona dry deciduous forest of Sri Lankamalleswara wildlife sanctuary, Southern Eastern Ghats, India. *Indian Journal of Ecology* **47**(2): 390-396.

Nanda A, Suresh HS and Krishnamurthy YL 2014. Phenology of a tropical dry deciduous forest of Bhadra wildlife sanctuary,

southern India. *Ecological Processes* **3**: 1-12.

Saha S 2007. Study of leafing, flowering and fruiting activities in three species of temperate forest at the Singalila range, Darjeeling. *Indian Journal of Ecology* **34**: 15-18.

Singh KP and Kushwaha CP 2005. Emerging paradigms of tree phenology in dry tropics.*Current Science* **89**: 964-975.

Singh KP and Kushwaha CP 2006. Diversity of flowering and fruiting phenology of trees in a tropical deciduous forest in India. *Current Science* **97**: 265-276.

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Singh SL and Sahoo U 2019. Shift in phenology of some dominant tree species due to climate change in Mizoram, North-East India. *Indian Journal of Ecology* **46**(1): 132-137.

Teketay D 2005. Seed and regeneration ecology in dry Afro montanne forests of Ethiopia: I. Seed production population structures. *Tropical Ecology* **46**: 29-44.

Yadav RK and Yadav AS 2008. Phenology of selected woody species in a tropical dry deciduous forest in Rajasthan, India *Tropical Ecology* **49**(1): 25-34.

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Regeneration Status of Some Tree Species in Garhjungle Sacred Forest, West Bengal, India

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Abstract: Sacred groves have significant effects on environment conservation due to the special precautions taken by local communities applying their religious faith and belief. The present investigation aimed to study the regeneration status of tree species and survival of naturally emerged seedlings in a sacred forest situated in the Rarh region of West Bengal, India. Regeneration status of species was determined based on population size of seedlings, saplings and adult trees. Shannon-Wiener diversity index (H) ranged from 1.88 to 2.38 and it is highest for saplings. When seedling density is highest followed by saplings and trees of a particular species, the regeneration status is said to be in good category. Among the 14 tree species recorded in the study area, one showed lack of regeneration indicating declining population, while 9 species were newly colonized. Poor regeneration status of the dominant species *Shorea robusta* indicates a serious threat as it is a naturally occurring climax species of lateritic zone of West Bengal. The present study has provided a baseline data for the long term monitoring of tree communities in the area that will help to assess the effect of present ecological consequences of ongoing and future climatic changes.

Keywords: Sacred forest, Regeneration, Lateritic zone, Diversity index, Sapling, Seedling

A patch of undisturbed forest consisting of a rich biodiversity and which is maintained by the local community with cultural and religious beliefs is generally considered as sacred grove. These are universal human phenomenon not associated with any specific religion or worldview, but have a strong religious perspective and are influenced by traditional local beliefs (Shrestha et al 2015). With limited human activity of resource utilization, sacred groves frequently possess old growth vegetation, integrated nutrient cycling with high soil fertility, and many ecologically and socially valuable biotic species (Godbole and Sarnaik 2004). Sacred groves function as natural gene pool reserve and set an example of environment conservation by community participation to ensure benefits to human societies in various ways. The vegetation analysis of Garhjungle sacred forest showed lower species richness, diversity as well as basal area in comparison with results from other sacred forests (Ganguli et al 2016a). Different growth forms of woody plant species is the main constituent for the formation of community structures of forest and the ecological characteristics of sites, species diversity and regeneration status (Khumbongmayum et al 2006). The population structure characterized by the presence of sufficient number of seedlings, saplings and adults indicates successful regeneration of forest species. Regeneration status of tree species depends on the maturity and diameter structure of their population (Bhuyan et al 2003). Characteristics of the forest floor, micro-environmental conditions under the forest canopy and anthropogenic activities influence the regeneration status of trees (Mishra et al 2003). An increased availability of light may stimulate or inhibit seed germination in forests. Tree fall gap is also very important factor in this regard as it affects seedling recruitment and establishment of both seedlings and saplings. Growth of seedlings is often limited by the availability of soil nutrients, especially N and P (Mishra et al 2003). The regeneration studies of forest trees help in biodiversity conservation and forest management as some forests including sacred groves are facing different types of anthropogenic disturbances. The comparative regeneration study under disturbed and undisturbed sites in natural forest stands of *Madhuca sp*. in Gujrat also revealed the fact that anthropogenic disturbances may lower down the regeneration status up to three times (Hegde et al 2018). Deteriorating health of Garhjungle sacred forest (Ganguli et al 2016a) was reported in a previous study. Sacred groves are treated as working models of community based conservation. The main criteria generally used for the selection of study area are - size and location of the groves, their legality and duration of the management practices by local communities. Based on the mentioned criteria, our study area has been selected and this will shed light to improve the management strategy of this forest. Present work attempts to understand the regeneration status of tree species in the sacred grove.

MATERIAL AND METHODS

Area description: The study was conducted in a sacred forest named Garhjungle which is located in Burdwan district

of West Bengal, India and is extending between 23°40'54.4"N latitude and 87°40'20.2"E longitude with an elevation of 65 to 68 meters above the sea level. The old natural forest is considered sacred among local people. Different types of anthropogenic disturbances such as extraction of fuel wood, collection of non timber forest products, frequent man made fire and cattle grazing were observed in this forest, in spite of having traditional restrictions. The study area falls under tropical climate with 34˚C to 45˚C temperature in the summer and 8˚C to 15˚C in the winter with distinct seasonality throughout the year. Annual rainfall ranges from 120 to 150 cm. The soil is red lateritic having high level of iron content and poor in nutrient status.

Vegetation sampling: The vegetation analysis was carried out by placing 25 random quadrats of 10m x 10m size covering 0.25 ha area. In each quadrat all the trees (dbh>1cm) were identified and their number and diameter at breast height (dbh) were recorded. Where dbh measurement was not possible, girth at breast height (gbh) was measured. Nested within each such quadrat, 2 plots of 5m x5m were used to sample the shrubs, climbers and tree saplings (< 1cm dbh, height >30 cm) and herbs including tree seedlings (< 1cm dbh, height <30 cm) were sampled by lying four 1m x 1m quadrats. Plant specimens were collected and identification of the unknown species was done by consulting regional flora (Guha Bakshi 1990, Sanyal 1994).

Data analysis: Species diversity was calculated using Shannon - Wiener index (H') (Shannon and Weaver 1949), species richness (M) was calculated following Margalef (1968), concentration of dominance (Cd) was calculated as per Simpson (1949) and evenness was measured according to Pielou (1966). Species diversity was calculated separately for each vegetation strata – trees, shrubs, herbs, saplings and seedlings. Population structure, survival of naturally sprouting seedling and maturation of sapling to adult species were studied to find the regeneration status of tree species during the study period (2013-2014).

Regeneration status of each tree species was evaluated considering the number of seedlings and saplings based on Uma Shankar (2001),

1. Good regeneration, if seedlings >saplings >adults;
2. Fair regeneration, if seedlings >or <saplings >or <adults;
3. Poor regeneration, if the species survives only at sapling stage or only seedlings stage (seedlings and saplings may be less or more or equal to adults);
4. No regeneration, if a species is present only in adult form;
5. Reappearing, if the species has no adults but only seedlings or saplings.

Regeneration status of tree species was studied through regression analysis.

RESULTS AND DISCUSSION

The 14 tree species belonging to 12 families were recorded in the study area. Total 1090 saplings of 11 tree species and 57 seedlings of 6 tree species were recorded. *Shorea robusta* had highest number of saplings (599) and seedlings (23). *Bombax ceiba* was recorded without any sapling and seedling, while six tree species (*Acacia catechu, Suregada multiflora, Glochidion lanceolarium, Limonia acidissima, Sapindus* sp.*, Syzygium cumini*) occurred only in sapling stage and three tree species (*Acacia auriculiformis, Azadirachta indica*, *Morinda citrifolia*) were observed only in seedling stage. *Phoenix sylvestris* was observed both in seedling and sapling stages, but not as a tree (Fig. 1). Seedlings were absent in 7 tree species (*Acacia nilotica, Semecarpus anacardium, Tectona grandis, Pterocarpus marsupium, Schleichera oleosa, Diospyros melanoxylon, Aegle marmelos*), and their proportion was only 6% in *Haldina cordifolia* and less than 2% in *Shorea robusta, Madhuca longifolia* var. *latifolia* and *Buchanania lanzan*. Seedling percent was highest (55 to 57%) for *Alangium lamarckii* and *Spondias pinnata* but saplings were absent. Sapling percent was highest for *Diospyros melanoxylon* but tree percent was lowest. *Haldina cordifolia, Schleichera oleosa, Shorea robusta, Madhuca longifolia* var. *latifolia* and *Buchanania lanzan* had higher percent sapling than trees, while *Acacia nilotica, Semecarpus anacardium, Tectona grandis* and *Pterocarpus marsupium* had higher tree% than that of saplings. Significant linear relation existed between number of saplings and trees, and also between number of saplings and seedlings (Fig. 2). The relation between number of seedlings and number of trees was not significant but became significant after exclusion of data for *Spondias pinnata*.

Ecological status of seedlings and saplings: The number of tree species in sapling and seedling stages varied in the different parts of the forest. Various ecological parameters like density, frequency, species richness and diversity indices were measured for both seedlings and saplings (Table 1 and 2). For tree species Shannon-Wiener Index or heterogeneity (H') was 1.88 (Table 3) and it is highest in the sapling stage (2.38). Species richness and evenness were highest in seedling stage (5.91 and 1.16) but concentration of dominance was lowest here. The low evenness in the tree layer leads to the higher concentration of dominance in this layer.

Regeneration status of all the 14 tree species were observed in the study area (Table 5). For a particular species, when seedling density is highest followed by sapling and tree density, the regeneration status is said to be in good category. It was observed that, one species of the study area showed lack of regeneration indicating declining population, while nine species were newly colonized. The regeneration status of the dominant species *Shorea robusta* was not satisfactory, which indicates a serious threat as this species is a naturally occurring climax species of lateritic zone of West Bengal. Micro-environmental factors which vary with seasonal changes have an effect on different growth stages of trees i.e. seedling, sapling, coppice and young trees that also helps to maintain the population structure (Khumbongmayum et al 2006). The established seedling of dominant species is the indicative measure of excellent recruitment of those species supported by the environmental conditions of the study site that is favourable for their establishment stages. This fact is also revealed from the population structure and regeneration study in a wildlife sanctuary of Assam (Sarkar and Devi 2014)

In present study, the tree species exhibited a weak negative correlation with seedlings (Table 4). Regression analysis has given a non-significant result between trees and seedlings while conversion of seedlings into saplings and saplings into trees was significant. Removal of *Spondias pinnata* improved the relationship between trees and seedlings. Previous vegetation study of this forest (Ganguli et al 2016a) indicated a young regenerating population exhibited through reverse J shaped diameter density

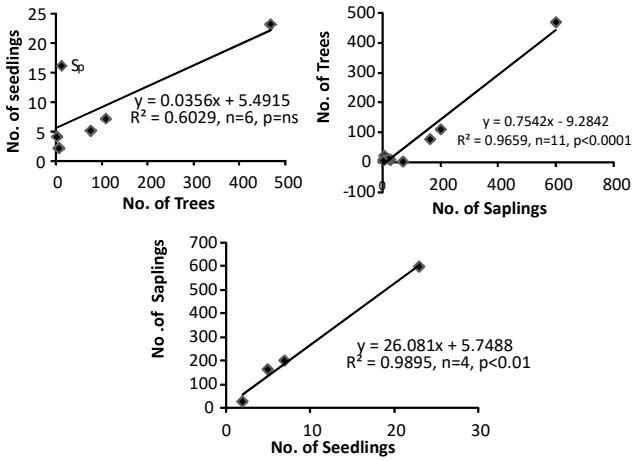

Fig. 2. Regression analysis showing regeneration status in Garhjungle forest

distribution of the tree species. During the study some disturbances were directly observed like - tree cutting, lopping, fire making, livestock grazing and litter collection. Some specific areas are also observed to be occupied as picnic spots. These activities can be treated as major drivers of forest degradation. In general, regeneration of species is affected by various anthropogenic factors (Barik et al 1996b, Iqbal et al 2012) and natural phenomena (Iqbal et al 2012).

Tree regeneration can be predicted by the structure of their populations. In present study, the concentration of dominance (Cd) is highest for trees followed by saplings and seedlings respectively. Trees are less diverse than seedling and sapling layers. The values of diversity index (H') and Cd

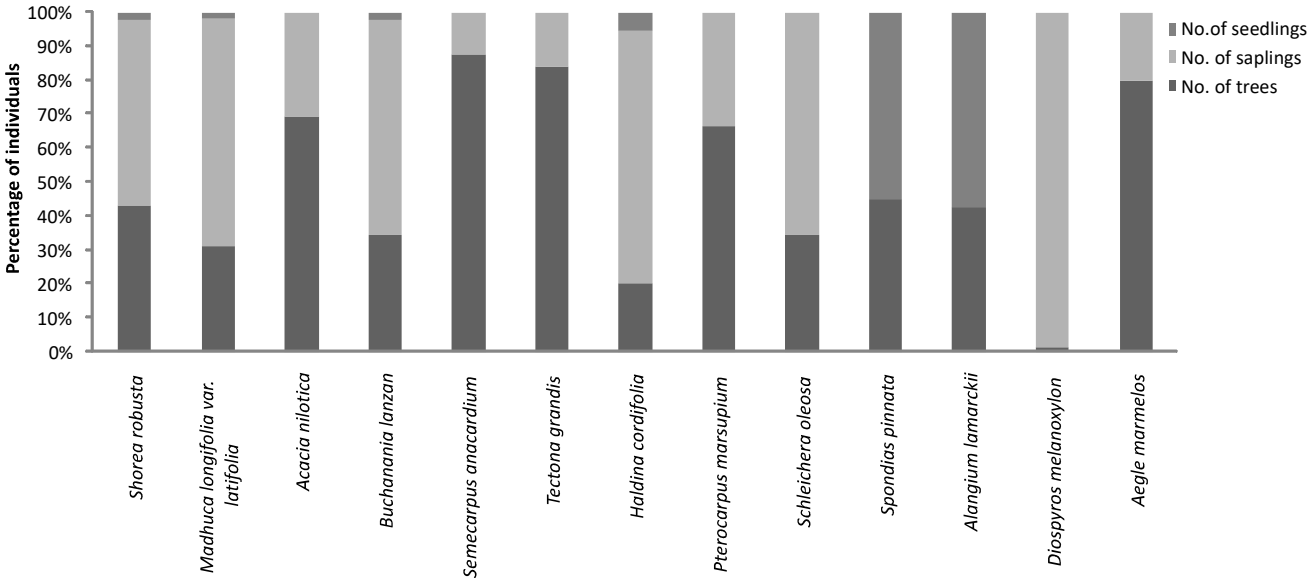

Fig. 1. Relative proportions of trees, saplings and seedlings in Garhjungle forest

were inversely related with each other in the study area, which is indicated that the higher species diversity negatively affect the Cd. These values are comparable to the earlier studies (Devi and Yadava 2006, Rawat et al 2018).The

Table 1. Density and frequency of saplings

Species	Family	Density	Frequency (%)
Acacia catechu Willd.	Mimosaceae	40	4
Acacia nilotica (L.) Willd. Ex Del.	Mimosaceae	32	4
Aegle marmelos (L.) Corr.	Rutaceae	8	2
Buchanania lanzan Spreng.	Anacardiaceae	1600	72
Diospyros montana Roxb.	Ebenaceae	552	40
Gelonium multiflorum Juss.	Euphorbiaceae	48	10
Glochidion lanceolarium Voigt	Phyllanthaceae	176	6
Haldina cordifolia (Roxb.) Ridsdale	Rubiaceae	208	8
Limonia acidissima L.	Rutaceae	8	2
Madhuca indica Gmelin	Sapotaceae	1304	54
Phoenix sylvestris (L.) Roxb.	Arecaceae	304	30
Pterocarpus marsupium	Fabaceae	32	6
Sapindus Sp.	Sapindaceae	40	2
Semecarpus sapling	Anacardiaceae	8	2
Shorea robusta sapling	Dipterocarpaceae	4792	80
Silichera sapling	Sapindaceae	152	6
Syzygium cumini	Myrtaceae	232	12
Tectona grandis	Verbenaceae	32	4

Table 2. Density and frequency of seedlings

Species	Family	Density	Frequency (%)
Acacia nilotica (L.) Willd. Ex Del	Mimosaceae	0.01	1
Alangium lamarckii Thw.	Alangiaceae	0.04	1
Buchanania lanzan Spreng.	Anacardiaceae	0.07	5
Haldina cordifolia (Roxb.) Ridsdale	Rubiaceae	0.02	1
Madhuca indica Gemlin	Sapotaceae	0.05	2
Shorea robusta Gaertn. F	Dipterocarpaceae	0.23	10
Spondius pinatta (L.F.) Kurz	Anacardiaceae	0.16	2

Table 3. Alpha diversity measures of Garhjungle forest

	H'	E(H'/H(max)	M=(S-1)/lnN	Cd
Seedling	2.25	1.16	5.91	0.26
Sapling	2.38	0.82	2.40	0.30
Trees	1.88	0.71	1.97	0.44

Table 4. Correlation of species number among different vegetation strata

Vegetation strata	Shrub	Herb	Sapling	Seedling
Tree	0.49 (p<0.01)	0.08	0.61 (p<0.001)	0.54 (p<0.005)
Shrub		-0.03	0.22	0.61 (p<0.001)
Herb			0.10	-0.20
Sapling				0.34

Table 5. Density, Basal area, Importance Value Index (IVI) and regeneration status of adult tree species of Garhjungle sacred forest

Species names	Families	Density	Basal area	IVI	Regeneration status
Shorea robusta Gaertn. F.	Dipterocarpaceae	1872 ± 1095.51	11.72	145.90	Fair
Madhuca indica Gmelin	Sapotaceae	304 ± 180.69	1.63	38.51	Fair
Acacia nilotica (L.) Willd. Ex Del.	Mimosaceae	36 ± 264.58	0.033	4.95	Poor (seedling absent)
Buchanania lanzan Spreng.	Anacardiaceae	436 ± 583.57	1.37	42.89	Fair
Semecarpus anacardium L.f.	Anacardiaceae	28 ± 70.71	0.016	3.41	Poor (seedling absent)
Tectona grandis L.f.	Verbenaceae	84 ± 275.38	0.88	11.91	Poor (seedling absent)
Haldina cordifolia (Roxb.) Ridsdale	Rubiaceae	28 ± 57.74	1.05	9.67	Fair
Pterocarpus marsupium Roxb.	Fabaceae	32 ± 54.77	0.48	9.39	Poor (seedling absent)
Schleichera oleosa (Lour.) Oken	Sapindaceae	40 ± 321.46	0.41	6.93	Poor (seedling absent)
Spondias pinnata (L.f.) Kurz	Anacardiaceae	52 ± 577.35	2.12	15.75	Poor (sapling absent)
Alangium lamarckii Thw.	Alangiaceae	12 ± 70.71	0.009	2.83	Poor (sapling absent)
Bombax ceiba L.	Bombacaceae	8	0.60	4.42	No regeneration
Diospyros melanoxylon Roxb.	Ebenaceae	4	0.003	1.34	Poor (seedling absent)
Aegle marmelos (L.) Corr.	Rutaceae	16	0.07	2.09	Poor (seedling absent)

overall regeneration status of the tree species of the study site is not satisfactory. Future composition of forests depends on potential regenerative status of tree species within a forest stand (Henle et al 2004). Poor or lack of regeneration of some species and simultaneous colonization by new species in this sacred forest indicate the possibility of a shift in the future species composition.

CONCLUSION

The population study of different strata showed poor regeneration status for most of the tree species. Presence of new species in the study area may be due to the invasion through dispersal from adjacent areas and favourable micro environmental conditions contributed to their establishment and growth. Various types of anthropogenic disturbances were observed during the study period which indicates the poor management as well as a shift in belief system, though it is a sacred forest. Management authority should be aware to address the prevalent factors affecting natural regeneration of the tree species.

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REFERENCES

Barik SK, Rao P, Tripathi RS and Pandey HN 1996b. Dynamics of tree seedling population in a humid subtropical forest of northeast India as related to disturbances. *Canadian Journal of Forest Research* **26**: 584-589.

Bhuyan P, Khan ML and Tripathi RS 2003. Tree diversity and population structure in undisturbed and human- impacted stands of tropical wet evergreen forest in Arunachal Pradesh, Eastern Himalayas India. *Biodiversity and Conservation* **12**(8): 1753-1773.

Devi LS and Yadava PS 2006. Floristic diversity assessment and vegetation analysis of tropical semi evergreen forest of Manipur, north east India. *Tropical Ecol*ogy **47**: 89-98.

Ganguli S, Gupta Joshi H and Bhattacharya K 2016a. Vegetation structure and species diversity in Garhjungle sacred forest, West Bengal, India. *International Journal of Environmental &Agriculture Research* **2**(9): 72-79.

Godbole A and Sarnaik J 2004. *Tradition of Sacred Groves and Communities Contribution in Their Conservation.* Applied Environmental Research Foundation, Pune, p 60.

Guha Bakshi DN 1990. *Flora of Murshidabad District, West Bengal, India*. Scientific Publishers, Jodhpur, India.

Hegde HT, Gunaga RP, Thakur NS, Jha SK and Dobriyal MJ 2018. Population Structure and Regeneration of Mahua (*Madhuca longifolia* var *latifolia* (Roxb.) A. Chev.) in Disturbed and Undisturbed Sites. *Indian Journal of Ecology* **45**(4): 724-727.

Henle K, Saree S and Wiegand K 2004. The role of density regulation in extinction processes and population viability analysis. *Biological Conservation* **13:** 9-52.

Iqbal K, Pala NA, Bhat JA and Negi A K 2012. Regeneration status of trees around Khoh river in Garhwal Himalaya. *Indian Journal of Forestry* **35**: 471-476.

Khumbongmayum AD, Khan M Land Tripathi RS 2006. Biodiversity conservation in sacred groves of Manipur, Northeast India, population structure and regeneration status of woody species. *Biodiversity and Conservation* **15**: 2439–2456.

Margalef R 1968. *Perspectives in Ecological Theory*. Chicago, IL, USA: University of Chicago Press.

Mishra BP, Tripathi RS, Tripathi OP and Pandey HN 2003. Effect of disturbance on the regeneration of four dominant and economically important woody species in abroad leaved subtropical humid forest of Meghalaya, Northeast India. *Current Science* **84**: 1449-1453.

Pielou EC 1966. Species diversity and pattern diversity in the study of ecological succession. *Journal of Theoretical Biology* **10**: 370-383.

Rawat DS, Dash SS, Sinha BK, Kumar V, Banerjee A and Singh P 2018. Community structure and regeneration status of tree species in Eastern Himalaya: A case study from Neora Valley National Park, West Bengal, India. *Taiwania* **63**(1): 16-24.

Sanyal MN 1994. *Flora of Bankura District*. Bishen Singh Mahindra Pal Singh, Dehradun, p 555.

Sarkar M and Devi A 2014. Assessment of diversity, population structure and regeneration status of tree species in Hollongapar Gibbon Wildlife Sanctuary, Assam, Northeast India. *Tropical Plant Research* **1**: 26-36.

Shankar U 2001. A case of high tree diversity in a sal (Shorea robusta)-dominated lowland forest of Eastern Himalaya: Floristic composition, regeneration and conservation. *Current Science* **81**(7): 776-786.

Shannon CE and Weaver W 1949. *The Mathematical Theory of Communication*. University of Illinois Press, Urbana, USA.

Shrestha LJ, Devkota MP and Sharma BK 2015. Tree regeneration in sacred groves of Kathmandu Valley, Nepal. *Ecoprint* **22**: 29-38.

Simpson EH 1949. Measurement of diversity. *Nature* **163**: 688.

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Wetland and Aquatic Angiosperm Flora of Denkanikottai, Krishnagiri, Tamil Nadu

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Abstract: A floristic study was carried out in different wetlands and aquatic habitats of Denkanikottai, Krishnagiri District of Tamil Nadu during 2017-2018. A total of 106 angiosperm species that belong to 79 genera and 36 families were identified. Among these 85 species represent dicotyledons and 21 species belong to monocotyledons. The predominant families are Compositae (11 genera and 12 species), followed by Leguminosae (7 genera and 8 species), Cypearceae (5 genera and 9 species), Plantaginaceae (5 genera and 6 species) and 13 families represented by singleton species. Nine species were widely distributed to present study area such as *Aponogeton natans, Ammannia baccifera, Centella asiatica, Ipomoea carnea, Mimosa pudica, Lindernia hyssopoides, Ludwigia adscendens, L. octovalvis* and *Portulaca oleracea*. Two insectivorous species were collected such as *Urticularia aurea* and *U. vulgaris*. We recorded endemic species *Rotala fimbriata* in the study area, which is earlier reported only from southern India. In the present study, we generated a baseline data on angiospermic biodiversity of wetland and aquatic habitats of Denkanikottai taluk, which is essential for conservation and management strategies of Wetland and aquatic habitats. In the present study area were recorded very richness in wetland and aquatic biodiversity.

Keywords: Wetland, Aquatic, Angiosperms, Endemic, Insectivores, Denkanikottai, Krishnagiri

Wetlands are playing a prominent ecological as well as economic role in aquatic ecosystems. They are also known as primary producers of ecosystems and have unique ecological features which provide numerous products and services to humanity (Prasad et al 2002). Ecosystem goods provided by the wetlands mainly include: water for irrigation, fisheries, non-timber forest products, water supply and recreation. Major services include carbon sequestration, flood control, groundwater recharge, nutrient removal, toxic retention and biodiversity maintenance (Turner et al 2000). In terms of average area under each type of wetland, natural coastal wetlands have the largest area (Bassi et al 2014). Wetlands are very important numbers such as coral reefs, beaches, reservoirs, Lakes and rivers which are considered to be a significant part of the tourism (MEA 2005). The wetlands are very rich in nutrients which are coming from natural pollutants and agricultural runoff. Wetland reduces this by serving as pools where sediment can settle (Chawdhury and Das 2009). India has about 7,57.06 wetlands with a total wetland area of 15.3 m ha, accounting for nearly 4.7% of the total geographical area of the country, out of this, area under Inland wetlands accounts for 69%, coastal wetlands 27% and other wetlands (smaller than 2.25 ha) 4% (SAC 2011). Tamil Nadu is a wetland rich state as they have 24,684 wetlands with a total area 8, 84,240, hectare. It contributes 62% of Inland natural (lake, ponds and rivers) 65% of coastal artificial wetlands 52% of coastal natural wetlands 28% of Inland artificial. However, there is no report on systematic study of wetland and aquatic plants of the Krishnagiri district with a number of water bodies enriched with flora and fauna. Consequently, explorations of wetland plants are necessary to gain more knowledge on species richness as well as their geographical distribution. The present study aims to document the wetland angiosperm plants in Denkanikottai taluk, Krishnagiri district, Tamil Nadu.

MATERIAL AND METHODS

Study area: Denkanikottai is a taluk in the Krishnagiri district, Tamil Nadu; it is located at 12°31'11" N - 77°46'48" E between south-western extreme of the Karnataka state, east of the Western Ghats with an altitude of 3,000 feet from the sea level. It is 61.4 km west of Krishnagiri and 24 km south of Hosur. It is a part of the Cauvery Elephant Reserve (450 km²). Data on climatic conditions, geological information and soil types were collected from Denkanikottai taluk and forest range office. During the study period from Dec 2016 - Nov 2018, the April showed the maximum temperature of 27.4ºC. Thereafter the temperature fell down steadily indicating the onset of winter season with a minimum temperature of 20.6ºC in December. The humidity in the summer of April and May is minimum (53 %) and maximum humidity ranges from 74- 94% (average 85%) in September 2017. The annual rainfall varied from 600 mm to 1,400 mm. The minimum rainfalls were Rayakottai (1,008 mm) and Anchetty (610 mm)

and maximum around Denkanikottai (1,218.40 mm) and Thally (1,400 mm). Different types of the soils such as black or mixed loamy, red and gravel are found in the Denkanikottai. In general, the soil in the taluk is quite loose and fresh with its colour from red to dark brown. The soil has low nitrogen and phosphate content with marked variation between different taluk. The major forest types were dry deciduous in nature with dry thorn and dry evergreen elements also. The forests are known for their rich floristic and faunal diversity. The forest area forms the prime elephant habitat in the Krishnagiri district. The major wild animals include elephants, sambar, spotted deer, gaur, wild boar and panther.

Samples collection and identification: The sample collections were made for year 2017-2018 from wetland and Lake area such as Yarab Dharga Lake (Denkanikottai), Peddaseruvu Lake (Andevanapalli), Varatharaja Lake (Anniyalam), Vannammal Lake (Kakkadasam village) and Doddakere Lake (Onnupalli village), Sankarayyyan Lake, Yeerareddy Lake (Geejanakuppam village) and Krishna reddy Lake (Arupalli village) in Denkanikottai taluk, Krishnagiri, Tamil Nadu. For the collected specimens field numbers were given and pressed. Important morphological features and details of occurrence in the hill were recorded in the field. The voucher specimens were prepared as standard methods and deposited to the Department of Botany, Government Arts College for Men, Krishnagiri-635001. The families and genus were arranged in Bentham and Hooker's system of classification (1862-1883).The species were identified with the help of following flora of Madras presidency (Gamble 1915-1934; Gamble 1936a, b), The flora of the Tamil Nadu Carnatic (Matthew 1983, 1988), Flora of Tamil Nadu (Henry et al 1981, 1987, 1989), An excursion flora of central Tamil Nadu India (Matthew 1991) and Aquatic angiosperms-A systematic account of common Indian aquatic Angiosperms (Subramanyam 1962).

RESULTS AND DISCUSSION

The 106 angiosperm species and 79 genera belonging to 36 families were identified, which include 85 species of dicotyledons and 21 species of monocotyledons from the aquatic and wetlands. Compositae is the largest family comprising of 11 genera and 12 species and Leguminosae with 7 genera and 8 species followed by Cypearceae and Plantaginaceae. The 13 families were monospecific (Table 1). *Cyperus* and *Lindernia* were the most dominant genera with 5 species and *Ludwigia, Nymphaea* and *Polygonum* with 3 species. In 12 genera were two species like *Triumfetta, Indigofera, Alternanthera, Ammannia, Rotala, Blumea, Heliotropium, Ipomoea, Urticularia, Limnophila, Cyanotis*

Table 1. List of angiosperm species of Wetland and Aquatic from Denkanikottai taluk, Krishnagiri, Tamil Nadu

Family and botanical name	Life form	Collection place
Nymphaeaceae		
Nymphaea nouchali Burm.f.	FA	SRL & KRL
N. nouchali var. *versicolor* (Sims) R.Ansari & Jeeja	FA	SRL & KRL
N. pubescens Willd.	FA	VRL
Polygalaceae		
Polygala arvensis Willd.	EA	VRL
P. elongata Klein ex Willd.	EA	SRL
Portulacaceae		
Portulaca oleracea L.	EA	SRL, YRL & PSL
Elatinaceae		
Bergia ammannioides Roxb. ex Roth	EA	KRL
Malvaceae		
Sida cordata (Burm.f.) Borss.Waalk.	EA	VML
Triumfetta pentandra A.Rich.	EA	KRL
T. rhomboidea J acq.	EA	KRL
Urena lobata L.	EA	VML
Oxalidaceae		
Oxalis corniculata L.	EA	PSL & DKL
Sapindaceae		
Cardiospermum halicacabum L.	EA	PSL& VML
Leguminosae		
Aeschynomene aspera L.	EA	SRL
Alysicarpus monilifer (L.) DC.	EA	SRL
Chamaecrista mimosoides (L.) Greene	EA	SRL
Desmodium triflorum (L.) DC.	EA	SRL
Indigofera linifolia (L.f.) Retz.	EA	SRL
I. linnaei Ali.	EA	SRL
Mimosa pudica L.	EA	YRL, PSL & VML
Stylosanthes fruticosa (Retz.) Alston	EA	PSL
Lythraceae		
Ammannia baccifera L.	EA	PSL, YRL & KRL
A. coccinea Rottb.	EA	SRL
Rotala densiflora (Roth) Koehne	EA	KRL
R. fimbriata Wight	EA	KRL
Cucurbitaceae		
Cucumis dipsaceus Ehrenb. ex Spach	EA	PSL
Mukia maderaspatana (L.) M.Roem.	EA	VML
Onagraceae		
Ludwigia adscendens (L.) H.Hara	FE	SRL, KRL & YRL
L. hyssopifolia (G.Don) Exell	EA	KRL
L. octovalvis (Jacq.) P.H.Raven	EA	SRL, KRL & YRL

Cont...

Continues Table 1

Family and botanical name	Life form	Collection place
L. perennis L.	EA	YRL
Molluginaceae		
Glinus oppositifolius (L.) Aug.DC.	EA	KRL
Mollugo pentaphylla L.	EA	PSL
Apiaceae	EA	
Centella asiatica (L.) Urb.	EA	PSL,YRL & KRL
Rubiaceace		
Dentella repens (L.) J.R.Forst. & G.Forst.	EA	KRL
Oldenlandia herbacea (L.) Roxb.	EA	VML & PSL
Richardia scabra L.	EA	VRL
Spermacoce ocymoides Burm.f.	EA	VRL
Compositae		
Acmella paniculata (Wall. ex DC.) R.K.Jansen	EA	VML
Bidens pilosa L.	EA	PSL & KRL
Blumea axillaris (Lam.) DC.	EA	VML
B.lacera (Burm.f.) DC.	EA	VML
Calyptocarpus vialis Less.	EA	PSL
Eclipta prostrata (L.) L.	EA	KRL
Emilia sonchifolia (L.) DC. ex DC	EA	PSL
Gnaphalium uliginosum L	EA	KRL
Grangea maderaspatana (L.) Poir.	EA	KRL & PSL
Sonchus brachyotus DC.	EA	KRL
Sphagneticola trilobata (L.) Pruski	EA	VML
Xanthium strumarium L.	EA	VML
Menyanthaceae		
Nymphoides indica (L.) Kuntze	FA	PSL
Apocynaceae		
Pergularia daemia (Forssk.) Chiov.	EA	VML
Tylophora indica (Burm. f.) Merr.	EA	PSL
Asclepiadaceae		
Asclepias curassavica L.	EA	PSL
Gentianaceae		
Exacum pedunculatum L.	EA	KRL
Boraginaceae		
Coldenia procumbens L.	EA	VML
Heliotropium marifolium J.Koenig ex Retz.	EA	VML
H.ovalifolium Forssk.	EA	PSL & KRL
Convolvulaceae		
Argyreia nervosa (Burm. f.) Bojer	EA	KRL & YRL
Ipomoea carnea Jacq.	EA	YRL, KRL, SRL, YDL & PSL
I.obscura (L.) Ker Gawl.	EA	DKL

Cont...

Continues Table 1

Family and botanical name	Life form	Collection place
Linderniaceae		
Lindernia antipoda (L.) Alston	EA	DKL
L. ciliata (Colsm.) Pennell	EA	KRL
L. hyssopoides (L.) Haines	EA	YRL,DKL & VML
L.parviflora (Roxb.) Haines	EA	PSL & YRL
L. rotundifolia (L.) Alston	EA	YRL
Torenia lindernioides C.J.Saldanha	EA	KRL
Orobanchaceae		
Striga densiflora (Benth.) Benth.	EA	SRL
Lentibulariaceae		
Urticularia aurea Lour.	S	KRL
Utricularia vulgaris L.	S	SRL
Acanthaceae		
Hygrophila auriculata (Schumach.) Heine	EA	PSL & YRL
Verbenaceae		
Phyla nodiflora (L.) Greene	EA	PSL & VML
Stachytarpheta jamaicensis (L.) Vahl	EA	PSL & KRL
Plantaginaceae		
Bacopa monnieri (L.) Wettst.	EA	PSL &VML
Dopatrium junceum (Roxb.) Buch.-Ham. ex Benth.	EA	KRL
Hippuris vulgaris L.	EA	SRL & KRL
Limnophila heterophylla (Roxb.) Benth.	EA	KRL
L.sessiliflora (Vahl) Blume	EA	KRL & VML
Scoparia dulcis L.	EA	KRL
Amaranthaceae		
Alternanthera philoxeroides (Mart.) Griseb.	EA	KRL & YRL
A.sessilis (L.) R.Br. ex DC.	EA	PSL & DKL
Polygonaceae		
Polygonum lapathifolium L.	EA	YRL
P. persicaria L.	EA	YRL & KRL
P. plebeium R.Br.	EA	PSL
Ceratophyllaceae		
Ceratophyllum demersum L.	S	KRL & YDL
Pontederiaceae		
Monochoria vaginalis (Burm.f.) C.Presl	FF	YRL & KRL
Eichhornia crassipes (Mart.) Solms	FF	YDL
Commelinaceae		
Commelina attenuate K.D.Koenig ex Vahl	EA	SRL
Cyanotis cristata (L.) D.Don	EA	SRL
C. fasciculata (B.Heyne ex Roth) Schult. & Schult.f.	EA	SRL

Cont...

Continues Table 1

Family and botanical name	Life form	Collection place
Murdannia nudiflora (L.) Brenan	EA	KRL
Hydrocharitaceae		
Hydrilla verticillata (L.f.) Royle	SA	YDL & VML
Nechamandra alternifolia (Roxb. ex Wight) Thwaites	S	KRL
Ottelia alismoides (L.) Pers.	SA	VML
Vallisneria natans (Lour.) H.Hara	SA	YDL
Aponogetonaceae		
Aponogeton natans (L.) Engl. & K. Krause	FA	PSL, YDL & SRL
Cypearceae		
Cyperus articulatus L.	EA	YRL & PSL
C. cyperinus (Retz.) Suringar	EA	SRL & KRL
C. difformis L.	EA	DKL
C. sp.	EA	DKL
C. trachysanthos Hook. & Arn.	EA	SRL & YRL
Fimbristylis dichotoma (L.) Vahl	EA	SRL
Kyllinga odorata Vahl	EA	SRL
Schoenoplectiella articulate (L.) Lye	EA	YRL
Scirpus articulatus L	EA	KRL
Poaceae		
Eragrostis sp.	EA	VML

Thally Lake: KRL - Krishna reddy Lake, **SRL** - Sankarayyyan Lake, **VRL** - Varatharaja Lake, **YRL** - Yeerareddy Lake. **Denkanikottai Lakes: DKL** - Doddakere Lake, **VML** - Vannammal Lake, **YDL** - YarabDharga Lake, **PSL** - Peddaseruvu Lake.

and *Aponogeton* and 61 genera were only one species. The six adaptations of hydrophytes can be classified depending upon their nature, habit, conduct with water, soil, air and light. Most of the species were found in emergent anchors (EA) (91 species). Six species occurred at floating leaved anchored (FA) such as *Aponogeton natans, Nymphaea nouchali, N. Nouchali* var. *versicolor, N. pubescens, Nymphoides indica* and *Ludwigia adscendens*.

Four species were observed in submerged (S), *Nechamandra alternifolia, Urticularia aurea, U. vulgaris* and *Ceratophyllum demersum.* These species were collected from Krishna Reddy Lake and Sankarayyyan Lake. *Hydrilla verticillata, Vallisneria natans* (Fig. 1m) and *Ottelia alismoides* were submerged anchored (SA) hytrophytes. These species were recorded from Vannammal Lake, and Yarab Dharga Lake. Two species were free floating (FF) such as *Eichhornia crassipes* and *Monochoria vaginalis.*The pollution indicator species such as *Eichhornia crassipes*, *Pistia* sp., *Lemna* sp. and *Typha* sp. were cited in Yarab Dharga and Denkanikottai Lake. The endemic species *Rotala fimbriata* is observed in the Krishna Reddy Lake (Fig. 1e).

Two insectivores' species *Urticularia aurea* and *U. vulgaris* were observed in Krrishna Reddy Lake and Sankarayyyan Lake (Fig. 1h-i). Species richness of wetland and aquatic flora was observed in Krishna Reddy Lake (40 species), Sankarayyyan Lake (25 species), Yerrareddy Lake (20 species) in the Thally area. Similarly the highest species observed in Pedda Seruvu Lake (28 species) and Vannammal Lake (21 species), very least species in Doddakere Lake (6 species) and Varatharaja Lake (4 species) Denkanikottai. Two Pteridophytes species were collected such as *Ceratopteris thalictroides* and *Marsilea quadrifolia* and two macro algae were observed like *Nitela furcata* and *Nitela* sp.

CONCLUSIONS

This is the first wetland and aquatic floristic survey carried out in Denkanikottai taluk, Krishnagiri district. Some rare and endemic species were recorded in this study area. Therefore the present investigations are essential for conservation and preparation of comprehensive flora of the Krishnagiri district and also contribute to the floristic documentation of the state.

REFERENCES

Bassi N, Dinesh Kumar M, Sharma A and Saradhi PP 2014. Status of wetlands in India: A review of extent, ecosystem benefits, threats and management strategies. *Journal of Hydrology: Regional Studies* **2**: 1-19.

Chawdhury M and Das AP 2009. Inventory of some ethno-medicinal plants in wetland areas in Maldah district of West Bengal. *Pleione* **3**(1): 83-88.

Gamble JS 1915-1934. *Flora of Presidency of Madras Vol- I*, Botanical Survey of India, Calcutta, p 1389.

Gamble JS 1936a. *Flora of Presidency of Madras Vol- II*, Allard & Co. London (Reprinted 1956) Botanical Survey of India, Calcutta.

Gamble JS 1936b. *Flora of Presidency of Madras Vol- III*, Allard & Co. London (Reprinted 1956) Botanical Survey of India, Calcutta.

Henry AN and Swaminathan MS 1981. Observations on the vegetation of Kanniyakumari district, Tamil Nadu. *Bulletin of the Botanical Survey of India* **23**(3&4): 135-139.

Henry AN, Chithra V and Balakrishnan NP 1989. *Flora of Tamil Nadu, India*, Series-I, Analysis, Vol-III. Botanical Survey of India, Southern Circle, Coimbatore, p 154.

Henry AN, Kumari GR and Chithra V 1987. *Flora of Tamil Nadu Vol-II,* Botanical Survey of India, Coimbatore.

Matthew KM 1991. *An excursion flora of Central Tamil Nadu, India,* New Delhi, p 486.

Matthew KM 1983. *The flora of Tamilnadu Carnatic*, The Rapinat Herbarium, Tiruchirapalli, Tamil Nadu, p 2154.

Matthew KM 1988. *Further illustrations on the flora of Tamil Nadu Carnatic Vol-IV*, The Rapinat Herbarium, Tiruchirapalli, Tamil Nadu, p 610.

Walter V Reid et al 2005. *Millennium Ecosystem Assessment (MEA), Ecosystems and Human Well-being: Wetlands and Water Synthesis.* World Resources Institute, Washington, DC, p 155.

Fig 1. a. *Bergia ammannioides* Roxb. ex Roth, b. *Bacopamonnieri* (L.) Wettst., c. *Indigofera linifolia* (L.f.) Retz., d. *Rotala densiflora* (Roth) Koehne, e. *Rotala fimbriata* Wight, f. *Lindernia antipoda* (L.) Alston, g. *Lindernia parviflora* (Roxb.) Haines, h. *Urticularia aurea* L., i. *Utricularia vulgaris* L., j. *Hippuris vulgaris* L., k. *Limnophila heterophylla* (Roxb.) Benth., l. *Limnophila sessiliflora* (Vahl) Blume, m. *Vallisneria natans* (Lour.) H. Hara, n. *Polygala arvensis* Willd., o. *Oxalis corniculata* L.

Prasad SN, Ramachandra TV, Ahalya N, Sengupta T, Kumar A, Tiwari AK, Vijayan VS and Vijayan L 2002. Conservation of wetlands of India: A review. *Tropical Ecology* **43**(1): 173-186.

Space Applications Centre (SAC) 2011. National Wetland Atlas. SAC, Indian Space Research Organisation, Ahmedabad. Study Group on Environment, n.d. *Report of the study group on environment including tourism, heritage, pollution & disaster-management,* National Capital Region Planning Board, New Delhi.

Received 10 August, 2020; Accepted 10 November, 2020

Subramanyam K 1962. *Aquatic angiosperms: A systematic account of common Indian aquatic angiosperms*. Botanical Monograph **3**(1-6): 1-190.

Turner RK, Van Den Bergh CJM, Soderqvist T, Barendregt A, Van Der Straaten J, Maltby E and Van Ierland EC 2000. Ecological-economic analysis of wetlands: scientific integration for management and policy. *Ecological Economics* **35**: 7-23.

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Ecological Status of Fodder and Fuelwood Species in Banari Devi Sacred Grove of Kumaun Himalaya, Uttarakhand

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Abstract: The present study was carried out in various forests Banari Devi Sacred Grove in Almora (1700-2000). Kumaun Himalaya to assess the ecological status of fodder and fuelwood species. A total of twelve woody plants species were representing from eleven families. Ericaceae was a dominant family represented by two genera *Quercus leucotrichophora* was the dominant species where in all selected forest stands. Tree density varied from 860 to 980 individuals ha^{-1} for tree, 360 to 520 ind. ha^{-1} for sapling and 2030-3020 ind ha^{-1} for seedling. The total basal cover ranged between (21.87-34.35 m^2 ha^{-1}). The species diversity ranged between 1.03 to 1.37 for tree, 1.24 to 1.46 for sapling, and 1.46 to 2.15 for seedling.

Keywords: Species composition, Kumaun Himalaya, Fodder plant, Tree diversity

Forests are the most complex and biologically dynamic entities amongst all the global ecosystems. The composition of the forest is diverse and varies from place to place because of varied climate, soil and topography (Singh 2006). Forest structure, species composition, and diversity are key ecological features significantly correlated with leading environmental as well as anthropogenic variables (Gairola et al 2008). The forest communities 1200-3000 msl, the different environmental governed by several environment factors viz: topography and climate. This region have gregarious forests of *Pinus roxburghii, Quercus leucotrichophora*, *Q. floribunda* and, *Q. semicarpifolia*. Plant species diversity is affected by numerous topographic gradients and climatic variations. The number of species in a certain forest differs distinctly along with the altitudinal range of its growth (Gairola et al 2011), which depends on the complex factors that characterize the habitat of individual species. Thus, it is essential to comprehend the dynamics and connection between various factors which affect richness and diversity of the forests. In recent times, studies have been carried out in different regions of the Himalaya on forest structure and regeneration (Mittal et al 2020), geo-statistical analysis of forest structure by Mandal and Chattarjee (2020), tree diversity and ecological status (Nayak and Sahoo 2020), and a effect of lopping on structure and composition of (Amare and Bhardwaj 2017) which shows that the lopping, pollarding and selective logging had a significant effect on stand structure and species composition.

With the increasing demand for plant resources, it is essential to understand the structure and function of ecosystem. In all kind of ecosystem in the Himalaya oak forests are high valued because of producing high-quality fuelwood for cooking, green fodder for livestock and supporting non-timber forest produces (NTFPs) and serve most efficiently in terms of soil fertility and water retention, and have sustained the agri-pastoral mode of the livelihoods of the provincial populations for generations (Negi and Semwal 2010). The main occupation of people residing in this region is agriculture and livestock farming, that acts as a major source of income to these people. Although the people of this area grew fodder plants and grasses, they generally depend upon the resources of different forests and fulfil their fodder requirements from these forests. Other than that many agricultural crops are used as fodder by people, because of rich source of protein and other nutrient. Leguminous trees and shrubs are richer in protein and minerals than grasses. Different authors stressed that the quality of the grasses is very sensitive to seasonal climatic variation and varies considerably with maturity. However, the studies on the fodder plants of Uttarakhand lack the ranking of fodder species. The present study aims to collect quantitative information on species composition and diversity of species used for fodder and fuelwood and ranked based on their local abundance, nutritive value, fodder usage and milk production capacity.

Study area: Banari Devi sacred groves is located at 30 km

from the Almora town between 29°33 N latitude and 79°41 E longitude. The total forest cover of Almora district is 1,778 sq.km (FSI, 2017) of which 0.20 sq.km is covered by the Banri-Devi Sacred groves. The forest extends from the base of villages Palna (1700m altitude) to the top hill (2000 m). The climate is temperate type, characterized by warm and short summer season, moist and wet rainy season, and pronounced severe winter. The region experiences moderate rainfall. Most of the rainfall (approximately 60%) is recorded between June and September.

MATERIAL AND METHODS

A total three stands in three altitude, (1750, 1850 and 2000 m) were selected for the study, varied in aspect as well as in species composition. A total of twenty 10x10 m quadrates were placed for trees and sapling and 5X5 m for the seedling in each forest stand. Standard phytosociological methods were followed to obtain quadrat data (Misra 1968, Muller-Dombois and Ellenberg 1974). In each quadrat circumference at breast height (CBH at 1.37 m from the ground) of all tree individuals were recorded. Based on CBH, individuals were considered as tree >31cm; sapling (<30 cm cbh, height >20 cm) and seedling < 20 cm height. The collected field data were analysed for different compositional or phytosociological (density, frequency, basal area, species richness, and diversity) parameters.

Species diversity was computed for different communities using the Shannon-Wiener Index (H') using the formula:

$$H' = -\Sigma (Ni/N) \log (Ni/N)$$

Where H' = Shannon-Wiener information index of species diversity, Ni = total number of individuals of the species and N = total number of individuals of all the species in one stand (Shannon & Weaver 1949).

The concentration of dominance was measured by Simpson's index (Simpson 1949).

$$CD = \Sigma (Ni/N)^2$$

Plant species as fodder: For investigation of fodder species, Participatory rural appraisal (PRA) meeting was organized at the village level involving 10-15 villagers, having experienced men and women, self-help groups, and social workers. The information was collected after long sessions of discussion about plants in their locality and their usage as fodder and fuelwood. The information was gathered through species listing and ranking. Maximum 10 points were given to the species according to its uses in different categories (local abundance, uses in fodder, quantity nutrition, and milk production capacity), and mean value was calculated for each mentioned variable (1 point = 10%). The sum of the mean of all the variables leads to total marks obtained (M) for each species and those species are then ranked accordingly I to XVI.

RESULTS AND DISCUSSION

The area comes under the temperate forest area with an altitude gradient of 1700-2000 m. *Quercus leucotrichophora* and *Myrica esculenta* were present in all the three strata (tree, sapling, and seedling) of forest. Stand (I) comprises of 9 species, stand (II), and stand (III) consists of 5 and 4 species respectively. *Q. leucotrichophora* was the dominant species in all three stands however *R. arboreum* was the co-dominant species in the stand (I) and stand (II) and *M. esculenta* in stand (III). The total tree density was varied from 860-980 individuals ha^{-1}. The tree density were more than the reported values of (300-420 individuals ha^{-1}) of six forest stands around the town area forest of Kumaun Himalaya (Arya 2014) and comparable with Joshi and Chandra (2020) in different forest stands of Almora. Maximum density (980 individuals ha^{-1}) recorded in stand (I) and minimum (860 individuals ha^{-1}) at the stand (II). The total tree basal area was varied from 21.87-34.35 m^2 ha^{-1}.

The sapling density range from 360-520 ind. ha^{-1} and seedling 2030-3020 individuals ha^{-1}. Higher number of seedling density is indicator of good regenerative capacity of forest stands (Pokhriyal et al 2012, Dutta and Devi 2013). This suggest that the forest had good regeneration potential. The present seedling density values were comparable with (860-3100 seedlings ha^{-1}) forest stand at Almora and around the town (Arya 2014) and these values were higher than earlier reported values 249.98-854 seedling ha^{-1} (Bragali 2013). The stands (I) show good regeneration because of the good number of seedling and sapling however the stands (II) and (III) show fair regeneration. The species diversity index found ranged between 1.03-1.37, while the concentration of dominance (CD) was 0.33-0.43 in three stands a total of 12 tree species were show contagious distribution pattern while only 5 species were show a random distribution pattern (Table 2).

Species used as fodder and fuelwood: A total of thirty seven fodder plant species were used by adjoining community. Out of which seven (19%) tree species were wild, eleven (30%) cultivated/domestic, and twenty (51%) grasses. Poaceae is the largest family which is used as fodder by local people of the Kumaun region for fulfilling their daily fodder needs. In wild tree species, a total of seven (19%) tree species were used as fodder. Among these species, *Ficus nemolaris* was commonly highly used as a fodder due to its high nutrient and milk production capacity. In cultivated tree species, a total of eleven tree species were used as domestic fodder. Among these species *Grewia optiva* and

Table 1. Ecological attribute of the selected study sites

Location	Stand I	Stand II	Stand III
Location and characteristic of study area			
Aspect	NW	N	NE
Altitude	1750	1850	2000
Forest type	Mixed oak	Mixed oak	Mixed oak
Vegetation Characteristic			
Dominant species	*Q. leucotrichophora*	*Q. leucotrichophora*	*Q. leucotrichophora*
Co-dominant species	*R. arboreum*	*R. arboreum*	*M. esculenta*
Total no. of tree species	8	5	4
Tree density (per ha)	980	860	970
Sapling density (per ha)	520	360	390
Seedling density (per ha)	3020	2030	2990
Regeneration status	Good	Fair	Fair
TBA ($m^2 ha^{-1}$)	21.87	24.79	34.35
Diversity index (H' Tree)	1.37	1.24	1.03
Concentration of dominance (CD)	0.33	0.34	0.43
Species Evenness (SE)	0.68	0.77	0.74

Table 2. Species composition and different phytosociological parameter of forest stands

Species	Stand (I)		Stand (II)		Stand (III)	
	Density	TBA	Density	TBA	Density	TBA
Tree						
Pyrus pashia	30	0.43	40	0.04	-	-
Acacia greggii	30	0.9	20	0.16	-	-
Daphiniphyllum himalayanse	20	0.18	-	-	-	-
Lyonia ovalifolia	10	0.23	-	-	-	-
Elaeagnus parvifolia	20	0.2	-	-	-	-
Pinus roxburhii	-	-	-	-	50	1.66
Total	980	21.87	860	24.79	970	34.35
Saplings						
Quercus leucotrichophora	220	0.51	110	0.44	70	0.26
Rhododendron arboreum	170	0.63	80	0.41	80	0.30
Myrica esculenta	30	0.10	120	0.15	200	0.66
Pyrus pashia	30	0.05	40	0.09	20	0.05
Senegalia greggii	40	0.06	10	0.01	-	-
Daphniphyllum himalense	10	0.05	-	-	-	-
Elaeagnus parvifolia	20	0.04	-	-	-	-
Pinus roxburghii	-	-	-	-	20	0.06
Total	520	1.44	320		390	1.33
Seedlings:						
Quercus leucotrichophora	1970	-	680	-	850	-
Rhododendron arboreum	160	-	340	-	230	-
Myrica esculenta	200	-	450	-	270	-
Pyrus pashia	420	-	350	-	1340	-
Acacia dealbata	50	-	-	-	-	-
Lyonia ovalifolia	80	-	-	-	-	-
Elaeagnus parvifolia	140	-	-	-	130	-
Senegalia greggii.	-	-	200	-	-	-
Ilex dipyrena	10		10		-	
Pinus roxburghii	-	-	-	-	130	-
Alnus nepalensis	-	-	-	-	40	-
Total	3020	-	2030	-		1.04

Table 3. Fodder plant species local abundance, nutrient value and rank of fodder plant species in the Banridevi forest and adjoining area

Botanical name	Common name	LA	FU	NVF	MPC	MO	Rank
Wild plant species traditionally used as fodder							
Ficus nemolaris	Dudhil	4.5	1	8.8	9.7	24	I
Bauhinia varigata	Kachnar	2.3	3.3	5.3	6.8	17.7	II
Q.leucotrichophora	Banj	2.7	3.1	4.6	4.0	14.4	III
Prunus cerasoides	Payaan	4.6	2	5.8	0.2	12.6	IV
Lyonia ovalifolia	Ayaar	2.1	2.2	0.7	0.1	5.1	VII
Rhododendron arboreum	Buraansh	2.6	2.6	0.2	0.1	5.5	V
Alnus nepalensis	Uteesh	1.1	2.7	0.7	0.1	5.5	VI
Cultivated plant species traditionally used as fodder							
Grevia optiva	Bhimal	5.2	1.0	10	10	26.3	I
Ficus roxburghii	Timil	4.6	2.0	8.0	9.0	23.6	II
Ficus palmata	Bedu	4.3	5.8	9.1	1.0	20.2	III
Saccharum officinarum	Ganna	5.1	1.0	7.1	5.0	18.2	IV
Toona ciliate	Tun	6.0	4.8	4.0	10	14.8	V
Musa paradisica	Kela	5.1	3.0	4.5	1.0	13.6	VI
Tinospora cardifolia	Giloy	3.6	2.0	5.5	2.0	13.1	VII
Curcuma longa	Haldi	5.8	4.7	2.0	0.0	12.5	VIII
Abelia chinensis	Nebhya	2.5	3.0	1.0	4.5	11	IX
Melia azedarach	Betain	4.8	3.5	1.0	0.0	9.3	X
Celtis australis	Khadik	4.7	3.0	1.0	0.0	8.7	XI
Green grasses used as fodder							
Sorghum bicolor	Chari	1.9	10	8.9	9.0	30	I
Cynodon dactylon.	Ghodi dub	5.2	4.0	7.7	7.8	24.7	II
Brachiaria villosa	Mals	6.2	1.0	9.0	7.0	23.2	III
Heteropogon contortus	Kuri	2.0	2.0	8.0	8.5	20.5	IV
Bothriochloa pertusa	Gulbang	7.2	9.9	1.0	0.1	18.2	V
Paspalum dilatatum	Bilmansi	8.2	8.5	1.0	0.1	17.8	VI
Chrysopogon gryllus	Dhaple ghas	7.2	9.5	1.0	0.1	17.8	VII
Pennisetum pedicillatum	Khusani ghaa	6.2	9.9	1.0	0.0	17.1	VIII
Dactylis glomerata	Mota	2.4	3.0	5.5	5.6	16.5	IX
Heteropogon sp.	Kumara	6.2	9.1	2.2	0.2	15.1	X
Imperata cylindrica	Siro ghaa	3.0	9.5	1.1	1	14.6	XI
Stelaria media	Badhyalu	4.2	9.5	0.5	0.4	14.6	XII
Saccharum spontaneum	Kansghaa	4.1	9.5	0.5	0.4	14.5	XIII
Chrysopogon fulvus	Manila	4.3	6	2.2	2.0	14.5	XIV
Rumex hastatus	Chalmad	5.0	9.2	0.1	0.0	14.3	XV
Lolium italicum	Raighaa	3.2	9.3	0.5	0.4	13.4	XVI
Pogonatherum paniceum	Charudia	3.1	8	1.1	1.0	13.2	XVII
Oxalis corniculeta	Chalmad	2.2	8.5	0.1	0.0	10.8	XVIII
Panicum maximum	Galpatta	1.4	8.5	0.2	0.1	10.2	XIX

LA=Local Abundance, FU= Used as fodder, NVF= Nutrient value of fodder, MPC= Milk production capacity, MO= Marks obtained

Ficus roxburghii were highly used as fodder with high nutrient and milk production capacity. In green fodder species including herbs and grasses, a total of twenty (51%) species were used as fodder. Among these species *Sorghum bicolor*, *Cynodon*sp and *Brachiaria villosa* were highly used as fodder species (Table 3). The collection of fodder varies from place to place along an altitudinal gradient, and also depends on species availability in any region and it was varied among the session in a year.

CONCLUSION

Oak forest is highly valuable in terms of green fodder and quality fuelwood and rich species diversity, higher density in oak forest support local fodder demands. Also, grasses species have the potential to provide forage throughout the year but some climatic variation (Rainfall, temperature) affect their productivity and quality. It was observed that more fodder species are needed to be planted to increase the fodder availability in the area and sustainable utilization of these fodder resources to be needed. Thus, the local knowledge about fodder plant species combined with the scientific and traditional knowledge of species could be the basis for in-situ conservation and cultivation of high-value fodder species outside the forest area.

REFERENCES

Amare T and Bhardwaj DR 2016. Effect of lopping on stand structure and tree species composition of *Quercusglauca* Thunb. Forests of Himachal Pradesh, India. *Indian Journal of Ecology* **43**(1): 218-223.

AryaD and Rawat J 2014.Species composition and diversity of six forest stands at Almora and around the town area forests of Kumaun Himalaya. International.*Journal of Conservation Science* **5**(1): 61-68.

Bragali K, Bisht P, Khan A and Rawat YS 2013. Diversity and regeneration status of tree species at Nainital Catchment, Uttarakhan, India. *International Journal of Biodiversity and Conservation* **5**(5): 270-280.

Chauhan, DS, Bhatt BP and Todaria NP 1999. Forest Panchayat: A model for people's participation in sustainable forest management in Garhwal Himalaya. In: Eds. Khan, M.L. and A. Arunachalam. *Sustainable Forest Management.*

Farooquee NA and Rawat DS 1997. *Development Dilemma Indian Scenario and Rural Himalaya* (A Central Himalayan Perspective, Gyanodaya Prakashan, Nainital.

Gairola S, Sharma CM, Suyal S and Ghildiya SK 2011. Species composition and diversity in mid-altitudinal moist temperate forests of the Western Himalaya. *Journal of Forest and Environmental Science* **27**(1): 1-15.

Joshi VC and Chandra N 2020. Pattern of diversity and regeneration potential along altitudinal gradient in selected forest stands of Kumaun Himalaya. *Indian Forester* **146** (4): 301-305.

Mandal M and Chattarjee ND 2020. Geo-statistical analysis to understand nature of forest patch shape complexity in panchet forest Division under Bankura District, West Bengal. *Indian Journal of Ecology* **47**(1): 96-101.

Mishra R1968. *Ecology Work Book* Oxford and IBH Publishing Co, Calcutta, pp 244.

Mittal A, Singh N and Tewari A. 2020. Quantitative analysis and regeneration status of forest trees species in Kumaun central Himalaya. *Indian Journal of Ecology* **43**(1): 218-223.

Mueller-Dombois D, Jacobi JD, Cooray RG and Balakrishnan N 1980. *Ohia Rain Forest Study: Ecological Investigations of the Ohia Dieback Problem in Hawaii.* Hawaii Institute of Tropical Agriculture and Human Resources, Honolulu, Hi (Miscellaneous publication 183).

Nayak S and Sahoo UK 2020. Tree diversity and ecological status of *Madhucalati folia* (Roxb.) J.F. Macbr in forests of Odisha. *Indian Journal of Ecology* **47**(1): 138-149.

Negi GCS and Semwal RL 2010. *Valuing the services provided by forests and agro-ecosystems in the Central Himalaya 37–39*. Mt forum Bull. January.

Pokhriyal P, Chauhan DS and Todaria NP 2012. Effect of altitude and disturbance on structure and species diversity of forest vegetation in a watershed of central Himalaya. *Tropical Ecology* **53**(3): 307-315.

Saxena AK and Singh JS 1984. Tree population structure of certain Himalayan forest associations and implications concerning future composition. *Vegetatio* **58**: 61-69.

Shannon CE 1949. The Mathematical Theory of Communication, by CE Shannon (and Recent Contributions to the Mathematical Theory of Communication), W. Weaver. University of illinois Press.

Simpson EH 1949. Measurement of diversity. *Nature* **163** (4148): 688-688.

Singh, JS 2006. Sustainable development of the Indian Himalayan region: Linking ecological and economic concerns. *Current Science* **90**(6): 784 788.

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Traditional Ecological Knowledge based Early Warning Systems for Adaptation to Climate Change

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Abstract: The tribal communities have a symbiotic relationship with the forest and natural resources which are beneficial for the mutual existence. The traditional ecological knowledge-based early warning system of the indigenous communities has a robust mechanism to predict, forecast, analyse and disseminate required information useful for the early prediction of hazards and accordingly to mitigate them with suitable climate change adaptations. The main aim of the present study is to document plants and animal-based knowledge used by the tribes of Adilabad district for early warning purposes to tackle and unforeseen circumstances. The study resulted in identifying 55 species of biotic and abiotic nature covering four knowledge spheres for ethnoecological purposes. The tribal communities are using indicators of animals (06), atmospheric sources (09), birds (07), cosmological sources (10), insects (09), plant-based (04), living beings from water (07) and water sources (02) to predict the occurrence of various types of hazards.

Keywords: Indigenous knowledge, Weather forecasting, Weather prediction, Mitigation, Disasters, Preparedness

Traditional Ecological Knowledge (TEK) uses indigenous, local and traditional knowledge as the basis for the sustainability of natural resources. The concept of TEK evolved with the direct interaction of human contact with the environment for thousands of years. The widespread usage of term TEK started from the early 1980s, but the practice is as old as from the starting of ancient food gathering and hunting cultures (Berkes 2017). TEK broadly refers to the knowledge forms which are unique and varies from societies to society and cultures to culture (Zidney et al 2020). There are many terms synonymous with the TEK and has similarities with marginal differences in their approach to indigenous knowledge. The definition given by Madhav Gadgil, states traditional knowledge as a body cumulative knowledge and beliefs systems handed down from generations to generation by cultural transmission about the relationship of human and with living beings with one another and their environment unique to a particular society or culture (Ghosh and Sahoo 2011).

The importance of TEK can be evidenced from the United Nations Convention on Biological Diversity, where Article 8(j) emphases on respecting, preserving and maintenance of knowledge practices of indigenous and local communities (Reimerson 2013). The report of the Millennium Ecosystem Assessment identified TEK as a strategically important mechanism to address the present unsustainable utilisation of ecosystem service (Karabulut et al 2019). The Intergovernmental Panel on Climate Change (IPCC) has highlighted the importance of TEK in addressing the adverse effects of climate change and sustainable maintenance of natural resources (Cooper et al 2008). Recently, the Intergovernmental Science-Policy Platform on the Biodiversity and Ecosystem Services (IPBES) has emphasised for the inclusion of indigenous and local communities' knowledge systems into ecosystem and biodiversity assessment for designing a conceptual framework (Schmeller et al 2017). An Early Warning System (EWS) is defined as the set of approaches and capacities required to generate and disseminate meaningful and timely information for extreme unforeseen events (Piciullo et al 2018). The EWS enables peoples, communities and institutions to prepare in advance for the unforeseen event and mitigate the situations through hazard preparedness strategies (Covello 2011). The traditional EWS are the systems developed by the indigenous communities to predict, forecast and disseminate the traditional practices of mitigating the grave hazards to prepare in advance by adopting locally available information systems.

MATERIAL AND METHODS

To study the traditional EWS practised by the tribal communities of the Adilabad district is based primarily on qualitative research methodology. The study is based on exploratory method, employing interview-based techniques of data collection. The fieldwork was conducted from August 2018 to July 2019 with the *Gondi* tribes. This study is conducted in Utnoor block, Adilabad district, which consists of 37 Gram Panchayats with 154 villages. Through stratified

random sampling method, the author selected ten villages for the study. The study was conducted in *Andholi, Anduguda, Birsaipet, Dhantenapalli, Lakkaram, Narsapur-J, Pulimadugu, Sakera, Salewada, Wadoni* villages. The study is based on 20 focused group discussions along with 70 individual interviews with the respondents consisting of tribal community members, local herbal healers, tribal headmen and tribal public representatives such as Sarpanches and Ward members. The data was collected from four spheres of traditional knowledge practices such as biotic knowledge sphere, hydrospheric knowledge sphere, atmospheric knowledge sphere and cosmological knowledge sphere as given in Table 1 for the study.

The Adilabad district derives its name from the then ruler of Bijapur, Ali Adil Shah. The district is located towards the extreme northern part of the Telangana state, India. The geographical coordinates of the district are located at a latitude of 19° 40′ 12.00″ North and longitude of 78° 31′ 48.00″ East. The Adilabad district is bordered by the Yavatmal district on North, Chandrapur district to Northeast, Asifabad district by the East, Mancherial district to the Southeast, Nirmal district towards the South and Nanded district of the Maharashtra state on the West. The district has a population of 7,08,972 which forms 3.13 per cent to the total population of the Telangana State. The district is divided into 18 Blocks, with 508 revenue villages (Mishra et al 2017). The Utnoor block is dominated by the tribal population and has an Integrated Tribal Development Agency (ITDA) for the welfare of the indigenous communities (Selvaraj et al 2018). The Adilabad district comprises an area of 4,153 Square Kilometers with a density of population of 170 persons per sq.km. As per 2011 census, the Scheduled Tribe population of the district is 2,24,622 which accounts for 31.68% of the district and 7.06% scheduled tribe population of the Telangana state (Government of India 2011). The major tribal communities living in the district are *Gonds, Kolams, Pardhans, Thotis, Andhs, Nayakpods* and *Lambada* communities (Suthari et al 2018). The traditional knowledge-based practices of the *Gondi* tribal community along with its associate tribal groups such as *Kolams, Pardhans, Thotis, Andhs* and *Nayakpods* were used for the study.

RESULTS AND DISCUSSION

The traditional knowledge employed by the tribal communities in Adilabad district is linked with the day by day livelihood activities of the communities (Patnaik 2010). The *Gondi* tribes of district refer disaster or hazard as "*Aapathi"*, which refers to natural and human-made disasters. The major natural hazards in the district include heavy rainfall, floods, hail storms, heavy winds, soil erosion, drought, scanty rainfall, irregular rainfall, thunder and lightning (Howk 2008). The artificial hazards in the district include forest fires, deforestation, water body's pollution, acidification and degradation of soil (Thomton and Herrero 2010). Both the natural and human-made hazards are termed into a single, holistic and interlinked concept of *aapathi*. The *Gondi* people use various methods to predict the occurrence of *aapathi* and accordingly plan for the preparedness and mitigation methods to tackle the unforeseen circumstances. The traditional knowledge used by the communities includes biotic knowledge sphere, atmospheric knowledge sphere, hydrosphere and cosmological knowledge spheres (Santha et al 2014). These four aspects related to *aapathi* observed by adult members of the tribe for predicting, forecasting and sending EWS to the community members.

Biotic knowledge sphere: The tribal community in Adilabad predicts the occurrence of rainfall by observing the movement of plants and animals. During the onset of monsoon season if ants were seen in abundance, then it is predicted to be good rainfall. For working of the EWS, if birds were seen making unusual chirping and flying, then it signifies the occurrence of rainfall within hours. If the birds were seen evacuating their nest without laying eggs, then it signifies a severe hazard in future. Abundance presence of butterfly, dragonfly, housefly and other insects signifies rainfall to come in the near future. The singing character of cricket is being observed to predict rainfall and drought, if cricket sings then, it will be rainfall and if stop singing, then it will be drought for the season. To predict rainfall for the season, tribal community people observe the nesting process of the crow, if crow catches sticks at the bottom, it will be more rainfall, and if it catches at the top, it will be predicted as drought-like situation. If the deer and other wild animals of the forest migrate to villages to drink water, it will be predicted as a drought-like situation. The abundance presence of grasshoppers suggests a more severe drought season to come in the near future. The good blossoming of *the neem* tree and good harvest for tamarind predicted as a sign for sufficient rainfall and if a mango tree gives good harvest, then it will be predicted as a drought-like situation.

The community members observe the singing and dancing of peacock during the onset of monsoon as a good sign of rainfall. If the plants and trees shed leaves early then, it will be predicted as early onset of monsoon, and if the same plants and trees show unusual flowering and fruiting, then it will be predicted as rainfall to occur within weeks. If the community members observe a large number of snakes coming out of burrows before monsoon season, then it is termed as an indication of rainfall within weeks. The group formation by goats and standing idle while grazing will be

Table 1. Indicators of early warning system used by tribal communities of Adilabad

Sources	Indicators used for prediction	Outcome of the prediction
Ants	Abundance of ants	Good rainfall to come
Birds	Evacuating nests before laying eggs	Heavy storm to occur in future
Birds	Unusual chirping and flying	Occurrence of rain
Butterfly	Abundance of butterflies	Good rainfall to come
Cat	Sneezing of cat during monsoon season	Rain to occur in future
Cow	Sitting in the pasture ground while grazing	Rainfall to occur within hours
Cricket	Singing and not singing	Rainfall to come and drought to come
Crow	Catching sticks for making nest	Catch at bottom-Good rain and at top-Bad rain
Deer	Coming to villages	Drought season
Dogs	Crying and shouting unusually in groups	Prediction for unforeseen circumstances
Dragon fly	Swarming in large numbers	Rainfall to occur within hours
Goat	Forming groups and standing while grazing	Occurrence of rainfall
Grasshoppers	Abundance of grasshoppers	Dry season or drought
Housefly	Abundance of flies	heavy monsoon and care for diseases
Insects	Appearance in large numbers	Rainfall to come
Mango tree	Good harvest	Drought to come
Neem tree	Full bloom of neem tree	Sufficient and good rainfall
Owl	Squeaking of owl during day time	Rainfall to come in a week
Peacock	Singing at the time of June	Rainfall to come
Peacock	Dancing at the time of June	Rainfall to occur within hours
Plant leaves	Early fall of leaves from plants and tree	Rainfall to come in future
Plants and Tree	Unusual and early flowering	Rainfall to come in a week
Snakes	Coming out from burrows in large numbers	Harsh weather conditions to come
Spider	Thick spider web	Heavy rainfall to come
Tamarind tree	Good harvest	Good rainfall to come
Termites	Movement in rows in large numbers	Rainfall to occur within hours
Birds	Return of migratory birds from water bodies	Prediction for rainfall
Crabs	Crabs seen on river sides	Rainfall to come
Crabs and fish	Large catch for fishermen	Prediction for rainfall
Fish	Fishermen catch more fish	Good rainfall to come
Fish	Different variety of fish seen in water bodies	Occurrence of rainfall
Frog	Big frogs occur in large and croak	Heavy rainfall to come
Prawns	Change in behavior and colour	Indication of rainfall
Tortoise	Seen at riverine side	Good rainfall to come
Water	Clear and still water in rivers and lakes	Prediction for rainfall
Water	High velocity, colour, foam, debris	Floods to come due to heavy rain
Clouds	Clouds covering sun during sunset	Heavy rainfall to come
Clouds	Thick and black clouds	Heavy rainfall to come
Clouds	Movement from west to east	Heavy rainfall to come
Clouds	White clouds along with wind during June	Prediction for rainfall
Humidity	High humidity and suffocation	Rainfall to come
Lightening	Occurrence in the month of June	Rain on way
Rainbow	Occurrence in the east during June	Good monsoon season
Wind	Occurrence of strong wind	Less rainfall
Wind	Wind blows from south west	Occurrence of cyclone
Jupiter	Ruling almanac during year	Good monsoon season
Mars	Ruling almanac during year	Very low rainfall season
Mercury	Ruling almanac during year	Good monsoon season
Moon	New moon day with clear sky	Rainfall to come
Moon	Halo effect of moon during monsoon season	Good rainfall and good harvest
Saturn	Ruling almanac during year	Very low rainfall season
Stars	Four to five stars around moon	Heavy rainfall to come
Sun	Sun rising along with moon	Rainfall to come
Sun	Sun looking like moon during sunset	Drought season
Venus	Ruling almanac during year	Good monsoon season

Source: Interview based responses from tribal communities, Utnoor, Adilabad, Telangana.State

predicted as the onset of rainfall within hours. For the tribal communities, if a cow is seen sitting in the grassland at the time of grazing, then it will be predicted as rainfall within hours. The movement of termites in large numbers and rows suggests a rainfall within a couple of hours. If the spider web is thick then termed as good rainfall, and if the spider web is thin, then it will be termed as drought-like situation. The tribal communities while observing such situations predicts the onset of rainfall or drought-like situation for better management of resources for their survival.

Hydrospheric knowledge sphere: The tribal communities in the Adilabad district predict the hazards with the observance of water bodies and its ecosystem. If the migratory birds from water sources return to their original places, then it suggested as the prediction for rainfall within weeks. If the crabs along the river come to landscapes, then it is suggested as the occurrence of rainfall within no time. Tribal community members while fishing, if they catch a large number of fish and crabs, then it is predicted as the onset of rainfall. While catching fish, if they observe a different variety of fish and it will be predicted as rainfall to come within a few weeks and there may be an incidence of floods. If the community members observe the changes in the behaviour and colour of the prawns and crabs, then it is to be termed as the onset of the monsoon season. If the community members observe the tortoise along with riverine side, then it will be termed as an indication for good rainfall. The clear and still water is seen in the rivers and lakes then it will be predicted as a time for rainfall. If the same water is seen with high velocity, different colour, heavy foam formation and occurrence of heavy debris suggests an indication of floods due to heavy rainfall.

Atmospheric knowledge sphere: The tribal people of the district predict the nature and commencement of rainfall, flood or drought by observing the characteristics of indicators from the atmosphere. The observation of clouds plays a crucial role in determining the occurrence of rainfall by the members of tribal communities. If the clouds are in white along with wind during the onset of monsoon season then will be the indication for the rainfall. If the clouds were seen covering sun during the sunset or thick clouds in black colour or movement of clouds from west to east, then it is predicted as heavy rainfall in coming days. If the movement of clouds is along with east to west, then there will be no rainfall and the drought-like situation will occur. If the community people observe that bullocks tied to plough urinate at the same time, then it will be predicted as an indication of rainfall within a day or two. If the community people observe lightning along with thunder during the onset of monsoon season, then it will be a prediction for the rainy season. The occurrence of the rainbow in the east direction before the monsoon season, then it will be termed as a good rainfall for harvest. At the time of formation of clouds if there is strong winds, then it will be termed as less rainfall and the drought-like situation. If the cloud formation is seen along with the movement of wind in a south-west direction, then it is an indication for an occurrence of a cyclone.

Cosmological knowledge sphere: The tribal communities use indicators of sun, moon, stars and other planetary indicators to predict the rainfall and drought-like situations. During the onset of monsoon season, especially on new moon day with a clear sky then it will be termed as the onset of the rainy season. If the moon during the onset of the rainy season seen with hallo effect then it will be predicted as good rainfall and bumper harvest for the season. If the community people observe a group of four to five stars around the moon before the monsoon season, then it will be treated as the occurrence of heavy rainfall in coming days. During monsoon season, if both the sun and moonrise at the same time, then it will be termed as an indication of rainfall on the way. During the sunset time, if the sun looks like a moon, then it will be an indication for a drought-like situation for the season. If the tribal members in the almanack observe the ruling of Jupiter, Mercury, Saturn and Venus, then it will be treated as good rainfall from the monsoon season. If there is a ruling of Mars in the almanack, then it will be an indication for the drought-like situation for the year. Depending on the various cosmological predictions, community members predict rain or drought-like situation and plan their adaptations to face adverse effects.

To predict, forecast and disseminate the information related to EWS, the tribal communities of the district used 47% biotic sources, 18% each for hydrospheric and cosmological sources and 16% atmospheric sources. The tribal communities adopted using biotic and abiotic sources to predict the occurrence of hazards. Various early warning system indicators used by the tribal communities include animals (06), Atmospheric sources (09), birds (07), cosmological sources (10), insects (09), plant-based (04), living beings from water (07) and water sources (02) to predict the occurrence of various types of hazards. The effective use of traditional practices can be supplemented with the scientific knowledge when both the knowledge spheres are applied together to address the imminent threats for maintenance of ecological sustainability (Elena and Sergey 2020). Evaluation of changes in global climatic conditions has become important due to the increase in floods and droughts in the past few decades (Parthiban and Amit Baburao 2020). The planning for adaptation to climate change needs a holistic approach than focusing on

compartmentalisation or distillation of knowledge which can be evidenced from the sectarian approach of scientific knowledge. The knowledge of the tribal communities with rich cultural heritage, religious wisdom and age hold history of habitat on which they are living can be used for better adaptations to climate change. For integrating tribal development, the authorities and policymaker need to understand the importance of ethics and values, culture and identity and cosmological knowledge spheres of the tribal communities to adapt right attitudes for assimilation of traditional knowledge into scientific knowledge.

CONCLUSION

The tribal communities in the study area are making use of the traditional knowledge based EWS for timely prediction, forecasting and dissemination of relevant information required by the people. The traditional knowledge-based EWS is helping the tribal communities to adapt the climate change for sustainable utilisation of the resources. The tribal communities find the use of traditional EWS beneficial and enhancing the authenticity of the cultural practices in line with modern EWS. Government authorities and institutions must conduct relevant research for understanding the importance of traditional EWS for integrating it with modern EWS for a higher rate of authenticity to the present-day warning systems. The indigenous knowledge of the tribal communities from Adilabad district depends on various ethnoecological practices for predicting and planning for adaptations to climate change. There is a need for the government, universities, research institutions and civil society organisations to take part in research and developmental aspects related to the identification and bringing the medicinal practices through scientific evidence made available to the various sections of the society. There is a need for further research to authenticate the usage of ethnoecological practices with scientific and technological inventions for better knowledge adaptations.

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REFERENCES

Berkes F 2017. *Sacred Ecology: Traditional ecological knowledge and management systems*. Routledge Publications, London, United Kingdom, p. 24.

Cooper PJM, Dimes J, Rao KPC, Shapiro B, Shiferaw B and Twomlow S 2008. Coping better with current climatic variability in the rain-fed farming systems of sub-Saharan Africa: An essential first step in adapting to future climate change? *Agriculture, Ecosystems & Environment* **126**(1-2): 24-35.

Covello VT 2010. *Strategies for overcoming challenges to effective risk communication: Handbook of risk and crisis communication*. Routledge, London, United Kingdom, pp. 155-179.

Elena VK and Sergey LA 2020. Impact of climate change on the shift of landscape and climate boundaries. *Indian Journal of Ecology* **47**(1): 17-22.

Ghosh PK and Sahoo B 2011. Indigenous traditional knowledge. *Orissa Review* **67**(6): 66-71.

Government of India 2011, *Census of India: Adilabad, Telangana State*. Ministry of Home Affairs, New Delhi, India.

Howk C 2008. *Disaster Nursing and Emergency Preparedness for Chemical, Biological, and Radiological Terrorism and Other Hazards*. *Nursing Education Perspectives* **29**(5): 304.

Karabulut AA, Udias A and Vigiak O 2019. Assessing the policy scenarios for the ecosystem water food energy nexus in the Mediterranean region. *Ecosystem services* **35**: 231-240.

Mishra RK, Krishna PS, Dubey A, Goud M and Kumari L 2017. Understanding local dimensions of migration: A case study of Adilabad District. *Indian Association of Social Sciences Institutions-Quarterly* **35**(3&4): 323-332.

Parthiban L and Amit Baburao M 2020. Evaluation of surface temperature and prediction of changes in future projections using quantile to quantile change factor Methodologyover Cauvery River Basin-Peninsular India. *Indian Journal of Ecology* **47**(2): 312-315.

Patnaik I 2010. *Distress situation in dryland areas impacts on livelihood pattern and the coping strategies: A review*. Research Unit for Livelihoods and Natural Resources, Hyderabad, India.

Piciullo L, Calvello M and Cepeda JM 2018. Territorial early warning systems for rainfall-induced landslides. *Earth-Science Reviews* **179**: 228-247.

Reimerson E 2013. Between nature and culture: Exploring space for indigenous agency in the convention on biological diversity. *Environmental Politics* **22**(6): 992-1009.

Santha SD, Gahan P and Aswin VS 2014. Local knowledge, early warning and coastal hazards: Participatory inquiry among fishworkers in Kerala, India. *Action Research* **12**(3): 273-292.

Schmeller DS, Niemelä J and Bridgewater P 2017. *The intergovernmental science-policy platform on biodiversity and ecosystem services: Getting involved*. The Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services, Bonn, Germany.

Selvaraj A, Karnan RV, Majumdar S, Divya Nancy G, Mane H, Durgulla P, Suchiradipta B and Siva Shankar A 2018. Sustainable agricultural development through value addition and linking of farmers to markets in Telangana state of India. *Advances in Research* **17**(5): 1-10.

Suthari S, Vatsavaya SR and Majeti NVP 2018. Ethnobotanical explorations in Telangana, the youngest state in Union of India: A synoptic account. *Plant and Human Health* **1**: 65-123.

Thornton PK and Herrero M 2010. *The inter-linkages between rapid growth in livestock production, climate change, and the impacts on water resources, land use, and deforestation*. The World Bank, Washington DC, United States.

Zidny R, Sjöström J and Eilks I 2020. A multi-perspective reflection on how indigenous knowledge and related ideas can improve science education for sustainability. *Science & Education* **29**(1):145-185.

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Species Composition, Diversity and Distribution along an Elevational Gradient in Oak–dominated Forests of Pir Panjal Range in Jammu and Kashmir

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Abstract: The present study was conducted to evaluate the impact of altitude on composition and diversity of Oak-dominated forests in Rajouri district of Jammu and Kashmir (India). A total of 32 woody species were encountered in the study area lying between 1200m and 2500m elevation. Three species of Oak viz. *Quercus leuchotrichophora, Q. floribunda and Q. semecarpifolia* dominant or co-dominant in the area. *Q. leuchotrichophora* shared the maximum acreage at all elevations. The associate species, however, remained changing across the elevational gradient. The phytosociological characteristics of the studied forests vary remarkably in response to changes in altitude. Stem density decreased while as total basal area was found to increase with altitude. Number of species was maximum at lowest altitude and steeply decreased with rise in altitude. Diversity indices (Margelef Index, Menhinik Index, Shanon Wiener Index, etc.) showed evident decline in their values with altitude. However an unexpected dip due to anthropogenic pressure at middle elevational range was also observed. These forests demand urgent attention for their conservation and management.

Keywords: Ecosystem, Forest, Biodiversity, Community composition, Environmental factors

Forest ecosystems are believed to be the great storehouses of biodiversity. They are evolved and influenced by a multitude of environmental factors. Flora of a place responds to and gets shaped by the changes in factors like altitude, climate, soil conditions and natural and anthropogenic disturbances. Elevation is recognized as a fundamental factor that influences forest community structure, species composition, diversity, density, regeneration and other ecological attributes of vegetation (Sharma et al 2009, Gairola et al 2011). It is one of the most important governing factors responsible for regional differences in species composition particularly in the Himalayan region (Sharma et al 2016). Vegetation composition with reference to altitude has been evaluated by several workers in parts of Jammu province (Raina and Sharma 2012, Sharma and Raina 2013), Pak administered parts of Jammu and Kashmir (Shaheen et al 2012) and Kashmir valley forests (Rather 2014). But no such study has been carried out in the Pir Panjal Himalayan range (Rajouri and Poonch districts of Jammu and Kashmir) which forms a distinct region and is even taxonomically underexplored despite its rich flora. Changes in forest composition along elevational transects in the western Himalayan region are evident in such studies but still require proper and detailed measurement (Chitale et al 2014) especially in the areas which are ecologically least investigated. Present study was undertaken to assess the effect of altitude on oak and its associate species along elevational gradient in some forests of the Pir Panjal Himalayan belt which is ecologically still underexplored. This investigation was carried out in temperate broadleaved Oak-dominated forests of Rajouri (southern slope of Pir Panjal mountain range) to assess the effects of altitude on stand structure, species composition, diversity, dispersion pattern and other ecological attributes of vegetation. Pure or mixed stands of Oak (*Quercus* spp.) form the principal floral group on the southern slopes of the range between 1200m and 3500 m elevation. The area is dominated at various altitudinal ranges (1300-3500 m) by one or the other species of oak particularly *Quercus leuchotrichophora* which is, ecologically as well as socio-economically, a highly valued plant of the region. These forests are also the main representatives of the temperate broadleaved Himalayan forests in Jammu and Kashmir. The approach adopted in this investigation is direct gradient analysis in which aspects of community composition, structure, diversity and dynamics are analysed with reference to the changes in evident ecological factors. The present work would be helpful and fundamental in generating baseline data and developing sound conservation and management strategies for the region. It may also help in understanding and predicting the biological impacts of the climate change.

MATERIAL AND METHODS

Study area: Pir Panjal Mountains, extending in a northwest

to southeast direction across Jammu and Kashmir in India, form the largest range in the western Himalayas and support wide range of vegetation including grasslands, scrubs and luxurious coniferous and broadleaved forests. The present study was carried out in Oak-dominated broadleaved mixed forests of Rajouri Forest Division (district Rajouri) of Jammu and Kashmir (India). The division, forming a part of southern slope of the Pir Panjal Himalayan range, lies between 74° 11' 03.03"E and 74° 40' 21.95"E longitude and 33° 08' 47.77"N and 33° 35' 05.16"N latitude with its altitude ranging from 1000-6000 m above sea level. Topography of the region is mountainous and varies from gentle slopes to very steep ridges. It is characterized by the presence of rich coniferous and broadleaved forests between 1000 m to 3500 m elevational range. Nearly fourteen percent (13.96%) of total forest cover in the region (Rajouri Forest Division) comprises of broadleaved forests in which Oak is, by and large, the principal species. Major slope of the catchment area is towards south and southwest and is drained by river Ans and other tributaries of the Chenab. Climate is generally mild in lower parts and harsher and cold with heavy snowfall in upper hillocks. Average annual rainfall is 1150 mm which is mainly received through southwest monsoon during July-September. Division is, administratively, divided into three forest ranges viz. Kalakote, Kandi and Rajouri. Kandi forest range was selected for the present work because it sufficiently represents the entire division in terms of topography, soil, climate and vegetation type.

Sampling and data collection: After preliminary surveying in the area, three forest sites across a wide altitudinal range (1200 m to 2500 m) were selected for the sampling. Sites were named as per their local names (Table 1). Data collection was carried out during 2017-18 using stratified random sampling technique. Twenty quadrates (each measuring 10×10 m for trees and 5×5 m for shrubs) were laid at each site for collection and subsequent analysis of phyto-sociological information. Plants with GBH (girth at breast height) more than 20 cm were considered as trees. Physiographic features (like elevation, aspect and slope steepness) were recorded using Garmin Etrex 10 GPS device.

Data analysis: Density, frequency and abundance were calculated using standard methods.

$$\text{Basal area} = \frac{(\text{cbh})^2}{4\,\Pi}$$

Where, cbh=circumference at breast height

Basal areas calculated for species were multiplied with densities of the respective species to obtain total basal area (m^2 ha^{-1}). Calculation of Importance Value Index (IVI) for trees and Provenance index (PI) in case of shrub species was done as below:

Table 1. General profile of study sites

Site	Forest	Elevational range (m)	Aspect	Slope/terrain
I	Gadyog-Kanthol	1200-1600	South western	Gentle
II	Jaglaanoo-Perinar	1600-2000	South eastern	Steep
III	Badhal-Nangathub	2000-2500	Western	Gentle

IVI=Relative Density+ Relative Frequency + Relative Dominance (for tree species)

PI= Relative density + Relative frequency (for shrubs)

Distribution pattern of all the tree species was determined by abundance/frequency (A/F) ratio (also known as Whitford Index) and was categorized as regular (if A/F < 0.025), random (if A/F between 0.025-0.05) or clumped (if A/F > 0.05). Number of species present in a forest was taken as Species Richness (SR). Margalef index (MI) and Menhinik index (MeI) of richness were calculated as MI= S-1/log N and MeI=S/√N where S=number of species and N= total number of individuals. Shannon–Wiener diversity index (H´) and Simpson's diversity index were calculated using the formulae:

$$\text{Shannon-Wiener diversity index (H')} = -\sum_{i=1}^{S} \text{pi In pi}$$

$$\text{Simpson index of diversity (SI)} = 1 - (\sum_{i=1}^{S} (\text{pi})^2)$$

where, pi is the proportion of the species and S is the number of individuals of all the species. Simpson index of diversity was expressed as 1-Cd to avoid confusion.

Peilou's index of evenness (e) was calculated as e=H´/log N, where H´ is Shannon Wiener index and N is total number of species present.

RESULTS AND DISCUSSION

Composition: A total of 32 species of trees (20) and shrubs (12) belonging to 30 genera were recorded from the entire study area. Three species of Oak viz. *Quercus leuchotriphora, Q. floribunda* and *Q. semecarpifolia* showed their dominance and/or co-dominance all across the study area. At the lowest altitude i.e., 1200-1600 m *Quercus leuchotrichophora* (IVI=148.410) was followed in terms of highest density, frequency and IVI values by *Q. floribunda*, *Pyrus pashia*, *Rhododendron arboreum* and *Punica granatum.* Among shrubs, *Berberis lycium* (PV=45.744), *Indigofera heterantha* (PV=34.308), *Rubus ellipticus* (PV=31.839), *Sarcococca saligna* (PV=26.901) were the prominent species. Mid-elevation i.e., 1600-2000 m (Table 3) showed *Quercus floribunda* becoming more prominent with

IVI=39.216 followed by *Aesculus indica* and *Rhododendron arboreum*. *Berberis lycium*, *Viburnum grandifolium*, *Elaeagnus umbellata* and *Rosa moschata* were prominent in the shrub layer.At higher elevation i.e. 200-2500 m (Table 4.), *Quercus floribunda* (IVI=54.399) became even more ubiquitous. *Q. semecarpifolia* (IVI=11.924) started appearing at this altitudinal range. *Buxus wallichiana* (IVI=31.210) was another important endemic species of this range. Other associate tree species of this altitude included *Pyrus pashia*, *Aesculus indica* and *Lyonia ovalifolia*. *Vibrnum grandiflora*, *Skimmia laureola* and *Berberis aristata* were present among shrubs.

Elevation is recognized as a fundamental factor that influences forest community structure, species composition, diversity, density, regeneration and other ecological attributes of vegetation (Scmidt et al 2006, Zhang et al 2006, Sharma et al 2009, Gairola et al 2011). This is because of its direct impact on microclimate (Adhikari et al 2015) especially in mountain regions where greater and abrupt environmental changes occur across a relatively small geographic range (Zhang et al 2006). Studies conducted in various parts of the Himalayas have indicated remarkable differences in species composition, distribution pattern and diversity attributable to altitudinal changes (Kharkwal et al 2005, Sharma et al 2009, 2010, Singh et al 2009, Acharya et al 2011, Gairola et al 2011, Adhikari et al 2015). The present study reveals that three species of Oak viz. *Quercus leuchotrichophora*, *Q. floribunda* and *Q. semecarpifolia* grow abundantly between 1300 m and 2500 m elevational zone. This is in accordance with the characteristic composition of temperate broadleaved forests of the western Himalayas where different species of oak often dominate the vegetation (Singh and Rawat 2012). Values on phytosociological aspects obtained in the present study are comparable with those observed by other workers

Table 2. Vegetation analysis of site I Gadyog-Kanthol forests

Species	Density (ha^{-1})	Total basal cover ($m^2 ha^{-1}$)	Abundance/Frequency (WI)	IVI/PV
Trees				
Quercus leuocotrichophora	440	55.617	0.054	148.410
Quercus floribunda	40	4.212	0.064	16.470
Rhododendron arboreum	40	1.561	0.025	16.369
Bombax ceiba	20	0.536	0.200	5.329
Grewia optiva	25	0.440	0.063	8.203
Pyrus pashia	110	1.696	0.036	27.495
Pinus roxburghii	50	1.248	0.125	11.941
Punica granatum	70	0.321	0.077	15.146
Ficus palmata	60	1.342	0.150	13.103
Zanthoxylum armatum	35	0.285	0.088	9.004
Celtis australis	35	0.642	0.056	10.772
Morus alba	10	0.103	0.100	3.676
Melia azadirachta	20	0.382	0.050	7.607
Ulmus wallichiana	20	0.464	0.087	6.476
Total	975	68.848		
Shrubs				
Ellaegnus umbellata	30		0.075	24.107
Ziziphus mauritiana	25		0.063	16.699
Berberis lycium	100		0.063	45.744
Carrisa spinarum	25		0.125	11.436
Indigofera heterantha	75		0.083	34.308
Rosa moschata	15		0.150	8.967
Rubus ellipticus	65		0.070	31.839
Sarcococca saligna	45		0.050	26.901
Total	405			

for similar vegetation groups in Kumaon (Singh and Singh 1986), parts of Jammu (Sharma and Raina 2013), Garhwal (Singh et al 2016), Uttrakhand (Lal and Laudhiyal 2016), Kumaon (Singh and Singh 1986), Garhwal (Singh et al 2016) and other parts of the Himalayas (Singh and Singh, 1986; Khera et al 2001, Paul et al 2019). *Q. leucotrichophora,* exhibiting highest frequency (100%), density (420 to 495 individuals/ha), basal cover (55.61 m²/ha to 87.49 m²/ha) and IVI (148.410 to 167.248), predominates the vegetation at all the study sites. This indicates wider eceological amplitude of the species and its tolerance to various biotic pressures. *Quercus floribunda* and *Q. semecarpifolia*, however, became more conspicuous respectively at middle (1600-2000 m) and higher (2000-2500 m) elevations. *Pinus roxburghii*, *Aescules indica* and *Buxus wallichiana* were the most important co-dominants at lower, middle and higher elevations respectively. Similar characteristics of vegetation have also been reported for other western Himalayan temperate forests by several workers (Sharma et al 2009, Singh et al 2009, Gairola et al 2011). Associate species like *Rhododendron arboreum*, *Pyrus pashia*, etc. were found throughout the study area (though exhibiting different values of stem density, frequency and IVI at different heights) and it signifies their wider altitudinal range and greater adaptability to varying edaphic and environmental conditions. Presence of the only conifer species intermixed with Oak at lowest altitudinal zone (bordering subtropical belt) indicates the ecotonal effect which was also responsible for the maximum number of species in this zone. On the contrary certain associate species including endemic *Buxus wallichiana* and *Q. semecarpifolia* were found only at the highest altitude due to their restricted natural range.

Total density (individuals/ha) of trees was 975, 840 and 770 at site I, II and III. Density of shrub was 380, 270 and 225 at sites I (lower elevation), II (mid elevation) and III (higher elevation) respectively. Decrease in stem density with a rise in altitude is in accordance with the trends observed by other workers in the Himalayan region (Gairola et al 2011, Acharya et al 2011, Shaheen et al 2012). Total basal area of trees was 68.84 m²/ha, 133.04 m²/ha and 100.33 m²/ha at sites I, II and III respectively. Studies indicate that total basal area increases with altitude (Gairola et al 2011). Basal cover for individual species as well for entire tree vegetation in the present was maximum at mid elevation and this is due to the presence of old growth forests.

Whitford Index (Abundance/Frequency ratio) ranged between 0.01 to 0.20 for trees and 0.03 to 0.69 for shrubs (Table 2, 3 and 4). Majority of plant species in the study area have shown clumped distribution/dispersion (indicated by WI index values) as it is very common in natural ecosystems.

Species diversity: Species richness and diversity indices varied across the stands studied, greatly from lower to middle but not much significantly between middle and higher altitudes (Table 5). 14, 6 and 7 species of trees and 8, 6 and 4 species of shrubs were found at sites I, II, III respectively. Shannon-Wiener Index was highest (1.99 for trees) at lower

Table 3. Vegetation analysis of site II Jaglanoo-Perinar forests

Species	Density (ha^{-1})	Total basal cover ($m^2\ ha^{-1}$)	Abundance/Frequency (WI)	IVI
Trees				
Quercus leuocotrichophora	495	87.496	0.010	167.248
Quercus floribunda	90	15.274	0.025	39.216
Aesculus indica	50	8.370	0.056	22.882
Lyonia ovalifolia	25	2.497	0.100	9.108
Rhododendron arboreum	85	16.681	0.033	35.423
Pyrus pashia	95	2.723	0.033	26.122
Total	840	133.041		
Shrubs				
Elaeagnus umbellata	55		0.138	32.492
Berberis lycium	75		0.047	52.020
Rubus ellipticus	40		0.044	32.997
Viburnum grandifolium	45		0.050	34.848
Rosa moschata	35		0.056	28.114
Ampelocissus latifolia	20		0.050	19.529
Total	270			

elevation and almost similar at middle (0.93) and higher altitudes (0.96). However, it gradually decreased (1.93, 1.84 and 1.34) for shrub layer moving from lower to higher elevation. Simpson's diversity index was minimum (0.70 for trees and 0.73 for shrubs) at 1200-1600 m altitudinal range. Margelef index values ranged from 0.74 to 1.88 for trees and 0.73 to 1.17 for shrubs whereas Menhenick index was between 0.20 and 0.44 for trees and 0.33 to 0.41 for shrubs, with their maximum values for trees and shrubs at lowest altitude. These values showed a decreasing trend from lower to higher altitudes. Peilou's evenness index (J') was calculated to be highest (1.20) at the middle altitude (0.49 to 0.75 for trees and 0.92 to 1.92 for shrubs). Highest values of species richness (SR) for trees (14) and shrubs (08) were at 1200-1600 m that is the lowest elevational range.

Diversity is generally believed to decrease with altitude and a similar trend was also found in the present study. A great majority of workers studying effects of altitude on vegetation in different parts of the world (Acharya et al 2011, Mota et al 2018) and particularly in the western Himalayas

Table 4. Vegetation analysis of site III Badhal-Nangathub forests

Species	Density (ha^{-1})	Total basal area (m^2 ha^{-1})	Abundance/ Frequency (WI)	IVI/PI
Trees				
Quercus leuocotrichophora	420	75.239	0.052	162.868
Buxus wallichiana	115	1.465	0.072	31.210
Pyrus pashia	55	1.095	0.061	19.345
Quercus floribunda	120	16.647	0.033	54.399
Quercus semecarpifolia	25	1.274	0.063	11.924
Aesculus indica	20	1.997	0.050	11.996
Lyonia ovalifolia	15	2.616	0.100	8.259
Total	770	100.333		
Shrubs				
Skimmia laureola	70	-	0.072	52.540
Elaeagnus umbellata	35	-	0.088	29.841
Vibrnum grandiflora	75	-	0.030	69.048
Berberis aristata	45	-	0.031	48.571
Total	225			

Table 5. Phytosociological analysis of sites

Parameter	Site I Gadyog-Kanthol forests		Site II Jaglanoo-Perinar forests		Site III Badhal–Nangathub forests	
	Trees	Shrubs	Trees	Shrubs	Trees	Shrubs
Main (Dominant) species	*Quercus leucotrichophora* (IVI=148.41)	*Berberis lycium* (PV=45.74)	*Quercus leucotrichophora* (IVI=167.24)	*Berberis lycium* (PV=52.0)	*Quercus leucotrichophora* (IVI=162.86)	*Viburnum grandifolia* (PV=69.04)
Species Richness (Total Number)	14	8	6	6	7	4
Margelef Index	1.88	1.17	0.74	0.89	0.90	0.73
Menhinik Index	0.44	0.41	0.20	0.36	0.25	0.33
Pielou Index (Evenness)	0.75	0.92	0.51	1.02	0.49	0.96
Shanon Wiener Index (H)	1.99	1.93	0.93	1.84	0.96	1.34
Simpson Index of Diversity (SI)	0.77	0.84	0.93	0.73	0.70	0.73
Total Basal area (m^2/ha)	68.84	-	133.04	-	100.33	-
Total Density (indl/ha)	975	380	840	270	770	225

(Kharkwal et al 2005, Singh et al 2009) has confirmed the decline of biodiversity with increasing elevation. Several studies, however, reported peak values of species richness at middle altitudes (Rahbek 2004, Kharkwal et al 2005). The values of diversity indices (Shanon Wiener index, Simpson index of diversity, Margalef index and Menhinik index) calculated for the study area are similar to those reported by other workers in other parts of the Himalayas (Sharma et al 2011, Sharma et al 2009 Singh et al 2016 Sharma et al 2017). The highest diversity at the lowest elevation may also be attributed to the edge effect as these sites were located just adjoining subtropical range. However it did not show a greater decline from middle to higher altitude and this can be due to low anthropogenic disturbances at the mid elevations and intense anthropogenic pressure at mid elevation.

CONCLUSION

Forest area investigated in the study is dominantly populated by at least three species of Oak almost all across the altitudinal gradient between 1300 and 2500m. Although *Quercus leuchotrichophora* grows abundantly irrespective of altitudinal zonation, its associate tree and shrub species keep replacing one another while moving across the elevational gradient. All phytosociological characteristics of the vegetation vary remarkably in response to changes in altitude. Tree species diversity decreased with altitude but an unexpected decrease at the middle range is attributed to anthropogenic pressures.

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REFERENCES

Acharya BK, Chettri B and Vijayan L 2011. Distribution pattern of trees along an elevation gradient of Eastern Himalaya, India. *Acta Oecologica* **37**(4): 329-336.

Adhikari Y, Fish A and Pauleit S 2015. Sustainable conservation perspectives for epiphytic orchids in the central Himalayas, Nepal. *Applied Ecology and environmental Research* **13**(3):753-767.

Chitale V, Behera M and Roy P 2014. Future of endemic flora of biodiversity hotspots in India. *Plos One* **9**(12): e115264.

Gairola S, Sharma CM and Suyal S 2011. Species composition and diversity in mid altitudinal moist temperate forests of the Western Himalaya. *Journal of Forest Science* **27**(1)**:** 1-15.

Gairola S, Sharma CM, Ghildiyal SK and Suyal S 2011. Tree species composition and diversity along an altitudinal gradient in moist tropical montane valley slopes of the Garhwal Himalaya, India. *Forest Science and Technology* **7**(3): 91-102.

Khera N, Kumar A, Ram J and Tewari A 2001. Plant biodiversity assessment in relation to disturbances in mid-elevational forest of Central Himalaya, India. *Tropical Ecology* **42**(1): 83-95.

Kharkwal G, Mehrotra P, Rawat YS and Pangtey YPS 2005. Phytodiversity and growth form in relation to altitudinal gradient in the Central Himalayan (Kunamon) region of India. *Current Science* **10:** 873-878.

Lal B and Lodhiyal LS 2016. Stand structure, productivity and carbon sequestration potential of Oak dominated forests in Kumaun Himalaya. *Current World Environment* **11**(2): 466.

Mota GS, Luz GR, Mota NM, Coutinho ES, Veloso MDD M, Fernandes GW and Nunes YRF 2018. Changes in species composition, vegetation structure, and life forms along an altitudinal gradient of rupestrian grasslands in south-eastern Brazil. *Flora* **238**: 32-42.

Paul A, Khan ML and Das AK 2019. Population structure and regeneration status of Rhododendrons in temperate mixed broadleaved forests of western Arunachal Pradesh, India. *Geology, Ecology and Landscapes* **3**(3):1-19.

Rahbek C 2004. The role of spatial scale and the perception of large-scale species-richness patterns. *Plant Ecology* **8**(2): 224-239.

Raina A and Sharma N 2012. Species composition and diversity of tree species along an altitudinal gradient in Sewa catchment of north-western Himalayas, Jammu and Kashmir, India, *Journal of Applied and Natural Science* **13**(1-2): 173-179.

Rather HA 2014. *Plant diversity and regeneration status in Kandi range of Kamraj forest division of Kashmir*. Ph. D thesis, Sher-e-Kashmir University of Agricultural Sciences and Technology of Kashmir**.**

Schmidt I, Zebre S, Betzin J and Weckesser M 2006. An approach to the identification of indicators for forest biodiversity in the Solling mountains (NW Germany) as an example. *Restoration Ecology* **14**(1): 123-136

Shaheen H, Ullah Z, Khan SM and Harper DM 2012. Species composition and community structure of western Himalayan moist temperate forests in Kashmir. *Forest Ecology and Management* **278**: 138-145.

Sharma CM, Ghildiyal SK and Gairola S 2009. Vegetation structure, composition and diversity in relation to the soil characteristics of temperate mixed broadleaved forest along an altitudinal gradient in Garhwal Himalaya. *Indian Journal of Science* **2**(7): 39-45.

Sharma CM, Baduni NP and Gairola S 2010. Effects of slope aspects on foest compositions, community structures and soil properties in natural temperate forests of Garhwal Himalaya. *Journal of Forestry Research* **21**(3): 331-337.

Sharma CM, Gairola S, Baduni NP, Ghildiyal S and Suyal S 2011. Variation in carbon stocks on different slope aspects in seven major forest types of temperate region of Garhwal Himalaya, India. *Journal of Biosciences* **36**(4): 701-708.

Sharma N and Raina AK 2013. Composition, structure and diversity of tree species along an elevational gradient in Jammu province of north-western Himalayas, Jammu and Kashmir, India. *Journal of Biodiversity and Environmental Sciences* **3**(10): 12-23.

Sharma CM, Mishra AK, Prakash O, Dimri S and Baluni P 2014. Assessment of forest structure and woody plant regeneration on ridge tops at upper Bhagirathi basin in Garhwal Himalaya. *Tropical Plant Research* **1**(3): 62–71.

Sharma CM, Mishra AK, Krishan R, Tiwari OP and Rana YS 2016. Impact of climate on structure and composition of Ridge Top forests in Garhwal Himalaya. *Taiwan* **61**(1): 6 1-69.

Sharma C, Mishra A, Tiwari O, Krishan R and Rana Y 2017. Effect of altitudinal gradients on forest structure and composition on ridge tops in Garhwal Himalaya. *Energy, Ecology and Environment* **2**(6): 404-417.

Singh JS and Singh SP 1986. Structure and function of the Central Himalayan Oak forests. Proceeding of Indian National Science Academy *Plant Science* **96**(3): 156-189.

Singh H, Kumar M and Sheikh MA 2009. Distribution pattern of Oak and Pine along altitudinal gradients in Garhwal Himalaya. *Nature and Science* **7**(11): 81-85.

Singh G and Rawat GS 2012. Depletion of oak (*Quercus* spp.) forests in the western Himalaya: Grazing, fuel wood and fodder collection. *Global Perspectives on Sustainable Forest Management 29*-42.

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Singh S, Malik ZA and Sharma CM 2016. Tree species richness, diversity, and regeneration status in different oak (*Quercus* spp.) dominated forests of Garhwal Himalaya, India. *Journal of Asia-Pacific Biodiversity* **9**(3): 293-300.

Zhang JT, Ru W and Li B 2006. Relationships between vegetation and climate on the Loess Plateau in China. *Folia Geobotanica* **41**(2): 151-163.

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Plant Diversity in The Natural Ecosystems of Kon Tum Province, Vietnam

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Abstract: Kon Tum Province is known as one of the largest forested areas in Vietnam. Besides, due to being located in the Central Highlands region, the flora is influenced by the interference between the geographic factors of North Vietnam - South China, Equator - Himalaya, Malaysia, tropical and endemic factors. These geographical factors make the flora here not only diverse in species composition but also diverse in lifeforms. The study on diversity of species composition in Kon Tum province during the period of 2014 - 2019 collected 1541 plant species, belonging to 749 genera, 177 families, 59 orders, 10 classes and 6 divisions. Research on the lifeforms (spectrum biology) using Raunkiaer's formula also showed that the distribution is consistent with the ratio in the standard lifeform of Vietnam and North Vietnam with the dominant group of Phanerophytes (Ph). The studied flora belongs to the tropical moist rain flora. Kon Tum province's flora is distributed in four natural forest types, evergreen rainforest, mixed broadleaf and coniferous forest, mixed tree-bamboo forest and coniferous forest. These types of forests are classified by topographic elevation.

Keywords: Biodiversity, Vietnam, Forest, Diversity, Ecosystem

Plants are an important component in the formation of ecosystems and are the basis of the food chain, taking energy from the sun and converting it into food for all other organisms through photosynthesis (Abid and Sarvajeet 2016). Plants also play an important role in the energy flow and biochemistry of nutrients between terrestrial and aquatic ecosystems and plant diversity is important tool to assess the status, diversity as well as resilience of ecosystems (Ran and John 2019). Study about plant biodiversity is defined by the variety in all the plant-taxonomic categories (species, genera, families, orders, etc.) and by the variety of ecosystems and plant communities to which they belong (Pullaiah et al 2015). There are many ways of plant diversity research being used. To clarify the characteristic properties of the vegetation, density and diversity measures were calculated for tree, sapling and seedling layers. For example, in the study of plants in Uttarakhand, Central Himalaya, India, the authors have shown a significant negative relationship between altitude and species richness, indicating a gradual decrease in richness with increasing altitude (Vijay et al 2017). In addition, biodiversity indices such as the Shannon-Weiner index and the Simpson index are also used to assess tree species composition and diversity of a community reserve forest (Ningthoujam et al 2018). On the practical significance, research on plant diversity is also an important economic basis for the country's sustainable development. There is increasing interest in biodiversity, its dynamics and contributions to rural livelihoods.

Kon Tum is a mountainous province in the Central Highlands region of Vietnam with a total area of 9716.83 km². Kon Tum province has an average height of 500 to 700 meters above sea level (a.s.l), the North has an altitude of 800 - 1200 meters a.s.l. The highest place is Ngoc Linh peak with the height of 2598 meters a.s.l (Nguyen and Kuznetsov 2016). Due to the influence of geographic location and strong differentiation of topography, apart from the typical plant elements of Vietnam, the flora of Kon Tum province has the characteristics of intersecting the flora of Northern Vietnam - South China and the tropical flora of India - Southeast Asia. Besides, the elements of tropical monsoon climate together with the plateau climate also have important effects on the flora. It can be said that geographic and climatic factors are the cause for Kon Tum to become one of the regions with the largest vegetation areas as well as the most diverse species composition in Vietnam.

However, along with economic development, human activities have had an impact on forest ecosystems. The vegetation not only changes in area, changing from one forest type to another, but also the composition of plant species is also affected. Therefore, it is necessary to study the status of plant species composition as a basis for proposing policies to conserve and develop biodiversity in

the region. This is also the scientific base for local socio-economic sustainable policies in the current climate change situation. With the purpose of contributing to strengthening the database serving the conservation and sustainable development of Kon Tum province, the authors have conducted research on the diversity of plant components in natural forest ecosystems.

MATERIAL AND METHODS

Study area: The study was conducted from 2014 to 2019 in the territory of Kon Tum province with an area of 9716.83 km^2. In which the survey focused on areas with natural forests of about 6400km^2. Areas with concentrated natural forests in Chu Mom Ray National Park, Ngoc Linh Nature Reserve and Thach Nham Special Use Forest. Most of Kon Tum territory is located in the west of Truong Son mountain range, the terrain is lower from north to south and from east to west, steep in the north and slope in the south. Diverse terrain, hills, mountains, plateaux, and valleys are alternately complicated. The North has Ngoc Linh peak and is the highest peak in Central Highland Vietnam with the height of 2598m. The average height in the north is from 800-1200m, in the south is only 500-700m. The terrain has a slope of more than 15 degrees, accounting for nearly two thirds of the total territory. Meanwhile, the terrain has a slope of less than 8 degrees, accounting for 28.91% of the area, most of which are basalt plateaus and valleys between mountains. On this type of terrain are mainly residential land, agricultural land, shrubs, grasslands, land with agricultural capacity. Due to the specific nature, climate of Kon Tum province has a common feature of the tropical monsoon climate region of Southern Vietnam and features the climate of the plateau (Nguyen and Kuznetsov 2016). The total annual temperature reaches 8000-8500°C, the annual average temperature in the low areas (below 600m) to reach 22 – 25°C and decreases gradually with the increase of the terrain height. The average rainfall in 1880mm. However, rainfall varies according to place and time. There is an area of abundant rainfall and reaches 2000-2500mm, even in the top of Ngoc Linh Mountain, the rainfall is over 2500mm. The outstanding feature is the rainy season lasting 4-6 months (from November to April next year). Humidity decreases sharply over time; large evaporation causes drought in areas without vegetation cover.

Due to the nature of the natural forest ecosystems of Kon Tum province, it is concentrated in the protected areas. Therefore, the field survey process was focused on Chu Mom Ray National Park and Thach Nham Special Use Forest from 2014 to 2017, Ngoc Linh Nature Reserve from 2018 to 2019. Field survey methods were based on the guidance of Nguyen Nghia Thin in "The Handbook of Biodiversity Research" (Nguyen 1997) and "The tropical forest ecosystems" (Nguyen 2004), applied to research biodiversity, especially plant diversity in Vietnam. The process consists of steps: identifying the survey area, establishing survey routes and sites, surveying plant communities, collecting and preserving plant samples. Phytogeography methods were used to study the structural features of the species composition and spatial structure of vegetation. The documents of Pham Hoang Ho (Pham 1999) were used to determine the nomenclature of plant species in Vietnam. Plant profiles describe the characteristics of woody plants, canopy, shrubs, grasses, and topography.

Plant lifeforms were determined according to Raunkiaer (1934) and refer to information on lifeforms determined according to research documents of Vietnamese authors. Some Basic Characters of Vietnam flora (Le 1999), checklist of plant species of Vietnam (Nguyen 2005), An Illustrated Flora of Vietnam (Pham 1999). The forest vegetation in Vietnam (Thai 1978). Mapping method and geographic information system (GIS) were applied to identify field survey routes, plots on the map. These methods were also used to collect and build a system of data on geology, topography, soil, to establish the map of forest ecosystems. The results of field surveys help develop a map of vegetation distribution in Kon Tum province. The topographic maps with a scale of 1/25000, GPS devices were used and SPOT remote sensing images to determine the location and boundaries of key points and survey routes in accordance with topographic differentiation, elevation, and plant communities.

RESULTS AND DISCUSSION

Diversity of plant species: Kon Tum province has a very diverse and rich flora with 1541 recorded species, belonging to 749 genera, 177 families, 59 orders, 10 classes, 6 divisions, including: Equisetophyta, Psilotophyta, Lycopodiophyta, Polypodiophyta, Pinophyta and Magnoliophyta. Magnoliophyta dominated with 1336 species, belonging to 658 genera and 145 families, accounting for 86.7% of the total species, 87.85% of the total genera and 81.92% of the total plant families of the entire Kon Tum flora. In particular, the taxon is mainly concentrated in Magnoliopsida class, with 1054 species, accounting for 68.4% of the total number of species. Polypodiophyta are also diverse with 175 species, accounting for 11.36%, the lowest is the two divisions Equisetophyta, Psilotophyta has only 1 species (Table 1).

Kon Tum flora is one of the component units in the Vietnamese flora. To evaluate the correlation with Vietnamese flora, two systems were compared (Table 2).

The Kon Tum flora has plant components belonging to all plant divisions in the Vietnamese flora system. The comparison results show that the proportion of all divisions in the Kon Tum flora and the Vietnamese flora (Le 1999, Pham 1999) has a similar proportion to the absolute dominance by Magnoliophyta with 86.7% (Kon Tum) and 92.62% (Vietnam).

From the result of comparing the ratio between two classes of Magnoliophyta division it can be understood that for every 3.74 species of Magnoliopsida, 1 species belongs to Liliopsida (Table 3). This ratio increases gradually to the spending genus of 3.91/1 and the family of 6/1. These ratios represent the dominance of Magnoliopsida over Liliopsida. In the Vietnamese flora, this ratio is 3.2/1, in some areas of Northern Vietnam is 3.8/1. This result affirms that Kon Tum flora is influenced by climate and topography but still has the nature of a tropical flora. In each study area, taxons with the most common number of species are considered to be typical taxons for the flora in that area.

The 10 most diverse plant genera with 134 species, accounting for 8.7% of the total number of species of the Kon Tum flora (Table 4). In particular, *Dendrobium* (Orchidaceae) and *Ficus* (Moraceae) are the two most diverse genera with 19 species, accounting 1.23% of the total number of species. Among diverse genera, least affected tropical forests were *Ficus, Dendrobium, Vaccinium, Lithocarpus*. This result also partly reflects the tropical properties of Kon Tum flora. There were 27 families with 15 or more species accounting for 374 genera (49.93% of the total number of genera) and 851 species (55.22%). Although 10 families account for only 5.65% of the total families of the entire Kon Tum flora, the number of species reaches 510 species (33.1%) and 233 genera (31.11%) (Table 5).

The most diverse families in Kom Tum are also among the most diverse families of Vietnam's flora. Especially among these many families with the presence of numerous members representing the mountain rainforest such as: Fagaceae, Lauraceae, Acanthaceae. Thus, this can be considered as the face of the flora typical for the tropical monsoon climate in Kon Tum and the Central Highlands.

Table 2. Comparison of flora in Kon Tum and Vietnam

Division	Province Kon Tum		Viet Nam	
	No. of species	Per (%)	No. of species	Per (%)
Psilotophyta	1	0.06	1	0.009
Lycopodiophyta	13	0.06	53	0.48
Equisetophyta	1	11.36	2	0.02
Polypodiophyta	175	0.84	698	6.26
Pinophyta	15	0.97	69	0.62
Magnoliophyta	1336	86.70	10330	92.62
Total	1451	100	11153	100

Diversity of plant lifeforms: Determining the lifeform spectrum for the Kon Tum flora contributes to clarifying the ecological characteristics of the flora. The classification of lifeform groups was applied according to Raunkiaer's classification system (1934) and reference to some research results of Vietnamese authors (Table 6).

***Phanerophytes* (Ph)**: A group of plants with buds lying on the ground from 0.25m to over 30m. This group plays a key role in the Kon Tum flora with 1007 species, accounting for 605.35%. They participate in most of the forest canopy. Based on species biology, this species distribution is classified into lifeforms, each playing a certain role in the forest structure. The Phanerophytes group consists of the following subgroups:

***Megaphanerophytes* (Mg):** Trees with buds above 30m. 40 species have been identified, accounting for 2.6% of the total number of species. Recorded with representatives:

Table 1. Statistics of plant diversity in Kon Tum province

No	Division	Class	Order		Family		Genus		Species	
		N	N	%	N	%	N	%	N	%
1	Equisetophyta	1	1	1.69	1	0.56	1	0.13	1	0.06
2	Psilotophyta	1	1	1.69	1	0.56	1	0.13	1	0.06
3	Polypodiophyta	2	8	13.56	22	12.43	75	10.01	175	11.36
4	Lycopodiophyta	1	2	3.39	2	1.13	4	0.53	13	0.84
5	Pinophyta	3	3	5.08	6	3.39	10	1.34	15	0.97
6	Magnoliophyta	2	44	74.58	145	81.92	658	87.85	1336	86.70
6.1	*Magnoliopsida*		*34*	*57.63*	*122*	*68.93*	*524*	*69.96*	*1054*	*68.40*
6.2	*Liliopsida*		*10*	*16.95*	*23*	*12.99*	*134*	*17.89*	*282*	*18.30*
	Total	10	59		177		749		1541	

Trigonobalanus verticillata, *Cinnamomum balansae*, *Michelia foveolata*, *Aglaia spectabilis*, *Toona surenei*, *Syzygium cumini*, *Madhuca pasquieri* and some species of Pinaceae, Podocarpaceae, Fagaceae. In vertical forest structure, this is a group of species forming emergent layers.

***Mesaphanerophytes* (Me):** Trees with buds from 8 to 30m. There are 269 species, accounting for 17.46% of the total species. This lifeform appears in 40 families in Pinophyta and Magnoliophyta. The families with the most species are: Lauraceae (22), Fagaceae (21) Meliaceae (16), Moraceae (12), Theaceae (9) with representatives: *Beilschmiedia percoriacea*, *Litsea glutinosa*, *Phoebe lanceolata*, *Lithocarpus corneus*, *Lithocarpus longipedicellatus*, *Quercus kontumensi*

***Microphanerophytes* (Mi):** Trees with buds from 2 to 8 meters include 205 species, accounting for 13.3%. This group of trees is mainly shrubs that grow scattered under the forest canopy to form understory layers in the vertical structure. Including 21 plant families with representative species such as: *Schefflera kontumensis*, *Scheffleropsis angkae*, *Rhododendron excelsum*.

***Nanophanerophytes* (Na):** Trees with buds from 0.25 to 2m have 118 species, accounting for 7.66%. This is a group of shrub trees with the following representatives: *Macropanax grushvitzkii*, *Aralia armata*, *Brassaiopsis acuminate*, *Ardisia aciphylla*, *Ardisia cambodiana*, *Ardisia elegans*, *Ixora dolichophylla*

***Epiphytes* (Ep):** There are 137 species, accounting for 8.89% of the total number of species. These species have the most diverse habitats and showed adaptability to different habitats (for example, living on rocks or trunks). Among these species, the most abundant family belongs to Orchidaceae

Table 5. Most diverse families in the flora of Kon Tum province

Family	Genus	Genus (%)	Species	Species (%)
Orchidaceae	46	6.14	133	8.63
Asteraceae	40	5.34	69	4.48
Rubiaceae	27	3.60	64	4.15
Fabaceae	28	3.74	53	3.44
Euphorbiaceae	22	2.94	43	2.79
Fagaceae	4	0.53	30	1.95
Lauraceae	12	1.60	30	1.95
Poaceae	25	3.34	30	1.95
Polypodiaceae	16	2.14	30	1.95
Acanthaceae	13	1.74	28	1.82

Table 6. Statistical results of plant lifeforms in Kon Tum province

Lifeform	Code	No. of species	Percent
Phanerophytes	Ph	1007	65.35
Megaphanerophytes	Mg	40	2.60
Mesaphanerophytes	Me	269	17.46
Microphanerophytes	Mi	205	13.30
Nanophanerophytes	Na	118	7.66
Epiphytes	Ep	137	8.89
Parasite	Pp	19	1.23
Liannes	Lp	148	9.60
Herbaceous	Hp	71	4.61
Chamaephytes	Ch	124	8.05
Hemicryptophytes	Hm	219	14.2
Cryptophytes	Cr	122	7.92
Therophytes	Th	69	4.48

Table 3. The ratio of the two classes Magnoliopsida and Liliopsida

Taxon	Family		Genus		Species	
	No. of species	Per (%)	No. of species	Per (%)	No. of species	Per (%)
Magnoliophyta	145	100	574	100	1.039	100
Magnoliopsida	122	84.14	455	79.64	819	78.89
Liliopsida	23	15.86	119	20.36	220	21.11
Magnoliopsida/Liliopsida	5.3		3.91		3.74	

Table *4*. Most diverse genera in the flora of Kon Tum province

Genus	Species	Percent	Sr. no	Genus	Species	Percent
Ficus	19	1.23	6	Elaeocarpus	11	0.71
Dendrobium	19	1.23	7	Bulbophyllum	11	0.71
Ardisia	15	0.97	8	Pteris	11	0.71
Blumea	13	0.84	9	Hedyotis	11	0.71
Lithocarpus	13	0.84	10	Symplocos	11	0.71

(87 species), Polypodiaceae (26 species). Representatives for Epiphytes: *Aerides falcata*, *Coelogyne stricta*, *Cymbidium mastersii*, *Monomeria barbata, Aglaomorpha coronans*, *Drynaria bonii*

***Parasite* (Pp):** 19 species, accounting for 1.23% of species recorded and distributed in 3 families. Although accounting for a low proportion in the living structure, it has contributed to increasing the diversity of this flora. The most abundant family belongs to Loranthaceae, Asclepiadaceae, Viscaceae and Santalaceae with 5,4, 2 and 1 species respectively.

***Liannes* (Lp):** 148 species were recorded, accounting for 9.6% of the fauna including 18 families. The low ratio of this lifeform demonstrates the high primitive nature of the forest ecosystems in the study area.

***Hemicryptophytes* (Hm)**: There are 219 species, accounting for 14.2% of the total species and are present in 22 families. This lifeform group is the main factor that forms the forest floor. Including some of the most numerous families such as Orchidaceae (19 species), Asteraceae (18 species), Poaceae (13 species). Some representatives were: *Sorghum serratum, Digitaria ciliari, Kyllinga cylindrica*, *Fimbristylis complanata, Lipocarpha chinensis, Hedyotis corymbosa, Borreria articularis.*

***Chamaephytes* (Ch)**: including 123 species accounting for 8.05% of total species, distributed in 7 families with representatives of species *Argyreia lanceolata, Ardisia florida, Porana racemosa, Tadehagi triquetrum, Passiflora foetida*

***Cryptophytes* (Cr)**: recorded 122 species belonging to 18 families accounting for 7.92% of the total species of the system. The dominant families include Orchidaceae, Araceae, Zingiberaceae with representatives: *Schismatoglottis cadieri*, *Arisaema balansae*, *Homalomena occulta, Sphenomeris chinensis*, *Pteridium aquilinum*; *Drynaria fortunei, Cymbidium insigne*

***Therophytes* (Th)**: This group has 69 species, accounting for 4.48% of the total species, including some families with many species such as Asteraceae, Poaceae, Lamiaceae. Together with the group of Hemicryptophytes, they have contributed to the formation of forest floor. This indicate that ecological conditions in the region are relatively favourable for plant growth, because a high percentage of Therophytes will indicate the greater severity of the habitat. Based on the analysis of lifeform data according to Table 6, we have formulated the lifeform spectrum for the flora of Kon Tum province as follows:

SB (Spectrum Biology) = 65.35 Ph + 8.05 Ch + 14.2 Hm + 7.92 Cr + 4.48 Th

The results were compared with Vietnamese plant lifeforms by Le Tran Chan (Le TC 1999), the Raunkiaer standard life form (1934) and the tropical rainforest lifeform of Richard P W (1996) (Table 7). The proportion of the groups according to the lifeform spectrum of the Kon Tum flora distributed in accordance with the standard life form of Raunkiaer and Vietnam, in which the Phanerophytes group predominated over the remaining groups. Compared with Richard's tropical rainforest lifeforms, it shows that Kon Tum flora has the characteristics of moist tropical rainforests with the proportion of Phanerophytes predominating isolated from other groups.

The Kon Tum flora is less affected and still has primary features. The relatively stable forest structure is shown by the high proportion of Phanerophytes (Ph) (65.35%); especially Liannes group (Lp) accounts for a very low rate (9.6%). The Cryptophytes and Therophytes were low (7.92% and 4.48%). These groups commonly found in places with less favourable habitat for plant species to grow and develop.

Current status of forest ecosystems: Diversity of plants, geographical factors and climate have contributed to the formation of typical forest ecosystems in Kon Tum Province. Based on the field survey, combined with the methods of mapping and GIS by using MapInfo program, status map of typical forest ecosystems of Kon Tum province was developed (Fig. 1). From the MapInfo program, the area of the ecosystems has been specified (Table 8).

The natural ecosystems of Kon Tum Province still predominate over the anthropogenic ecosystem. The area of natural forest ecosystems accounts for 62.81% of the total territory. In particular, the area of evergreen broadleaf forest is dominant. The total area distributed in the low mountains and high mountains is 453345.09 hectares (47.17%). In terms of distribution, evergreen broad leaf rainforest on high mountains and mixed broadleaf and coniferous forest are concentrated in the East - Northeast of the province. There is also a small area of mixed tree and bamboo forest also distributed here. The southern region has low topography so evergreen broadleaf rainforest on low mountain and mixed tree-bamboo forests appear here. Other types of ecosystems are scattered throughout the study area and highly

Table 7. Comparison life form spectrum

	Life form				
	Ph (%)	Ch (%)	Hm (%)	Cr (%)	Th (%)
Kon Tum	65.35	8.05	14.2	7.92	4.48
Vietnam	54	10	20.4	10.3	5.3
Standard life forms (Raunkiaer)	46	9	26	6	13
Tropical rainforest life form (Richard)	88	12	0	0	0

Table 8. Statistical area of ecosystems in Kon Tum Province (2019*)*

Ecosystems	Area (hectares)	Per cent
Evergreen broadleaf rainforest on high mountains (upper 1000m)	270178.17	28.11
Mixed tree and bamboo forest on high mountains (upper 1000m)	4544.57	0.47
Evergreen broadleaf rainforest on low mountains (under 1000m)	183166.92	19.06
Mixed tree and bamboo forest on low mountains (under 1000m)	46298.32	4.82
Mixed broadleaf and coniferous forest	27799.94	2.89
Bamboo forest	71649.75	7.45
Grass and shrubs	16181.96	1.68
Agricultural	323122.97	33.62
Aquatic	18180.60	1.89
Total	961123.20	100.00

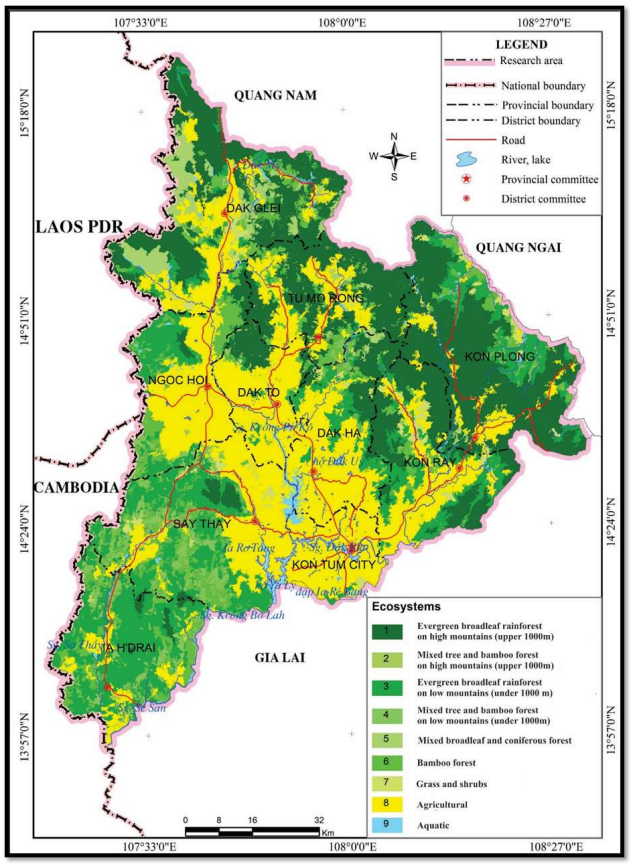

Fig. 1. The map of forest ecosystems in Kon Tum Province (2019)

fragmented because they are often influenced by anthropogenic activities.Besides, the agricultural ecosystem is an anthropogenic ecosystem that is closely related to natural ecosystems. Increasing the area of this ecosystem also means the decrease of the area of natural ecosystems. Within the study territory, this ecosystem is concentrated mainly in the centre of Kon Tum province with a total area of 33.62%. The distribution of this ecosystem depending on the aquatic ecosystems in the region. At the same time, this is also a relatively flat terrain to facilitate agricultural development. In addition, fragmentation of agricultural ecosystems in natural ecosystems is visible. Small areas of agriculture land mixed with broadleaf evergreen rainforests and mixed tree and bamboo forests appear more in the southern region and a few areas in the north-northeast. These are mostly areas of natural forests that have been converted into agricultural land under human impacts. This shows that the demand for land use of people for economic purposes is on the rise.

CONCLUSION

Kon Tum province's flora is one of Vietnam's diverse flora with 1541 species, belonging to 749 genera, 177 families, 59 families, 59 classes, 6 divisions have been recorded. The proportion of divisions in the Kon Tum flora and Vietnamese flora is similar to the absolute dominance by Magnoliophyta with 1336 species, of 658 genera and 145 families. The ratio between Magnoliopsida and Liliopsida also shows that Kon Tum flora, although affected by climate, topography, still has the nature of a tropical flora.Based on the analysis of lifeform data, the research flora is characterized by tropical rain and moisture with the proportion of Phanerophytes predominating from other groups in the overall lifeforms of the flora. This is shown by the formula:

SB (Spectrum Biology) = 65.35 Ph + 8.05 Ch + 14.2 Hm + 7.92 Cr + 4.48 Th

The tropical flora less affected and still has primitive features and relatively stable forest structure expressed by a high proportion of Phanerophytes (Ph). In addition, Cryptophytes and Therophytes have low rates which also represent this is a favourable habitat for plant growth and development. The evergreen broadleaf rainforest is dominant in the study area. However, natural forests are affected under

human impacts. Although the agricultural ecosystem is distributed in the central area of Kon Tum province, there are still fragmented areas interspersed in natural ecosystems. Therefore, there should be reasonable policies to protect the natural ecosystems and at the same time ensure sustainable development of livelihoods for the residents.

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REFERENCES

Abid A and Sarvajeet G 2016. *Plant Biodiversity: Monitoring, Assessment and Conservation*, CABI, Egham, UK, p 628.

Le TC 1999. *Some Basic Characters of Vietnam Flora*, Science and Technics Publishing House, Hanoi, Vietnam, p 307. (In Vietnamese)

Nguyen DH and Kuznetsov AN 2016. Structural characters of forest landscapes in Ngoc Linh Natural Reverse, Kon Tum province, pp.386-392. **In:** Nguyen C H and Pham H H (eds), Proceedings of the 9th *National Scientific Conference on Geography*, December 24-25, 2016, Quy Nhon University, Quy Nhon City, Vietnam. (In Vietnamese)

Nguyen KV, Nguyen TH, Phan KL and Nguyen TH 2010. *Climate charts of Vietnam*, Publishing house of Hanoi National University, Hanoi, Vietnam, p 126 (in Vietnamese and English).

Nguyen NT 1997. *The handbook of biodiversity research*, Agricultural Publishing House, Hanoi, Vietnam, p 223.

Nguyen NT 2004. *The tropical forest ecosystems*, VNU Publishing House, Hanoi, Vietnam, p 248.

Nguyen TB 2005. *Checklist of Plant Species of Vietnam*, Agriculture Publishing House, Hanoi, Vietnam, p 1248.

Ningthoujam LD, Dipendra S and Tripathi SK 2018. tree species composition and diversity in tropical moist forests of Mizoram, Northeast India. *Indian Journal of Ecology* **45**(3): 454-461

Pham HH 1999. *An Illustrated Flora of Vietnam*, Tre Publishing House, Ho Chi Minh City, Vietnam, p 1776 (in Vietnamese and English).

Ran W and John G 2019. Remote sensing of terrestrial plant biodiversity. *Remote Sensing of Environment* **231**. DOI: 10.1016/j.rse.2019.111218

Raunkiær C 1934. *The Life Forms of Plants and Statistical Plant Geography*, Oxford University Press, Oxford, UK, 632 p.

Richards PW 1996. *The tropical rain forest: an ecological study*. Cambridge University Press, Cambridge, UK, 575 p.

Thai VT 1978. *The forest vegetation in Vietnam*, Science and Technical Publishing House, Hanoi, Vietnam, 276 p.

Vijay A, Balwant K and Rawat JS 2017. Tree species diversity, community composition and distribution across six forest stands of Uttarakhand, Central Himalaya, India. *Indian Journal of Ecology* **44**(4): 722-728.

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Forest Dependence, Institutions and Enforcement: An Empirical Study in the Drought Prone District of Purulia, West Bengal

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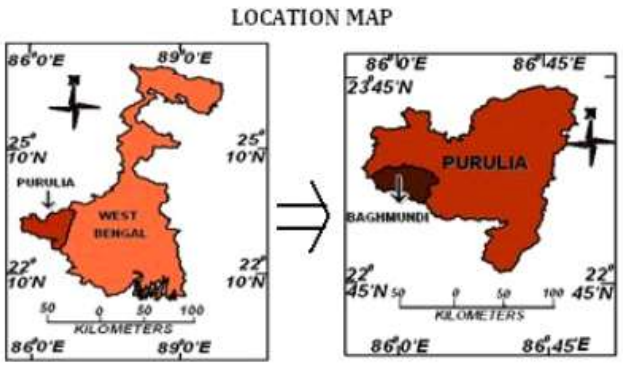
Abstract: The paper attempts to measure forest dependence by constructing a forest dependence index based on forest product collection for meeting livelihoods and to examine how village level forest institutions and enforcement have impacted on forest dependence index. Besides, the paper tries to identify the factors influencing forest dependency and its implication for forest conservation. The present paper is based on primary data collected from the Purulia forest division in the district of Purulia, one of drought prone districts of West Bengal during the month of January, 2020. A multistage sampling technique and questionnaire method are followed for data collection. In the field survey, nine villages and 252 households are involved. Forest dependence index was 0.38 and more than 60 percent of households are highly forest dependent. The forest dependence index is influenced by caste, agricultural employment, off-farm employment, forest income, institutional and enforcement indices. There existed strong forest governance implying that institutions and enforcement have efficiently worked to prevent high forest dependency. This paper has important policy implication for forest conservation, the creation of alternative employment and income from off-farm sectors.

Keywords: Forest dependency index, Forest products collection, Off-farm sector, Institution, Enforcement, Forest conservation

In India 350 million people (27% of total population) are dependent on forest for livelihood generation. Most of them are poor and underprivileged like tribal and others. In most of the developing countries, the local poor people are dependent on forest products like food, fuel wood, fodder, timber, medicine etc. from which they generate cash income as well as meeting subsistence needs (Angelsen et al 2014, Mukul et al 2016). In addition, all over the world, more than 2 billion people depend on forests resources for their livelihoods, and to meet their primary energy demands (IPBES 2019).India has already enacted more than 200 laws for protecting the environment (Sandhu and Sidhu 2015). Local institutions have a significant role for forest conservation. The institutions at the local level are Joint Forest Management Committees (JFMC), Community Forest Management groups (functioning in Orissa), Van Panchayats (functioning in Uttarakhand), traditional village level institutions or Village Councils (schedule VI area) and Biodiversity Management Committees, Forest protection committee (in West Bengal) etc. There are some governmental initiatives like Forest Conservation Act 1980, Wild life Protection Act 1972, Joint Forest Management 1991 and Green India Mission 2011 for sustainable forest management. The Scheduled Tribes and Other Forest Dwellers (Recognition of Forest Rights) Act, 2006, in addition to individual rights, provides for Community Forest Rights, including the right to protect, regenerate and manage community forest resource. A lot of researchers have studied the role of the forest resources and institutions from different perspectives. Forest plays multifunctional role in terms of providing environmental services (Adhikari 2005), in terms of household's income generation in Africa and Asian countries including India (Babulo et al 2008, Bwalya 2013, Cordova et al 2013). Forestsalso act as safety nets of the rural poor and aspoverty alleviation strategies (Sunderlin et al 2004, Nielsen et al 2012). Forests are open access resources which governed by institutions and enforcement. Appropriate monitoring and enforcement by community-based institutions and forest governance prevent deforestation (Ostrom and Nagendra 2006, Nagendra and Gokhale 2008). Given the backdrop, the objectives of the paper are twofold. First is to construct forest dependence index, institutional index and enforcement index of the households who are living in the forest fringes villages in the district of Purulia, West Bengal. Second is to estimate the factors influencing forest dependency at the household level and its implication for forest governance.

MATERIAL AND METHODS

Study area: The study has been conducted in the district of Purulia, one of the drought prone districts of West Bengal, India. This district is the western part of West Bengal (Fig.1). The district is poverty proneand the poverty rate in this district is 32.7% (Census 2011). The forest area of this district is 14%



Source: Roy and Jana (2015)

Fig. 1. Location of the study area of Purulia district and Baghmundi Range office

of its geographical area. The number of forest protection committees (FPCs) under Purulia forest division is 213 as of 2015. About 30729.22 hectares forest area has been protected by these FPCs and 21608 members of FPCs are involved in the protection of forests. This district is third tribal and scheduled caste dominated district (19.38%) among the districts of West Bengal. The important non-timber forest products available in this district are Sal, Kalmegh, Kendu leaf, Amla and Mahua flowers etc.

Data collection: The present study is based on the primary datacollected from the selected Purulia forest division in the district of Purulia. A multistage sampling technique has been followed. The survey is carried out in the month January, 2020. A questionnaire method is adopted to collect data from the head of the households. The Purulia forest division is constituted by eight (08) forest range offices. Out of eight, one range office i.e, Bagmundhi range office is selected purposively and three beat offices are selected under this range office. In addition, nine villages under these three beat offices are selected on the basis of the distance of the villages from forest. After the selection of villages, 20% of households from each village are selected randomly. Thus, total number of sample households consists of 252.

Analytical Methods

Forest dependence index: The forest dependency is measured by forest dependence index (FDI).For Forest Collection Importance, added two sub-indicators like number of forest products collected (FPC) and forest dependent households (FDH). FPC take the values 1,2, 3 corresponding to one forest product collected, two forest products collected and three forest products collected respectively. FDH =1 if household is forest dependent and 0 otherwise.

For physical asset, four sub-indicators like distance between residence and forest (D) in KM, average time spent by the household (hours per day) for non-timber forest products (NTFPs) collection (TNTFP), percentage of households engaged in the collection of NTFPs (PHNTFP) and gender engaged in the collection of NTFPs, {Male=1, Female=2, Both=3, Nil=0} (GCNTFPs). For wealth, four indicators like forest land {Yes=1, No=0}(FL), Agricultural land (acre) (AL), livestock owner {Yes=1, No=0}(LW) and type of house {pacca=1, kacha =2, thatch hut =3, traditional tribal hut=4, other=5}(TH). For non-forest livelihood strategies, five sub-indicators like income from agriculture (IAG), income from petty business (IPB), income from services (ISER), income from wage (IW) and income from handicraft (IH).

In order to formulate index normalize value of each indicator was considered. The normalize value lies between 0 to 1. “0” shows minimum and “1” shows maximum values. This normalization procedure was followed by the methodology of Human Development Index (UNDP 2006).

After normalization we are to take the averages of all sub-indicators.

$$FCI = \sum (FPC+FDH)/2 \quad \text{----------(1)}$$

$$PA = \sum (D + TNTFP + PHNTFP + GCNTFP)/4 \quad \text{----------(2)}$$

$$Wh = \sum (FL+AL+LW+TH)/4 \quad \text{----------(3)}$$

$$NFLS = \sum (IAG+IPB+ISER+IW+IH)/5 \quad \text{----------(4)}$$

$$\text{Forest Dependency Index} = \sum (FCI+PA+Wh+NFLS)/4 \quad (5)$$

The number of households is classified into less forest dependence, moderate dependence and high dependence on the basis of the values of forest dependence indices. Less forest dependence households are those who belong to the forest dependence index values less than equal to 0.2. Moderate forest dependence households are in between 0.21 and 0.4 and high forest dependence households are those who belong to more than forest dependence values 0.40.

Institutional index and enforcement index: In order to formulate institutional index three main indicators were considered like participation, monitoring and perception index (Abebe 2011). Each main indicator is sub-divided into two or more indicators. The each and every households were asked to respond their views in three Likert-type of scale (Yes=1, No= 2, Don't know =3) on all indicators' statement. For participation index (PI), two indicators were chosen. One is participation in the afforestation and other is present in the general body meeting of the forest protection committee. The households were asked to respond on whether they are participating in the afforestation program and attending the general body meeting of forest protection committee. For monitoring index (MI), three indicators were chosen like following up forest management bylaws, supervision of forest management plan implementation and maintaining forest boundary. The households were asked to respond on

whether they are involved in following up forest management bylaws, forest management plan implementation and maintenance of forest boundary demarcation.

For perception index (PCI), three indicators were selected like existence of any informal rules for the use of forest product, existence of any government rules regulating forest use and community members obey government rules for forest use if exist. The households were asked to respond on whether they realize any existence any informal rules for the use of forest product, existence of any government rules regulating forest use and community members obeys government rules if exist. After normalizing the indicators as per Human Development Index (UNDP 2006), an Institutional Index (II) was calculated as

Institutional Index = 1/3[PI +MI+PCI] ----------(6)

For the construction of enforcement index, the households were asked to respond on whether they have been protecting an illegal logging and helping forest patrolling, whether there is any rule for getting permission to collect extra forest products beyond the specified amount and whether the permission is issued by the village level forest protection committee. After normalization enforcement index was calculated.

Multivariate Regression Models (Linear and log-linear model)

Multiple regression models are used to estimate the factors responsible for forest dependence. Two types of regression models are applied for this purpose- linear and Log-linear regression model.

Linear Regression Model

Model specification: To investigate socio-economic and other determinants of forest dependence at the household level, the linear and log linear regression models are applied. The specification of the OLS type linear model is as follows:

$$Y_i = \alpha + \beta_1 X_{1i} + \beta_2 X_{2i} + \beta_3 X_{3i} + \beta_4 X_{4i} + \beta_5 X_{5i} + \beta_6 X_{6i} + \beta_7 X_{7i} + \beta_8 X_{8i} + \varepsilon_i \text{ ----------(7)}$$

Log-linear Regression Model

After natural log transformation of the dependent variable Y the model specification is given below:

$$\text{Log}(Y_i) = \alpha + \beta_1 X_{1i} + \beta_2 X_{2i} + \beta_3 X_{3i} + \beta_4 X_{4i} + \beta_5 X_{5i} + \beta_6 X_{6i} + \beta_7 X_{7i} + \beta_8 X_{8i} + \varepsilon_i \text{ ---------(7a)}$$

Where Y_i is Forest Dependent Index (FDI) of the ith household as the dependent variable.

X_{1i} = Family size (in numbers), X_{2i} = Sex of the household head (Male =1, Female =0)

X_{3i} = Caste of the household's head (ST=1, SC=2, OBC=3 and GEN=4)

X_{4i} = Percentage of households engaged in agriculture,

X_{5i} = Percentage of households engaged in other activities like wage labour, 100 days work, petty business and handicraft.

X_{6i}= Monthly forest income as percentage of total income (Rs)

X_{7i} = Institutional index, X_{8i} = Enforcement index, ε_i– is the random disturbance term.

RESULTS AND DISCUSSION

The main indicators and their sub-indicators are presented in Table 1. Forest Dependence Index (FDI) of the households as a whole in the district of Purulia is 0.38 (Table 2) and the forest collection importance is highest (0.655), followed by physical asset index (0.490), wealth index

Table 1. Description of main indicators and sub-indicators of forest dependence index

Main indicators	Sub-indicators	Description
Forest collection Importance	Collected forest products	In numbers
	Household dependent on forest	Yes=1, No=0
Physical asset	Distance from home to forest	In KM
	Average time spent by households for collecting NTFP	Hours per day
	Household engaged in collection NTFP	Percentage of households engaged in the collection of NTFPs
	Gender engaged in collection NTFP	Male=1, Female= 2, Both =3, Others=4, Nil=0
Wealth	Forest land	Yes=1, Nil=0
	Land holdings	In acre
	Livestock owner	Yes=1,Nil=0
	Types of house	Pacca=1, Kachha=2, Thatch Hut=3, Traditional Tribal Hut=4, Others=5
Non forest livelihood	Income from agricultural (monthly)	(Rupees)
	Income from petty business (monthly)	(Rupees)
	Income from service (monthly)	(Rupees)
	Income from Wages (MGNREGA & non-MGNREGA) (monthly)	(Rupees)
	Income from handicraft (monthly)	(Rupees)

Source: Author's calculation from primary data

(0.287) and non-forest livelihood strategy index (0.089). The 13% of households are less forest dependent, 25 percent of moderate forest dependent while 62 percent of households are high forest dependent (Table 3).

Institutional index and enforcement index: The institutional index is constituted by participation, monitoring and perception indices was 0.49 (Table 4). The monitoring index was highest (0.824) and perception index lowest. The high value of monitoring index shows the indication of good forest governance. This also means that the monitoring system of the forest department with community is successful in managing forest resource and to prevent deforestation. The value of enforcement index was 0.427 (Table 5). In the enforcement index forest patrols index (0.794) is highest. The high value of forest patrols and low value of illegal logging are the indication of good forest governance. Both linear and Log linear models are overall significant as indicated by F-values and adjusted R^2 and explain the same sign of the estimated coefficients. Among six explanatory variables included in both models only two variables are showing insignificant results (Table 7).

The coefficient of caste is negative and significant which indicate that the high forest dependency is concentrated in scheduled tribe (ST) and scheduled caste (SC) communities. The estimated coefficient in households engaged in agriculture is positive and significant which indicates that the households who are engaged more in agriculture their forest

Table 2. Forest dependence index (FDI) in the Purulia forest division

Main indicators	Sub-indicators	Index value
Forest collection importance	Collected forest products	0.445
	Household dependent on forest	0.865
		0.655
Physical asset	Distance from home to forest	0.341
	Avg. time spend by HHs for collecting NTFP	0.482
	Household engaged in collection NTFP	0.494
	Gender engaged in collection NTFP	0.642
		0.490
Wealth	Forest land Cultivated	0.008
	Total land holding including forest land	0.128
	Livestock	0.790
	Type of house	0.223
		0.287
Non forest livelihood strategies	Agricultural income	0.176
	Business income	0.048
	Service income	0.036
	Monthly wage income	0.157
	Handicraft Income	0.029
		0.089
	Forest Dependence Index	0.380

Source: Author's calculation from primary data

Table 3. Distribution offorest dependent households in the Purulia forest division

Forest Dependency Index	Assigned Attribute	Households	
		Number	Per cent
≤ 0.20	Less forest dependence	34	13.49
0.21-0.0.40	Moderate forest dependence	63	25.00
>0.40	Highforest dependence	155	61.51

Source: Author's calculation from primary data

Table 4. Institutional Index in the Purulia forest division

Main indicators	Sub-indicators	Index value
Participation Index	Afforestation	0.753
	Presence in the meeting of forest protection committee	0.356
		0.555
Monitoring Index	Follow ups forest management bylaws	0.861
	Supervise forest management plan implementation	0.801
	Forest boundary maintenance	0.812
		0.824
Perception Index	Existing any informal rule for the use of forest products	0.232
	Government rules regulating forest use	0.018
	Community member obeys government rules for forest use	0.033
		0.095
	Institutional Index	0.491

Source: Author's calculation from primary data

Table 5. Sub indicator of Enforcement Index in the Purulia forest division

Sub-indicators	Index value
Protesting illegal logging	0.232
Helping forest patrols	0.794
Rules for getting permission to collect forest product	0.452
Permissions issued by village forest protection committee	0.202
Enforcement Index	0.427

Source: Author's calculation from primary data

Table 6. Basic statistics of independent variables

Variables	Mean	Standard deviation
Family size (numbers)	5.04	2.11
Sex of the household head (Male =1, female =0)	0.09	0.30
Caste (ST=1, SC=2, Gen=3, OBC=4)	2.40	1.11
Per cent of households engaged in agriculture	17.49	18.68
Per cent of households engaged in other occupations like MGNREGA, petty business and handicrafts etc.	44.57	28.49
Per cent of forest income to total income	24.39	15.10
Institutional index	0.459	0.113
Enforcement index	0.420	0.172

Source: Author's Calculation

Table 7. Results of the linear and Log linear regression models in the district of Puruliain West Bengal, India

Independent variables	Linear		Log Linear	
	Coefficient	SE	Coefficient	SE
Family size	-0.0036^{+}	0.0024	-0.010^{+}	0.011
Sex of the household head	-0.015^{+}	0.016	-0.080^{+}	0.071
Caste	-0.21285*	0.04859	-0.099*	0.020
Per cent of HHs engaged in agriculture	0.002325*	0.00028	0.009*	0.001
Per cent of HHs engaged in other occupations like wage labour, petty business and handicraft etc.	-0.00052**	0.000212	-0.002*	0.0009
Per cent of forest income to total income	0.003162*	0.000379	0.014*	0.001
Institutional index	-0.545*	0.186	-0.474*	0.178
Enforcement index	-0.290**	0.121	-0.397*	0.142
Constant	0.355*	0.029	-1.147	0.119
	Observation = 252		Observation= 252	
	F(8,243)=39.52		F(8,243)=39.47	
	Prob> F = 0.0000		Prob> F = 0.0000	
	R-squared = 0.55		R-squared = 0.56	
	Adj R-square=0.53		Adj R-square=0.55	

Source: Author's calculation,: *,** indicates significant at 1 and at 5% level and + shows insignificant

dependency is higher and vice versa. It seems to the fact that the households who are engaged in agriculture they are also engaged side by side in the collection forest products for livelihood generation. This result is contrary to the results of (Illukpitiya 2006) where it was estimated that forest dependency was negatively related to agriculture and there agriculture was more efficient. The estimated coefficient in households engaged in other occupations is negative and significant, indicating forest dependency goes on diminishing as the households are moved towards other occupations like works under MGNREGA, casual works and other works and vice versa. The estimated coefficient of forest income to total income is positive and significant which also implies that the forest dependency is positively related to income from forest, high forest dependency is explained by more and more income is accrued from forest. This finding is supported by the study in Gujarat (Baloch et al 2015), in Jharkand (Belcher et al 2015) and in Nepal (Rayamajhi et al 2012). Some studies relating to off-farm employment opportunities, agricultural income, household size, education and incorporation to outside market also influenced forest dependency (Hedges and Enters 2000, Asfaw et al 2013). The estimated coefficients of institutional index and enforcement index are negative and significant, implying that if institutions and enforcement work more efficiently the forest dependency could be reduced and vice versa.

CONCLUSIONS

The forest collection importance, physical asset, relative wealth and non-forest livelihood strategies are considered to be most important main indicators for the construction of forest dependence index. The contribution of forest collection

importance was highest. More than 60 percent of households are highly forest dependent. The forest dependence index is influenced by caste, agricultural employment, off-farm employment, forest income, institutional and enforcement indices. Special importance should be given on the development of agriculture, setting up agro-forestry industry and handicraft industry and alternative income opportunities through MGNREGA employment program. The focus should also be given on efficient functioning of institutions and enforcement that can prevent the high dependency of forest.

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REFERENCES

Abebe DB 2011. Forest dependency, property rights and local level institutions: Empirical evidence from Ethiopia. Paper presented at the *13th Biennial conference of International association for the Study of Commons*, Hyderabad, India. January 10-14.

Adhikari B 2005. Poverty, property rights, and collective action: Understanding thedistributive aspects of common property resource management. *Environment and Development Economics* **10**(1): 7-31.

Angelsen A, Jagger P, Babigumira R, Belcher B, Hogarth NJ, Bauch S and Wunder S 2014. Environmental income and rural livelihoods: A global comparative analysis. *World Development* **64**(S1): S12-S28.

Asfaw A, Lemenih M, Kassa H and Ewnetu Z 2013. Importance, determinants and gender dimensions of forest income in eastern highlands of Ethiopia: The case of communities around Jelo Afromontane forest. *Forest Policy and Economics* **28**: 1-7.

Babulo B, Muys B, Nega F, Tollens E, Nyssen J, Deckers J and Mathijs E 2008. Household livelihood strategies and forest dependence in the highlands of Tigray. Northern Ethiopia. *Agricultural System* **98**(2): 147-155.

Baloch SR, Khan A, Bala N and Bohra NK 2015. Socio-economic status and forest resources dependency of forest fringes villages of Valsad district, Gujarat, India. *International Journal forest Usufructs Management* **16**: 92-105.

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Belcher B, Achdiawan R and Dewi S 2015. Forest-based livelihoods strategies conditioned by market remoteness and forest proximity in Jharkhand, India. *World Development* **66**: 269-279.

Bwalya SM 2013. Household dependence on forest income in rural Zambia. *Zambia Social Journal* **2**(1): 67-86.

Census of India 2011. District Census Handbook, Puruliya, West Bengal, Series 20, Part XII-A.

Córdova JPP, Wunder S, Smith-Hall C and Börner J 2013. Rural income and forest reliance in highland Guatemala. *Environmental Management* **51**(5): 1034-1043.

Hedge R and Enters T 2000. Forest products and household economy: A case study from Mudumalai Wildlife Sanctuary, southern India. *Environmental Conservation* **27**: 250–259.

Illukpitiya PMP 2006. *Agricultural Efficiency and dependency on forest resources: An economic analysis of rural households and the conservation of natural forests in Sri Lanka*. Ph.D. thesis submitted to the University of Hawai.

IPBES 2019. UN Report: Nature's dangerous decline- 'unprecedented', species extinction rates 'accelerating'. Paris, France. http:// refhub.elsevier.com/s 2351-9894(19)30155-6/sref27.

Mukul SA, Rashid AZMM, Uddin MB, Khan NA 2016. Role of non-timber forest products in sustaining forest-based livelihoods and rural households' resilience capacity in and around protected area: a Bangladesh study. *Journal of Environment Planning and Management* **59**(4): 628-642.

Nagendra H and Gokhale Y 2008. Management regimes, property rights, and forest biodiversity in Nepal and India. *Environmental Management* **41**(5): 719-733.

Nielsen MR, Pouliot M and Kim BR 2012. Combing income and assts measures to include the transitory nature of poverty in assessments of forest dependence: Evidence from Democratic Republic of Congo. *Ecological Economics* **78**: 37-46.

Ostrom E and Nagendra H 2006. Insights on linking forests, trees, and people from the air, on the ground, and in the laboratory. *Proceedings of the National Academy of Sciences* (PNAS) **103**(51): 19224-19231.

Rayamajhi S, Smith-Hall C and Helles F 2012. Empirical evidence of the economic importance of central Himalayan forests to rural households. *Forest Policy and Economics* **20**: 25-35.

Sandhu VE and Sidhu AS 2015. Environmental Governance in India: A Systematic Review of the initiatives. *Pacific Business Review International* **8**(4): 49-57.

Sunderlin, William D, Angelsen, Arild and Wunder S 2004. Forests and Poverty alleviation. In FAO(ed.), *State of the world's Forests*: FAO, Rome, 61-73.

UNDP 2006. *Human development report*, United Nations Development Program, http://hdr.undp.org/hdr2006/statistics/

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Floristic Diversity Pattern and Vegetation Analysis of Moist Sal Forest of Chilpi Range, Kawardha Forest Division, Chhattisgarh

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Abstract: The present paper deals with the floristic diversity assessment and vegetation composition analysis in Chilpi range of Kawardha Forest Division, Chhattisgarh. A total of 9 species belonging to 6 families were recorded. Dipterocarpaceae family was represented highest individuals (>132) per ha followed by Combretaceae (35) and Lecythidaceae (5).*Shorea robusta* showed highest value of IVI (185.08) followed by *Terminalia tomentosa* (35.42) and *Anogeissus latifolia* (16.85). The quantitative features such as density and important value index (IVI) varied greatly among forest and different forest types. The diversity index of sapling layer with Shannon index (1.926) were higher than the tree species (1.531). It may be expected that plant density will become improve with upcoming sapling generation. Moreover this study creates a base to improve the management plan for the better growth of this natural Sal forest.

Keywords: Floristic, Vegetation, Forest, diversity index, Chhattisgarh

Forests are areas of natural habitat, productivity, all uncultivated or non-domesticated lands covers with trees of varying density and compositions. Forests are considerably diverse systems and represent some of the biodiversity rich areas on earth e.g. tropical forest. The characteristics, structure and composition of forest are mostly determined by the altitude, temperature, humidity and rainfall. A mature forest can be stratified vertically into four layer like over story or canopy layer, sub canopy layer, shrub and herb layer. Therefore, the amounts of light received by the different vertical layers of forest are different. Tropical forest constitutes the most diverse plant communities on earth and it cover's 7% of the earth's land surface, but harbor more than half of the world's species and are currently vanishing at an overall rate of 0.8-2% per year (Sagar et al 2003, Naidu and Kumar 2015). Dependence on forest is inevitable in India, therefore, the pressure on forests by the ever-increasing population in logarithmic (Jayakumar et al 2002, Pragasan 2010). Therefore, the present study has been undertaken to assess the floristic diversity and vegetation analysis in moist sal forest of Chilpi range in Kawardha Forest Division.

MATERIAL AND METHODS

Study area: The Chilpi valley forest lies between 22° 17′*18*″N latitude and 81° 05′41″E longitude in Kawardha forest division of Chhattisgarh. The study was conducted from Dec. 2017 to April 2018. The study area is dominated by Tropical moist deciduous forest with species like *Careyaarborea, Anogeissus latifolia, Terminalia chebula, Buchanania lanzan, Mitragyna parvifiloa, Cleistanhus collinus* etc.

Survey, sampling, data compilation and analysis: The extensive field survey was undertaken during year 2018 and the data were collected through the random sampling method in the different forest compartments covering the all parts of Chilpi forest range. The floristic diversity analysis was carried out by Quadrate method and required quadrates of 20 m × 20 m size were laid out at the study sites. In each quadrate, GBH of individual (> 30 cm girth) trees and saplings (≤ 30 cm girth) was measured. Density, frequency and basal area values were calculated for each species following Curtis and McIntosh (1950). The important value index (IVI) of each species was derived by summing up the relative frequency, relative density and relative basal area by following Philips (1959). On the basis of the survey data from the quadrate sampler, the diversity and forest vegetation was investigated.Floral diversity in both the sites was calculated in terms of Shannon Index, Concentration of dominance or Simpson's Index, Equitability and Species richness.

RESULTS AND DISCUSSION

Composition of Tree Layer

A total of 180 trees ha^{-1} representing 9 species and 6 families were observed in the study area. Dipterocarpaceae family was represented highest individuals (>132) per ha followed by Combretaceae (35) and Lecythidaceae (5). S*horea robusta* was the most dominant tree followed by *Terminalia tomentosa* and *Anogeissus latifolia* as well as represented the highest density respectively (Table 1). Lowest density was recorded in case of *Buchanania lanzan, Mitragyna parvifiloa* and *Cleistanhus collinus.* Highest basal

area was observed in *Shorea robusta* followed by *Terminalia tomentosa* and *Anogeissus latifolia* whereas the lowest basal area was observed in *Mitragyna parvifiloa*. Basal area of individual tree species varied from 0.34 to 19.49 m^2 ha^{-1}. *Shorea robusta* showed highest value of IVI (185.08) followed by *Terminalia tomentosa* (35.42) and *Anogeissus latifolia* (16.85). Similarly *Cleistanhus collinus* showed lowest value of IVI (6.31) followed by *Mitragyna parvifiloa* (6.83) and *Buchanania lanzan* (7.61). The total tree density and tree basal area of site I was recorded 180 trees ha^{-1} and 26.34 m^2 ha^{-1}, respectively.

Composition of Sapling Layer

A total of 132.5 saplings ha^{-1} representing 9 species and 8 families were recorded in the study area. Dipterocarpaceae family was represented highest individuals (82.5) per ha followed by Combretaceae (17.5) and Anacardiaceae (15). *Shorea rbusta* was the most dominant tree followed by *Terminalia tomentosa* and *Buchanania lanzan* as well as represented the highest density respectively (Table 2). Lowest density was in *Mitragyna parvifiloa, Phyllanthus emblica* and *Syzizium cumini.* Highest basal area was observed in *Shorea robusta* followed by *Terminalia tomentosa* and *Buchanania lanzan* whereas the lowest basal area was observed in *Syzizium cumini*. Basal area of individual tree species varied from 0.05 to 2.46 m^2 ha^{-1}. *Shorearobusta* showed highest value of IVI (146.79) followed by *Buchanania lanzan* (43.89) and *Terminalia tomentosa* (39.22). Similarly *Syzizium cumini* showed lowest value of IVI (7.46) followed by *Mitragyna parvifiloa*(9.03) and *Terminalia chebula* (9.16). The total tree density and tree basal area of site I was 132.5 trees ha^{-1} and 4.67 m^2 ha^{-1}, respectively.

Diversity Indices

More diversity was found in saplings layer with Shannon index 1.926 followed by trees (1.531), this indicates that the sapling generation had more diversity than existing tree generation. The Concentration of dominance were found higher in trees 0.556 followed by saplings (0.418). The higher evenness was in sapling layer with equitability 0.877 followed by trees (0.697). The species richness was similar in both the layers sapling layer (1.637) followed by trees (1.541). This

Table 1. Floral composition of tree layer

Species	Family	Density (Trees ha^{-1})	Frequency (%)	Basal area (m^2 ha^{-1})	IVI
Shorea robusta	Dipterocarpaceae	132.5	90	19.49	185.08
Terminalia tomentosa	Combretaceae	17.5	40	2.38	35.42
Careya arborea	Lecythidaceae	5	20	0.65	13.58
Anogeissus latifolia	Combretaceae	7.5	20	1.15	16.85
Terminalia chebula	Combretaceae	5	20	0.52	13.09
Buchanania lanzan	Anacardiaceae	2.5	10	0.54	7.61
Mitragyna parvifiloa	Rubiaceae	2.5	10	0.34	6.83
Cleistanhus collinus	Phyllanthaceae	2.5	10	0.19	6.31
Terminalia bellirica	Combretaceae	5	20	1.08	15.22
Total		180	240	26.34	300

Table 2. Floral composition of sapling layer

Species	Family	Density (Trees ha^{-1})	Frequency (%)	Basal area (m^2 ha^{-1})	IVI
Shorea robusta	Dipterocarpaceae	82.5	70	2.46	146.79
Terminalia tomentosa	Combretaceae	15	30	0.67	39.22
Careya arborea	Lecythidaceae	5	20	0.23	17.79
Terminalia chebula	Combretaceae	2.5	10	0.13	9.16
Buchanania lanzan	Anacardiaceae	15	40	0.67	43.89
Phyllanthus emblica	Phyllanthaceae	2.5	10	0.14	9.51
Mitragyna parvifiloa	Rubiaceae	2.5	10	0.12	9.03
Diospyrous melanoxylon	Ebneaceae	5	20	0.20	17.16
Syzizium cumini	Myrtaceae	2.5	10	0.05	7.46
Total		132.5	220	4.67	300

Table 3. Floral diversity of tropical moist Sal Forest

Parameters	Tree	Sapling
Shannon index (H')	1.531	1.926
Conc. of Dominance (cd)	0.556	0.418
Equitability (e)	0.697	0.877
Species Richness (d)	1.541	1.637

study reflected very poor species richness and dominance of single species was not found in any layer.

The total tree basal area was 26.34 m^2 ha^{-1}, which provided similar result found in tropical deciduous forest of Achanakmar- Amarkantak Biosphere Reserve by Yadav (2016) between 9.96 - 41.6 m^2 ha^{-1} as well as Tropical forest of Odisha 28.45 m^2 ha^{-1} by Mishra *et. al*. (2018). The sapling basal area cover was 4.67 m^2 ha^{-1}, which was higher than 0.06-1.24 m^2 ha^{-1} in dry tropics as studied by Pawar et al (2014) while found similar range 0.86- 5.07 m^2 ha^{-1} by Yadav (2016). The tree and sapling density in the present study varied from 132.5 to 180 stems ha^{-1}, which is similar with the studies of Jayakumar and Nair (2013) and come within the range from 30 to 610 as studied in dry tropics by Pawar *et. al.* (2014), particularly in the dry tropics; the basal area and density was quite lower than other tropical forest; it may due to lack of rainfall and floral type. *Shorea robusta* is the most dominant species in both the layers i.e. trees and saplings with highest IVI values 185.08 and 146.79 respectively; which was supported with the IVI values of 167.29 in Moist Sal forest of Ranchi as described by Kumar & Saikia (2018) and higher than 115.3- 135.2 in Sal dominating topical dry deciduous forest by Raj (2019). The climax nature of *Shorea robusta* may cause it ecologically most important species regardless the dying back condition.

The Shannon index was varied between 1.531-1.926 which indicates lesser species diversity and it may be due to high anthropogenic stress, illicit felling and severe cattle grazing. The concentration of dominance was between 0.418-0.556; which indicate the concentration of dominant species is very less in other words the scattered was found among the dominant species. The equitability was found 0.697-0.877 shows lesser evenness in species distribution among all the quadrates. The species richness was found 1.541-1.637; this reflected presence of fewer species in both the layer. All the diversity values come at par with other Sal forests studied by Kumar and Saikia (2018) and Raj (2019).

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CONCLUSION

During our study period we have observed that all the forest area of this division was subjected to continuous biotic pressure resulting into rapid degradation. Due to perpetual grazing as observed in many areas, the new seedlings and saplings of important species like bamboo, medicinal plants and other NTFP species are often subjected to continuous damage.

REFERENCES

Curtis JT and McIntosh RP 1950. The interrelations of certain analytic and synthetic phytosociological characters. *Ecology* 31: 434-455.

Hubbell SP and Foster RB 1992. Short-term dynamics of a neotropical forest: why ecological research matters to tropical conservation and management. *Oikos* **63**: 48-61.

Jayakumar R and Nair KKN 2013. *Species Diversity and Tree Regeneration Patterns in Tropical Forests of the Western Ghats, India*; ISRN Ecology.

Jayakumar S, Soosairaj S, Samy DIA and Britto JS 2002. Similarity analysis in two tropical dry evergreen forests in the Eastern Ghats of Tamil Nadu. *Journal of Hill Research* **15**: 4-11.

Kumar R and Saikia P 2018. Floristic analysis and dominance pattern of sal (*Shorea robusta*) forests in Ranchi, Jharkhand, eastern India. *Journal of Forestry Research* **3:** 415-427.

May RM and Stumpf MPH 2000. Species-area relationships in tropical forests. *Science* **290**: 2084-2086.

Mishra RK, Parhi S and Biswal AK 2018. Diversity of over storey plant communities of tropical forest covers of Balasore district, Odisha, India. *Advances in Plants &Agriculture Research* **8**(1): 20-26.

Naidu MT and Kumar OA 2015. Tree species diversity in the Eastern Ghats of northern Andhra Pradesh, India. *Journal of Threatened Taxa* **7**(8): 7443-7459.

Nayak S and Sahoo UK 2020. Tree diversity and ecological status of *Madhuca latifolia* (Roxb.) J.F. Macbr in forests of Odisha. *Indian Journal of Ecology* **47**(1): 138-149.

Pawar GV, Singh L, Jhariya MK and Sahu KP 2014. Effect of anthropogenic disturbances on biomass and carbon storage potential of a dry tropical forest in India. *Journal of Applied and Natural Science* **6**(2): 383-392.

Pragasan A and Parthasarathy N 2010. Landscape-level tree diversity assessment in tropical forests of southern Eastern Ghats, India. *Flora*. **205**(11): 728-737.

Raj A 2019. Structure and diversity of Sal dominating tropical deciduous forest of Chhattisgarh, India. *International Journal of Chemical Studies* **7**(1): 2352-2355.

Sagar R, Raghubanshi AS and Singh JS 2003. Tree species composition, dispersion and diversity along a disturbance gradient in a dry tropical forest region of India. *Forest Ecology and Management* **186**: 61-71.

Yadav DK 2016. Species structure and diversity in Achanakmar-AmarkantakBiosphere reserve, Central India. *Journal of Applied and Natural Science* **8**(3):1241-1248.

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Seymska Population of Russian Desman (*Desmana moschata* L.) in North-Easten Part of Ukraine: A History of Formation and Current State

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Abstract: Endemic of the East European Plain and the oldest representative of Europe's modern fauna is the Russian desman (*Desmana moschata L.*). The animal is subject to strict protection. The International Union of nature protection has identified the status of Russian desman as an endangered species. The desman is registered in the European Red List as a vulnerable species. It is also listed in Annex II of the Berne Convention. In the Red Book of Ukraine desmans are listed as an endangered relict species. Nowadays only the seymska population *D. moschata* can be found in Ukraine. It is highly fragmented and numbers about 300-500 individuals. In terms of structure we can delineate 3 areas: the seymska-the largest, is in the floodplain of the Seym river; the vyrivska-covers the floodplain of the Vyr river, the left tributary of the Seym river; the klevenska-covers the floodplain of the Kleven river, the right tributary of the Seym river. In general, the population is in a very depressed state and is very affected by anthropogenic pressure.

Keywords: *Desmana moschata L.*, A modern state, The north-eastern Ukraine, The seymska population

The biota evolution, in particular animals evolution on Earth, is undulating with periods of flowering and extinction of species. Researchers of the evolution process have identified at least five periods of animals extinction. The most famous among them is Permian, when at least 95% of all living creatures that inhabited our planet disappeared. The recent studies of ecologists, taxonomists, zoologists and other fundamentalist researchers have provided a basis for statements about the sixth extinction that is going on today. According to the News line resource (2019), referencing William J. Ripple (Oregon State University in Corvallis, the USA), before the anthropogenic era per 10000 species of animals 2 of them disappeared every 100 years. During the twentieth century and the early part of the twenty-first century these figures increased by 114 times. In the coming decades the fauna of the Earth will lose at least 150 animal species, about 70% of modern species will significantly reduce their numbers and more than 60% of the species may completely disappear. The main reasons that will lead to such consequences are the powerful commercial use of modern fauna, excessive anthropogenic influence on animal habitats, destabilization of their habitats and significant reduction of unoccupied spaces in nature (William J. Ripple et al 2017, 2019). Earlier scientists (Vandna Devi et al 2019, Jeph and Khan 2019) also report in their works about a strong negative impact on the natural biodiversity of global climate changes, about anthropogenic pressure and other man-made factors.

Ukraine, despite its agrarian status, is one of the unique regions of the world where transformed or a little-transformed territories have remained well-preserved. The vast majority of territories are parts of different at rank nature conservation objects. It is here that species of flora and fauna, which are unique both to Ukraine and to the world, have been preserved and protected. One of them is the Russian desman (*Desmana moschata L.)*. This insectivorous mammal belongs to the mole (Talpidae) family and is endemic to the Eastern European Plain and is the oldest representative of modern fauna in Europe, if we take into account the age of fossil specimens. The oldest remains of these animals date back to the Pleistocene era. They were found in France, the Netherlands, Germany, Poland, Sweden, the United Kingdom, Hungary and Ukraine. As of today the Russian desman hasn't been officially registered in the territory of Western Europe. Its range is restricted to relatively small territories in Russia (European part and Western Siberia), eastern Ukraine and western Kazakhstan (Fig. 1). The area of this mammal is disjunctive. Relatively small populations are concentrated mainly in the basins of the Volga, Don, Dnieper and Ural rivers.

Sources: uk.wikipedia.org (2019)

Fig. 1. The modern area of the Russian desman distribution

The number of species is low and there is a clear possibility of further decline. Keeping this in mind the animal has been put on a number of red lists. In particular, the International Union of Nature Protection has designated the status of the Russian desman as an endangered species (Endangered, EN). In the European Red List it is registered as a vulnerable species (Vulnerable, V). This category includes species that are threatened with extinction as a result of on-going negative factors.

Taking into account the rate of reduction of the Russian desman population in a number, it is quite predictable that in the near future this animal will be transferred to the endangered species group. For this reason it is listed in Annex II (species to be protected) of the Berne Convention (Convention on the Conservation of European Wildlife and Natural Habitats). In the Red Book, in all its three editions, the Russian desman is included in the status of endangered relict species. It follows from the foregoing that there is an urgent need to study the current distribution, the number of this unique animal in detail, to monitor the territories suitable for its continued survival and to think properly about the creation of conditions for the survival and resettlement of this micromammal.

The purpose of this work is to summarize the literature resources on the distribution of the desman in the territory of Ukraine, especially in its north-eastern part. The main reason to begin the research work was the detection of *D. moschata* in the Kleven river (the right tributary of the Seym river) in the territory of the Regional Landscape Park Seymskyi (Krolevets district, Sumy region). The animal was observed downstream in the Kleven riverbed area during a route survey.

MATERIAL AND METHODS

Literature, reports of research expeditions, desman territory surveys, desman identification activities in the territory of the Sumy region, archival documents of the Department of the Nature Reserve Fund and Environment of the Department of Ecology and Natural Resources Protection of the Sumy Regional State Administration were analysed during this research work.

RESULTS AND DISCUSSIONS

At present, within the European continent, the Russian desman's area is concentrated in the European part of the Russian Federation in the territory of 37 regions in the basins of the Volga, Don, Dnipro and Ural rivers. These are areas where the desman has existed since ancient times and where relatively few individual populations of this animal have remained. According to "Materials on the fauna of the Nizhny Novgorod Zavolzhye" (2002) at the beginning of the 21st century the number of desmans in Russia is about 35000 individuals. 20000 of them are in the Volga basin, 10000 are in the Don basin and another 5000 are in the Dnipro and Ural basins. However, other sources give different information. According to the results of fundamental studies Khakhin (2009) concluded that now the area of the desman in Russia is discrete by its nature and the status of the species is critical. This situation is observed in most areas where *D. moschata* in habits, except Ryazan, Kursk and Kurgan regions, where the animal population status is the most favourable (Table 1).

In general the author's account of the desman population shows an irreversible and all-encompassing decline in the number of species throughout its territory. According to the results of these studies the total number of desman in Russia was 28000 individuals in 2001. However, in 2005 the number was reduced to 25000 individuals. If the situation doesn't change, the number of species (600 individuals per year) will be reduced and it's highly likely the number of desmans in the Russian Federation will number about 17200 individuals in 2019.

The current population of desman in Ukraine is closely related to the population of this animal in Kursk region, Russia, and is its peripheral south-western area. The desman population in Kursk region was created through the resettlement of 95 animals from the Khopyor Nature Reserve in 1956 – 1961. By 1976 the animal had already inhabited the whole territoryin Kursk region, the territory which was suitable for its life. Nowadays it is the largest desman population in the Dnipro Basin. It numbers about 3 thousand individuals (Khakhin 2009). In the 1970's the animal also penetrated the territory of Ukraine – Putyvl district, Sumy region. It is highly likely that it's the only population of *D. moschata* in Ukraine today. The desman's presence here is documented and confirmed by factual material. In the twentieth century the spread of *D. moschata* in Ukraine was

somewhat different. Zahorodniuk (2002) observed the range of the desman in Ukraine has historically been formed in 3 parts: Dniprovska, Siversko-Donetska and Seymska (Fig. 2). The Dniprovska population existed until the 1930s. The reason for its disappearance, as mentioned by Pidoplichko (1951), could have been the completion of the natural process of shortening of this part of the area, which began in prehistoric times.

Table 1. Dynamics in the number of *D. moschata* in Russia (Khakhin 2009)

Constituent entities of the Russian federation	The number of individuals		
	1985 year	2001 year	2005 year
Astrakhan region	a few	a few	a few
Republic of Bashkortostan	a few	a few	a few
Bryansk region	a few	a few	50
Vladimir region	8,0thsd.	2,5thsd.	2,5thsd.
Volgograd region	1,5thsd.	2,5thsd.	2,5thsd.
Vologda region	a few	a few	a few
Voronezh region	5,0thsd.	2,0thsd.	1,2thsd.
Ivanovo region	1,0thsd.	200	200
Kaluga region	200	100	100
Kirov region	a few	a few	a few
Kostroma region	100	300	300
Kurgan region	2,0thsd.	2,0thsd.	1,5thsd.
Kursk region	2,0thsd.	3,5thsd.	3,0thsd.
Lipetsk region	2,0thsd.	1,0thsd.	1,0thsd.
The Mari El Republic	not marked	not marked	not marked
The Republic of Mordovia	1,0thsd.	500	500
Moscow region	a few	50	50
Nizhny Novgorod region	500	1,5thsd.	1,5thsd.
Novosibirsk region	a few	a few	a few
Orenburg region	500	150	100
Orel region		20	20
Penza region	500	200	200
Rostov region	200	100	1,0thsd.
Ryazan region	7,0thsd.	6,0thsd.	5,0thsd.
Samara region	a few	a few	a few
Saratov region	1,0thsd.	100	100
Smolensk region	300	400	400
Tambov region	5,0thsd.	3,0thsd.	3,0thsd.
The Republic of Tatarstan	a few	a few	a few
Tver region	a few	a few	a few
Tomsk region	100	a few	a few
Ulyanovsk region	100	a few	a few
Chelyabinsk region	300	100	100
The Chuvash Republic - Chuvashia	a few	100	100
Yaroslavl region	700	300	300
Total amount	~ 40 thsd.	~ 28 thsd.	~ 25 thsd.

The most powerful and the largest population of *D. moschata* in Ukraine was Siversko-Donetska. Up to this moment the question of its extinction hasn't been solved yet. However, the recent thorough field studies of Zagorodniuk (2002) do not shed any light on this mystery. The scientist, as part of a zoological expedition, examined the most promising 1000-kilometer part of the Siverskyi Donets floodplain from the Oskol River in Kharkiv region to the Derkul River, which is on the border of Lugansk and Rostov regions. About 70 flood lakes and riverbeds were surveyed, but in every case the results were negative. Neither animals' traces nor signs of their existence were found in the Siverskyi Donets Basin. Survey of hunters, taxidermists and questionnaires of local residents also yielded negative results. According to the results of the Zagorodniuk's research, it was concluded that there is an extremely high probability of the desman being absent in Siverskyi-Donetsk. The author considers the impact of anthropogenic factors as the main reason for the "landslide reduction of the Donetska population both in area and in number, both in quality of lands and in the number of habitable places".

The Seymska population is the youngest and highly likely the only one in Ukraine now. Its formation began in the 1970's through the natural penetration of animals from the territory of Russia and development of habitable reservoirs in

Comment: The author refers to Pidoplichko data (1951). The note "Modern finds" refers to the mentioned date

Fig. 2. The desman's area in Ukraine (Zagorodniuk 2002)

the river Seym and its tributaries. The desman's expansion in the territory of Ukraine probably started from the territories close to the Tetkiko locality, Kursk region, Russia, which spread to the border with Ukraine. On this territory Serdiuk (1978) described *D. moschata*. It is thought that these neighbouring territories nowadays are the source of the constant replenishment of "Ukrainian" desman population with new individuals. Skorobagatov (2000) mentioned that a possible immigration hotspot is a system of peat pits located on the Russian side opposite the village of Buniakine, Putyvl district, Sumy region. The immigrant individuals inhabit quarries near this specific location. Animals settle down in the reclamation canals, floodplain lakes and in the Seym riverbed downstream (Fig. 3, 4). The results of a number of research trips, conducted in the mentioned territory of Sumy region during different periods of time, can confirm the accurateness of this theory. Serdiuk (1978) conducted a survey of territories in the Putyvl district near the villages of Volyntsevo, Kozlivka and Chaplyshchi. These villages are located some distance from Buniakine, downstream of the Seym river. In Lake “Bolonia”, near Volyntsevo he observed 20 inhabited desman burrows. One inhabited burrow was found near the nameless lake near Kozlivka, but near Chaplyshchi in the floodplain, the author found desolated animal burrows. Thus, the desman actively migrates in search of bodies of water most favourable to its survival.

In 1978 an expedition of the Institute of Zoology of the Academy of Sciences of the USSR, consisting of V. Kryzhanovskyi, V. Abelientsev, H. Panov, I. Leheida, found out that desmans had been caught by local residents near Boiaro-Lezhachy village, in the gulf of the river Seym, and in “Khorobre” lake, as well as near the locality Ryzhivka in the system of lakes between the rivers Seym and Vyr. It should be noted that during the survey of bodies of water, where Serdiuk had worked before, neither animals nor traces of their stay could be found. The work report states that the lakes were highly dried up and had been subjected to extremely strong anthropogenic pressure, which made them unusable (Kryzhanovsky et al 1978). Probably the animals either died or migrated to other bodies of water. We can hypothesize that it was possibly a migration due to the fact that two adult desmans were found near the village of Volyntsevo in the same year 1978, but it was a reclamation canal during its reconstruction (Merzlikin 1992). New discoveries of animals near the mentioned localities date back to 1990 - 2006. According to Merzlikin, Mishta (2008) near Kozlivka village in the system of reclamation canals and the Horn River (the Seym's distributary), individual and inhabited burrows of the desmans were constantly found last in 2006. Near Volyntsevo in old peat quarries, single specimens of desmans were extracted by means of poaching in 1991 and in 2000. A hunting dog found a desman in the reclamation canal near Buniakine in the summer of 2001. Villagers from Boiaro-Lezhachy saw a few desmans in Lake Horobre in 2001-2002. At the same time the same authors report finding *D. moschata* and on the other territories close to the localities mentioned above. Some desman specimens were found in the reclamation canals to the northeast from Volyntsevo near the villages Yurieve and Lynove in 2000. Some individual specimens of animals were found in the reclamation canals near Manukhivka village, downstream from the river Seym near the village of Boiaro-Lezhachy, and in old riverbeds «Vileia» and «Pereriz» in 2002. Near Pisky village, which is located on the left bank of the Seym between Manukhivka and Kozlivka, local residents noticed some desmans during the spring floods every year from 1992 to 2006. In the same place a young desman was caught by a cat in 2001. Downstream in the Seym from Chaplyshchi village near Chumakove village, local residents noticed desman in the gulf of the river in 2003. Desman was also observed in former peat-mining quarries in 2004. In the bodies of water in the suburbs of the villages Peresypok, Chervone Ozero, Zinove several desmans were regularly observed from 1999 to 2005.

On the territory of the Regional Landscape Park Seymskyi, which extends from Chumakove to Chernihiv region downstream of the river Seym, according to the data of Merzlikin, Mishta (2008), some desman specimens were found near the previously mentioned village Zinove in the former peat lands «Zhuravlyne» and «Karasevi bolota», near the village of Dych and Putyvl town in 2004 and near the villages of Skunosove in 2000. In the last two cases the animals were caught by fishing nets in the river Seym. Below the town of Putyvl, Merzlikin (1995) observed a desman near the Kamen village in a flood lake in 1990. In 1991, as the author reports, 6 animals were caught by locals in lakes and in reclamation canals downstream of the river near the village of Zholdaky. According to the author this is the most remote point from the place of a settlement where the presence of *D. moschata* is accurately described. The author believes that the animal occupies more distant territories today and probably has penetrated into the water bodies of the region of Chernihiv. However, there were no literature sources to confirm this point of view. The territory, described above, where for almost 50 years the cases of desman detection have been registered, is, in our opinion, the native area of the seymska population of *D. moschata* in Ukraine. During this time two more areas began to form – the vyrivska, in the river Vyr (the left tributary of the Seym) and the klevenska in the river Kleven (the right tributary of the Seym). The vyrivskyi

district covers the territory of the river Vyr near the village Novi Vyrky and its lower downstream to Vorozhba locality (Fig. 5).

Most likely, the settlement of this area began in the 1970's. Tsyupka (2012) observed the maximum number of animals was found near the village of Novi Vyrky in the 1980s, when several dozen animals were caught in fishing nets every year. However, by 2005 the number of such cases had decreased to 7, and in 2006 to 2. The decrease in the number of animals happened to a large extent as a result of anthropogenic pressure and the migration of animals upstream of the river Vyr. The author reports about the desman's detection near the village Stari Vyrky, 3 km. away from the previous settlement and near the village of Vorozhba, 3 km. up from the village Stari Vyrky. Merzlikin and Mishta (2008) also report the identification of young *D. moschata* near Vorozhba. According to their data a young animal was caught in fishing nets in the river Vyr in the area of the riverbed between the railway bridge and the village. This happened in 2001. The same authors report about some desman sightings in 1997 and in 2001 in one of the ponds near Kindrativka village, Sumy region. Information was given by local residents and wasn't confirmed by factual research.

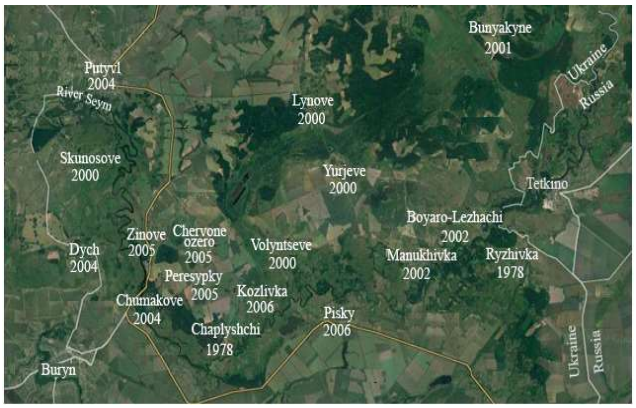

Fig. 3. The maternal area of the seymska population of *D. moschata*in (the numbers indicate the year when the animal was last observed)

Fig. 4. The maternal area of the seymska population of *D. moschata*in (the numbers indicate the year when the animal was last observed)

Highly likely the last reports were in reality about muskrats, which are common animals in our bodies of water. If the information had been accurate, then the desmans would have had to cover the distance of a few tens of kilometres from the town Bilopillia, where the tributary Kryga flows into the Vyr river and up to the village Kindrativka. The accuracy of this report is rather doubtful and needs to be checked. The Kleven area of desman is probably the youngest. This assumption is based on the lack of information in literature on the existence of *D. moschata* in the Kleven river during the formation of the seymska population of this animal.

For the first time the desman was found by Yemets (2019) in the aforementioned river. It occurred during an ecological survey of the area of Kleven river mouth from the Yatsyne village Putyvl district to the village of Kamin in Krolevets district. On the evening in August 6, 2018, not far from the village of Lytvynovychi (geographical coordinates: 51.395, 33.649), Krolevets district (Fig. 6) desmans were seen on intertwined leaves of white lily near a riverbank.

Fig. 5. The vyrivska area of the seymska population of *D. moschata* (the numbers indicate the year when the animal was last observed)

Note: The sign points to the place where a desman was detected

Fig. 6. The klevenska area of the seymska population of *D. moschata*in (the numbers indicate the year when the animal was last observed)

Visual contact lasted no more than 4-5 seconds after which the animal disappeared under water.

Unfortunately, this time was not enough to set up a camera and to take a photo of the animal in its natural environment. The desmans appeared in the Kleven river in approximately 1990 when they were observed by Merzlikin (see above) near Kamen village in the floodplain of the river Seym. By that time the animals had already inhabited 8 kilometres of the territory (the distance from the village of Kamen to the place where it was found). The results of the analysis of the ecological state of the river Kleven in this part of the territory between the villages of Yatsyne and Kamin made it possible to identify the part of the river mouth, which is the most promising area for a desman existence. This could be the part from the sluice near the village of Kamin to the sluice in the village Lytvynovychi (the animal was discovered here) and further upstream to the village of Stara Sharpivka. The banks of the river in this part are densely covered with shore vegetation and in places with shrubs and trees. The water level is regulated by the floodgates and is generally maintained mostly at the same level except during spring floods.

Recently floods have not been as strong and do not happen every year. The flow of the river in the described area is slow and the depth is enough to prevent the water from freezing all the way to the bottom. At the same time all food required by desmans can be found in the river. During spring floods the river joins with a number of floodplain lakes and a system of reclamation canals, allowing the animal to move to other bodies of water. The complete elimination of industrial cattle breeding in locations near the Seym floodplain influenced the desman's settlement in the river in 1990-2000. This has greatly reduced the anthropogenic pressure on the floodplains. At the same time, the aforementioned part of the channel is not an active recreation area. The inclusion of the floodplains of the Seym and Kleven in Regional Landscape Park Seymskyi and the normalization of its work contribute to the successful development of the mentioned territories by this rare animal.In spite of the long period of existence of the seymska population of *D. moschata*, its condition and number of species it contains remain unstudied. According to Mishta, Merzlikin (2009) the number of the desman here is 300-500 individuals. In our opinion, this data needs clarification, because no research of the seymska population, highly likely the last *D. moschata* population in Ukraine, has been carried out there for the last 20 years. At the same time our data analysis of different literature sources show that this population is not in good condition. The unsystematic and sporadic detection of single specimens of this animal in recent years testifies in favour of this opinion. The significant reduction of the desman's number began in the 1980's and continues to this moment. The main causes of the reduction in the population are excessive anthropogenic pressure on the animal's habitat. It is demonstrated by the use of prohibited fishing gear (nets, fishing tackle, electric fishing rods), grazing animals on the protected zones of rivers and banks of floodplains, excessive and unreasonable recreational load on water bodies, plowing of floodplains etc. At the same time the significant change of the hydrological regime of the Seym river negatively influences the desman's habitat. The full or partial absence of spring floods has already led shoaling and drying of floodplains. As a result, these places have become unfavourable for desmans existence.

CONCLUSION

The seymska population of *D. moschata* is the youngest and highly likely the last in Ukraine. It is composed of three areas: the maternal seymska, which covers riverbeds, bays, floodplain lakes, reclamation canals and water bodies in the former peat quarries in the floodplain of the Seym river; vyrivska, which covers riverbeds and a number of floodplains of the Vyr river, the left tributary of the Seym; klevenska, which is in a state of formation and covers an area of the Kleven riverbed (on the right tributary of the Seym) in its downstream. In general, the seymska population of the Russian desman is highly fragmented, small in number with very low animal density and in a state of great depression. The main factors that cause this condition are excessive anthropogenic pressure on the animals' habitat and certain global climatic changes.

REFERENCES

Jeph Anita and Khan JB 2019. Study on Some Threatened, Rare and Endangered Plant's Species in Reserve Forest Area of Jhunjhunu District, Rajasthan. *Indian Journal of Ecology* **46**(4): 755-759.

Khakhin G 2009. *Russian desman in danger: Dynamics of numbers and problems of protection*, Wildlife Conservation Center, Moscow, Russia, p. 156.

Kryzhanovsky V, Abelentsev V and Panov G 1978. *About the results of the survey of desman habitats upstream of the Seym river (Putyvl district, Sumy region).* Archival documents of the Department of Nature Reserve Fund and Environment of the Department of Ecology and Conservation of Natural Resources of Sumy Regional State Administration, Sumy.

Materials about the fauna of the Nizhny Novgorod, Zavolzhye 2002, pp. 294-325. **In**: *The Works of the State Nature Reserve "Kerzhensky"*, v.3, Nizhny Novgorod, Russia.

Merzlikin I 1992. On the influence of anthropogenic factors on the state of mammalian fauna of Sumy region, pp. 141-145. **In**: *Problems of protection and rational use of natural resources of Sumy region.* Collection of scientific works, Sumy, Ukraine.

Merzlikin I 1995. Preliminary report on desman (*D. moschata*) in the territory of Sumy region (Ukraine), pp. 30-32. **In**: *Scientific works of the Zoological Museum of Odessa State University named after I. Vernadskyi*, vol. 2, Odessa, Ukraine.

Merzlikin I and Mishta A 2008. New observations of the Russian desman (*D. moschata*) in Sumy region, pp. 206-208. **In**: *Findings of Animals of the Red Book of Ukraine*, Kyiv, Ukraine

Mishta A and Merzlikin I 2009. Russian Desman, *Desmana moschata* (Linnaeus, 1758), p. 486. **In:** I . Akimov (eds). *Red Book of Ukraine. Animal World*, Global consulting, Kyiv, Ukraine.

Newsline 2019. Scientists have named the reason why humanity should give up meat. https://www.newsline.com.ua/society/uchenye-nazvali-prichinu-pochemu-chelovechestvo-dolzhno-otkazatsya-06022019171700.

Pydoplychko I 1951. Desmans, pp. 186-190. **In**: I. Pydoplychko (eds). *About the Ice Age.* Issue 2, Publisher of the Academy of Sciences of the Ukrainian SSR, Kyiv, Ukraine.

Serdiuk N 1978. New data on the desman's distribution in Ukraine. *Journal of Zoologists* **2**: 79-80.

Skorobogatov E 2000. *Preliminary report on research work "Inventory of desman lands in the Seym river floodplain of Sumy region"*. Archival documents of the Department of Nature Reserve and Environment Department of Ecology and Conservation of Natural Resources of Sumy Regional State Administration, Sumy.

Tsyupka V 2012. New findings of the Russian desman (*Desmana moschata*) in the Seym River basin, pp. 145–147. **In**: *Proceedings of the Theological School*, vol. 11, Kyiv, Ukraine.

Uk.wikipedia.org 2019. The modern distribution of the desman. https://uk.wikipedia.org/wiki/Хохуля_руська

Vandna Devi, Fulekar MH and Bhawana Pathak 2019. Public perception on climate change and its impacts on various aspects: A case study of great Himalayan National Park (India). *Indian Journal of Ecology* **46**(3): 623-630.

William J. Ripple, Christopher Wolf, Thomas M. Newsome, Michael Hoffmann, Aaron J. Wirsing and Douglas J. McCauley 2017. Extinction risk is most acute for the world's largest and smallest vertebrates. *PNAS Early Edition* **114**(40): 10678-10683

William J. Ripple, Christopher Wolf, Thomas M. Newsome, Matthew G. Betts, Gerardo Ceballos, Franck Courchamp, Matt W. Hayward, Blaire Van Valkenburgh, Arian D. Wallach and Boris Worm 2019. Are we eating the world's megafauna to extinction? *Conservation Letters* **12**: e12627.

Yemets O 2019. Meeting with *Desmana moschata* on the territory of the Seimsky RLP, p. 57. **In**: M.Yu. Rusin & M.A. Ghazali (eds). Mammals on map of Ukraine. Materials of the *First Ukrainian Mammal Mapping Conference*, Kyiv, Kyiv Zoo, 28–29 March, 2019, Ghazali, Kyiv, Ukraine.

Zagorodniuk I, Kondratenko O, Domashlinets V 2002. *Russian Desman (Desmana moschata) in the Siversky Donets Basin,* National Academy of Sciences of Ukraine, Kyiv, Ukraine, p. 64.

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Floristic study of Urban Green Space of Purulia Region, India

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Abstract: The floristic study was undertaken at an urban green space in Purulia, West Bengal during 2018-2019. A total of 88 species of Magnoliophyta (angiosperms) were documented systematically on the basis of Cronquist's system of classification out of which 80.7% are dicots and 29.3% are monocots. The dicots dominated over monocots in terms of their contribution to flora. The ratio of tree, herb and shrub were 37.5%, 45.45% and 17.05%, respectively. The present conservation status of the plants as per IUCN indicated that only 18 species were classified under different categories such as 1 critically endangered, 1 endangered, 1 near threatened, 2 data deficient and 13 least concern, while most of the species were not evaluated. This study can provide insights to comprehend the dynamics of the flora and help for future plantation program, designing and management of landscape in this campus and other urban green spaces in the adjacent areas.

Keywords: Floristics, Magnoliophytes, Urban ecology, Conservation status, Biodiversity

The exponential growth of the human population and subsequent rapid urbanization in developing countries like India encourage transformation processes of both natural and ecological systems on the local, regional and global scale. In order to assess such processes, studies focusing on urban ecology have flourished rapidly in recent years (Celesti-Grapow 2006, Kowarik 2011). Within urban ecosystems, themes like the flora in and around human settlements have earned great importance recently (Celesti-Grapow et al 2013, Aronson et al 2014). In cities, urban green spaces are immensely valuable because they provide ecosystem services, social benefits and possible contribution to biodiversity conservation (Nehru et al 2012, Zari 2018) and may exist in the form of botanical gardens, parks, unused fields, woodlands (Smith et al 2006, Primack and Miller-Rushing 2009, Kitha and Lyth 2011, Chen and Sun 2018), urban forests/ wildscapes (Nerlekar and Kulkarni 2015), peri-urban home gardens (Kunhamu et al 2015), campuses of educational and research institutes (Renukarya et al 2015, Nerlekar et al 2016, Balan and Harikrishnan 2017). Study of urban flora across the cities has also been performed in various parts of the world (Celesti-Grapow et al 2013, Wang et al 2020).

Purulia city is the headquarter of Purulia district that comprise of several urban green spaces. Though flora of Purulia district has been conducted previously (Malick 1966). However, flora of urban green spaces in Purulia city have not been documented. In view of the foregoing the present work was undertaken to present an inventory of the current floristic diversity and assess the existing conservation status of plants as per IUCN in the Jagannath Kishore College Campus in Purulia district. This fundamental study will provide information for proper planning and designing of landscape management and tree plantation in this campus as well as in the urban green spaces of the adjoining areas.

MATERIAL AND METHODS

Study area: Purulia, lying between 22º60′ and 23º50′ North latitude and 85º75′ and 86º65′ East longitude, is the western-most district of West Bengal that occupies an area of 6259 sq km with forests covering nearly 87.60 thousand hectares. The district is characterized by undulating topography with rugged hilly terrain in the western and southern part. General elevation ranges from 100 to 300 meters. Master slope ranges between 10 to 20 m/km. climatologically, Purulia district falls under semi-arid and drought-prone region. The soil is of lateritic type and the temperature ranges from 26ºC to 44ºC during summer and from 11ºC to 24ºC during winter. Average rainfall recorded during last fifty years is 1375.2 mm.The study site Jagannath Kishore College campus lies between latitude 23.317135 longitude 86.368746 (Source: Google map) of Purulia district of West Bengal state (Fig. 1). The campus covers an area of 20 acres. The campus harbours various indigenous/naturalized as well as cultivated plant species.

Methodologies: The plant species inhabiting this site were recorded by periodic field studies during the year 2018-2019. The plant specimens were collected and identified with the help of pertinent taxonomic literature (Guha Bakshi 1984, Bennet 1987, Prain 1903). After identification, the plant species were enumerated under respective families and arranged according to Cronquist's system of classification

(1988). The existing conservation status of each taxon provided is based on IUCN criteria (ver. 4).

RESULTS AND DISCUSSION

Floristic composition: The present site had a total of 88 species affiliated to 85 Genera and 38 Families. Members of the families Fabaceae, Euphorbiaceae, Malvaceae, Lamiaceae, Asteraceae and Poaceae were mainly distributed throughout the study site (Table 1). Of the 38 families, the most dominant family is Fabaceae with 11 species, followed by Euphorbiaceae with 6 species. About 4 species are recorded each from the families Malvaceae, Apocynaceae, Rubiaceae and Asteraceae. The remaining families are characterized by 1-3 species. The study site is represented by a diverse collection of plant species. Such variable accounts of species diversity have been reported from other Institute campuses of India as well (Balan and Harikrishnan 2017).The dicots are represented by 29 families, 68 genera and 71 species while monocots represent 9 families, 17 genera and 17 species (Table 2). Ratio of dicot/monocot at different taxon level showed that dicots dominated over monocots in all the cases. Habit analysis (Fig. 2) revealed that, out of the 88 taxa identified, the majority were herbs (40; 45.45%) and followed by trees (33; 37.5%) and shrubs (15; 17.05%).The main reason for dominance of herbs is that these can easily grow in any condition of environment in a given area.

Important uses of the existing flora: Major utilities of the plants included medicinal, edible, timber-yielding, ornamental, chemical compound-yielding, etc. (Table 1). The study revealed that 72 species are used as medicine, while13 and 12 species are used in the form of food and fruit respectively. Also 27, 25, 15 and 10 species are used for ornamental purpose, chemical compound, timber and fuel generation respectively. Interestingly there were 9 species that are used as insect repellents/poisons. The prominent plants with multipurpose activities were *Azadirachta indica* (7 utilities) and *Mangifera indica* (6 utilities).

Current conservation status of the existing urban flora: Furthermore, a study was made to understand the current conservation status of the recorded plant species as per IUCN. It was observed among 88 species; only 18 species were enumerated for conservation status at a global scale, while most of the species are still not evaluated (Table 3). About 13 species have been given the status of least concern, 2 are under data deficient category, while critically

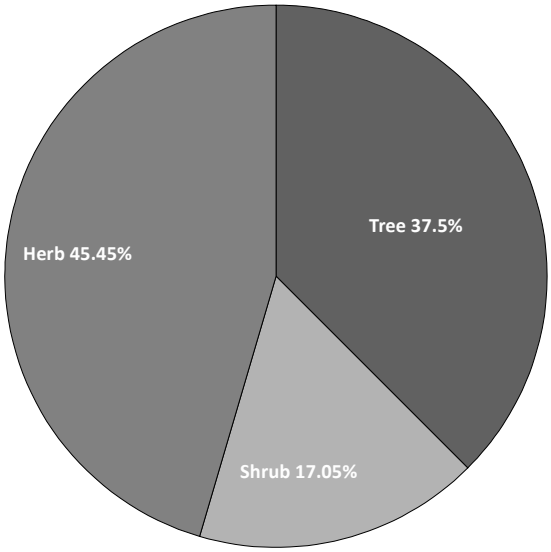

Fig. 2. Habit analysis of flowering plants in the study site

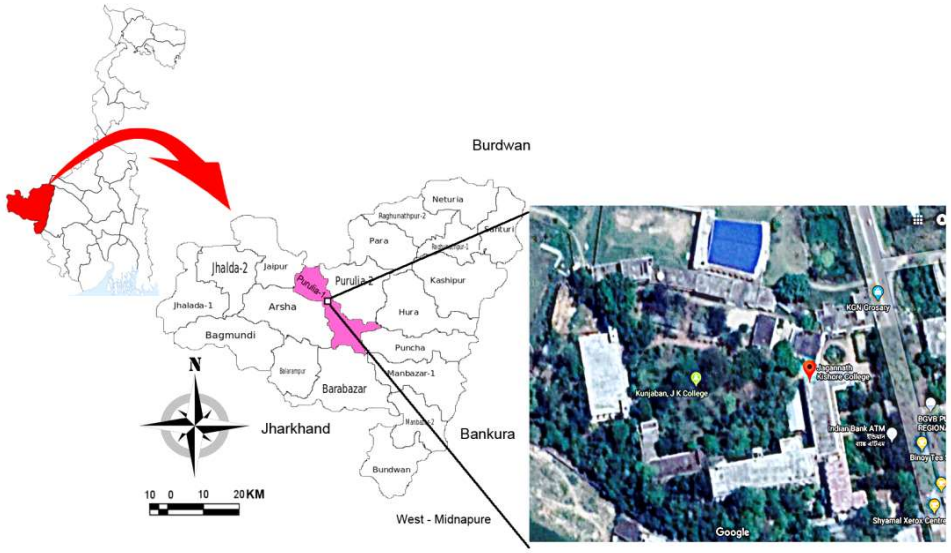

Fig. 1. Location of the study site with prominent land marks (2019)

Table 1. An enumeration of the flowering plants on the basis of Cronquist's classification 1988 (Corresponding habit of each species is mentioned in the parentheses)

Class	Subclass	Order	Family	Name of species	Utility**
Magnoliopsida	Magnoliidae	Magnoliales	Annonaceae	1. *Polyalthia longifolia* (Sonn.) Thwaites (Tree)	4, 6, 8
				2. *Annona squamosa* L. (Tree)	1, 3, 10
	Hamamelidae	Uritales	Moraceae	3. *Ficus benghalensis* L. (Tree)	1, 6, 7
				4. *Ficus religiosa* L. (Tree)	1, 7, 8
	Caryophyllidae	Caryophyllales	Nyctaginaceae	5. *Boerhavia diffusa* L. (Herb)	1
				6. *Mirabilis jalapa* L. (Shrub)	1, 6
			Amaranthaceae	7. *Achyranthes aspera* L. (Herb)	1, 2
				8. *Alternanthera sessilis (*L.) R. Br. ex DC. (Herb)	1, 2
				9. *Gomphrena celosioides* Mart. (Herb)	2, 6
	Dilleniidae	Dilleniales	Dilleniaceae	10. *Dillenia indica* L. (Tree)	1, 2, 3, 6
		Malvales	Malvaceae	11. *Hibiscus rosa-sinensis* L.(Shrub)	1, 6, 7, 8
				12. *Hibiscusschizopetalus* (Dyer.) Hook.fil. (Shrub)	6
				13. *Sida acuta* Burm.f. (Herb)	1
				14. *Pterospermum acerifolium* (L.) Willd. (Tree)	1, 4, 5, 6
		Violales	Caricaceae	15. *Carica papaya* L. (Tree)	1, 2, 3
			Cucurbitaceae	16. *Coccinia grandis*(L.)Voigt.(Herb/climber)	1, 2
		Capparales	Capparaceae	17. *Cleome viscosca* L. (Herb)	1
			Moringaceae	18. *Moringa oleifera* Lam. (Tree)	1, 2, 7
		Ebenales	Sapotaceae	19. *Mimusops elengi* L. (Tree)	1, 2, 11
	Rosidae	Rosales	Rosaceae	20. *Rosa indica* L. (Shrub)	1, 6
		Fabales	Fabaceae	21. *Desmodium gangeticum* DC. (Herb)	1
				22. *Acacia auriculiformis* A. Cunn (Tree)	1, 4, 5, 7
				23. *Clitoria ternatea* L. (Herb)	1, 6, 7
				24. *Tamarindus indica* L. (Tree)	1, 2, 3, 4, 7
				25. *Delbergia sissoo* Roxb. (Tree)	1, 4, 5 ,7, 10
				26. *Mimosa pudica* L (Herb)	1
				27. *Alysicarpus monilifer* (L.) DC. (Herb)	1
				28.*Tephrosia purpurea* (L.) Pers. (Herb)	1, 7, 10
				29. *Crotalaria pallida* Aiton. (Herb)	1
				30. *Butea monosperma* (Lam.) Taub. (Tree)	1, 4, 5, 7, 9
				31. *Delonix regia* (Boj. Ex Hook.) Raf. (Tree)	1, 4, 6, 7, 11
		Myrtales	Lythraceae	32. *Punica granatum* L. (Tree)	1, 3, 7
			Myrtaceae	33. *Psidium guajava* L. (Tree)	1, 3, 5, 7, 11
				34. *Syzygium cumini* (L.) Skeels (Tree)	1, 3, 4, 5, 7
				35. *Melaleuca viminalis* (Sol. ex Gaertn.) Byrnes (Tree)	1, 6
			Combretaceae	36. *Terminalia bellirica* (Gaertn.) Roxb. (Tree)	1, 7, 11
		Euphorbiales	Euphorbiaceae	37. *Croton bonplandianum* Bail. (Herb)	1
				38. *Acalypha indica* L. (Herb)	1, 11
				39. *Euphorbia heterophylla*L. (Herb)	1, 10

Cont...

Continues Table 1

Class	Subclass	Order	Family	Name of species	Utility**
				40. *Euphorbia hirta* L. (Herb)	1
				41. *Jatropha gossypifolia* L. (Shrub)	1, 7, 11
				42. *Phyllanthus simplex* Retz. (Herb)	1
		Sapinadales	Anacardiaceae	43. *Mangifera indica* L (Tree)	1, 2, 3, 4, 5, 7
			Meliaceae	44. *Azadirachta indica* A.Juss (Tree)	1, 2, 4, 5, 7, 10, 11
				45. *Swietenia mahagoni* (L.) Jacq.F (Tree)	1, 4
				46. *Melia azedarach* L. (Tree)	1, 4, 7, 10
			Rutaceae	47. *Murraya paniculata* (L.) Jack (Shrub)	1, 7, 11
				48. *Aegle marmelos* Corr. (Tree)	1, 3, 7, 11
				49. *Citrus aurantiifolia* (Christm.) Swingle (Shrub)	1, 3, 7
		Gerniales	Oxalidaceae	50. *Oxalis corniculata* L. (Herb)	1
				51. *Averrhoa carambola* L. (Tree)	1, 3, 11
	Asteridae	Gentiales	Apocynaceae	52. *Catharanthus roseus* (L.) G. Don (Shrub)	1
				53. *Nerium indicum* Mill. (Shrub)	6, 10
				54. *Thevetia parviflora* L. (Shrub)	6, 10
				55. *Plumeria rubra* L. (Tree)	1, 6, 7
		Solanales	Solanaceae	56. *Solanum sisimbrifolium* Lam. (Herb)	Not known
		Scrophulariales	Acanthaceae	57. *Ruelia tuberosa* L. (Herb)	1
				58. *Andrographis paniculata* (Burm.f.) Wall. ex Nees (Herb)	1
			Bignoniaceae	59. *Tecoma castanifolia* (D. Don) Melch. (Shrub)	1, 6
		Lamiales	Verbenaceae	60. *Lantana camara* L.* (Shrub)	1, 12
				61. *Duranta erecta* L. (Shrub)	
			Lamiaceae	62. *Tectona grandis* L.f. (Tree)	4, 5, 7
				63. *Gmelina arborea* Roxb. (Tree)	4, 5, 7
		Rubiales	Rubiaceae	64. *Ixora grandiflora* L. (Shrub)	1, 6
				65. *Musaenda frondosa* L. (Tree)	1, 6
				66. *Oldenlandia corymbosa* L. (Herb)	1
				67. *Neolamarckia cadamba* (Roxb.) Bosser (Tree)	1
		Asterales	Asteraceae	68. *Synedrella nodiflora* (L.) Gaertn. (Herb)	1
				69. *Parthenium hysterophorus* L.* (Herb)	12
				70. *Tridax procumbens* L. (Herb)	1, 10
				71. *Ageratum conyzoides* L.* (Herb)	1, 12
Liliopsida	Arecidae	Arecales	Arecaceae	72. Caryota urens L.(Tree)	1, 4, 6, 9
				73. *Dypsis lutescens* (H. Wendl.) Beentje and J.Dransf. (Tree)	6
				74. *Hyophorbe lagenicaulis* (L. H. Bailey) H. E. Moore (Tree)	6
		Arales	Araceae	75. Caladium bicolorVent. (Herb)	1, 6
				76. Pistia stratiotesL. (Herb)	1
				77. *Di*effenbachia seguine(Jacq.) Schott (Herb)	6
	Commelinidae	Commelinales	Commelinaceae	78. *Murdannia triquetra*(Wall. ex C.B.Clarke) G.Brückn.(Herb)	6
				79. *Commelina benghalensis* L. (Herb)	1
		Cyperales	Cyperaceae	80. *Cyperus rotundus* L. (Herb)	1, 11
				81. *Kyllinga brevifolia* Rottb. (Herb)	1
			Poaceae	82. *Elusine indica* (L.) Gaertn. (Herb)	1, 11
				83. *Eragrostis tenella* (L.) Wight and Arn. Ex Nees (Herb)	Not known
				84. *Cynodon dactylon* (L.) Pers. (Herb)	1
	Zingiberidae	Zingiberales	Musaceae	85. *Musa paradisiaca* L. (Shrub)	1, 2, 3, 6, 11
	Liliidae	Liliales	Aloeaceae	86. *Aloe vera* (L.) Burm.f. (Herb)	1, 6
			Liliaceae	87. *Asparagus racemosus* Willd. (Herb/climber)	1, 2
			Agavaceae	88. *Agave americana* L. (Herb)	1, 6

* Invasive species

**Utility codes: 1. medicinal, 2. food, 3. fruit, 4. timber, 5. fuel, 6. ornamental, 7. chemical compounds 8. religious, 9. fibre, 10. poison/repellent, 11. other uses, 12. noxious(Source: Tropical Plants Database, Ken Fern. tropical.theferns.info. 2020-07-20)

Table 2. Taxonomic analysis of the vegetation in the study site

	Subclass	Order	Family	Genera	Species
Magnoliopsids (Dicots)	6	20	29	68	71
Liliopsids (Monocots)	4	6	9	17	17
Magnoliopsids:Liliopsids	1.5:1	3.3:1	3.2:1	4:1	4.2:1

Table 3. A list of the plants observed from study site with existing conservation status as per IUCN

Family	Species	Habit	Existing conservation status (on global scale) as assigned by IUCN	Factors leading to depletion/rarity	Reference
Amaranthaceae	*Alternanthera sessilis* (L.) R.Br. ex DC.	Herb	Least Concern	It is a weed and is not subject to any known threats	Lansdown and Beentje 2017
Caricaceae	*Carica papaya* L.	Tree	Data deficient	habitat fragmentation	Contreras 2016
Fabaceae	*Acacia auriculiformis* A. Cunn	Tree	Least Concern	no major threats	Contu 2012
Fabaceae	*Tamarindus indica* L.	Tree	Least Concern	no major threats	Rivers and Mark 2017
Fabaceae	*Mimosa pudica* L	Herb	Least Concern	no major threats	Groom 2012
Fabaceae	*Delonix regia* (Boj. ex Hook.) Raf.	Tree	Least Concern	Livestock farming and ranching	Rivers 2014
Lythraceae	*Punica granatum* L.	Tree	Least Concern	threatened by livestock grazing	IUCN 2007
Anacardiaceae	*Mangifera indica* L.	Tree	Data deficient	Population severely fragmented, continuing decline of mature individuals	World Conservation Monitoring Centre 1998
Meliaceae	*Azadirachta indica* A. Juss	Tree	Least Concern	Invasive non-native/alien species/disease; Problematic species/ disease of unknown origin	Barstow and Deepu 2018
Meliaceae	*Swietenia mahagoni* (L.) Jacq. F	Tree	Endangered	Logging and wood harvesting	Bahamas and Barstow 2020
Meliaceae	*Melia azedarach* L.	Tree	Least Concern	no major threats	Barstow 2018
Arecaceae	*Caryota urens* L.	Tree	Least Concern	severe disturbance such as logging trails and forest clearance for shifting cultivation (Johnson 1996)	Loftus2014
Arecaceae	*Dypsis lutescens* (H.Wendl.) Beentje and J.Dransf.	Tree	Near Threatened	habitat loss from expanding agriculture and harvesting of plants from the wild to supply the local horticultural markets	Rakotoarinivo and Dransfield 2012
Arecaceae	*Hyophorbe lagenicaulis* (L.H. Bailey) H.E. Moore	Tree	Critically Endangered	Invasive and other problematic species, genes and diseases	Page 1998
Araceae	*Pistia stratiotes* L.	Herb	Least Concern	no major threats	Beentje et al 2017
Commelinaceae	*Commelina benghalensis* L.	Herb	Least Concern	no major threats	Beentje and Lansdown 2018
Cyperaceae	*Cyperus rotundus* L.	Herb	Least Concern	no major threats	Lansdown et al 2018
Cyperaceae	*Kyllinga brevifolia* Rottb.	Herb	Least Concern	no major threats	Lansdown 2017

endangered, endangered and near threatened status are recommended for 1 species each of *Hyophorbe lagenicaulis, Swietenia mahagoni* and *Dypsis lutescens* respectively.

Apart from the human activities, fast-spreading invasive alien species viz., *Lantana camara*, *Parthenium hysterophorus* and *Ageratum conyzoides* found in the site, also pose potential risk to the naturalized and cultivated flora of the campus as they inhibit the growth of other plants due to their own rapid development (Mallick et al 2019). Therefore, strict conservational measures are to be taken to protect the important plant species from all possible threats.

CONCLUSION

In the present study, only Angiosperms were covered. The college campus is also rich in other group of plants like Algae, Fungi, Bryophytes, Pteridophytes and Gymnosperms. Apart from the diverse flora, the campus is home to animals, such as squirrel, canis, felis, bovine among others. A rich variety of birds including Black Drongo, house crow, sparrow, Asian Koel, Purple sunbird, Lesser Golden-back Woodpecker, Red-Vented Bulbul, etc., can be seen in the campus. Butterflies and insects are another unexplored group. It is very important to study the non-flowering plants and fauna of the campus to have an in-depth knowledge of the biodiversity of the campus. Moreover, study of floristic composition of vegetation is crucial for urban biodiversity and conservation management by providing habitats for wildlife and contributing to the ecologically sustainable management of natural resources.

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REFERENCES

Bahamas GTA Workshop 2018, Barstow M 2020. Swietenia mahagoni. *The IUCN Red List of Threatened Species 2020*: e.T32519A68104916. https://dx.doi.org/10.2305/IUCN.UK.2020-1.RLTS.T32519A68104916.en.

Balan AP and Harikrishnan S 2017. Floristic diversity of the Indian Cardamom Research Institute campus, Myladumpara, Western Ghats, India. *Journal of Threatened Taxa*, *9*(10): 10804-10822.

Barstow M 2018. *Melia azedarach*. *The IUCN Red List of Threatened Species 2018*: e.T61801956A61801958.https://dx.doi.org/10.2305/IUCN.UK.2018-1.RLTS.T61801956A61801958.en.

Barstow M and Deepu S 2018. *Azadirachta indica*. *The IUCN Red List of Threatened Species 2018*: e.T61793521A61793525. http://dx.doi.org/10.2305/IUCN.UK.2018-1.RLTS.T61793521A61793525.en.

Beentje HJ and Lansdown RV 2018. *Commelina benghalensis*. *The IUCN Red List of Threatened Species 2018*: e.T177240A120145118. http://dx.doi.org/10.2305/IUCN.UK.2018-2.RLTS.T177240A120145118.en.

Beentje HJ, Drius M and Gupta AK 2017. *Pistia stratiotes*. *The IUCN Red List of Threatened Species 2017*: e.T168937A84295055. http://dx.doi.org/10.2305/IUCN.UK.20171.RLTS.T168937A84295055.en.

Bennet SSR 1987. *Name changes in flowering plants of India and adjacent regions*. Triseas Publishers, Dehradun.

Burrows CJ 1990. *Processes of Vegetation Change*. Oxford: Routledge Press.

Celesti-Grapow L, Capotorti G, Del Vico E, Lattanzi E, Tilia A and Blasi C 2013. The vascular flora of Rome. *Plant Biosystems-An International Journal Dealing with all Aspects of Plant Biology* **147**(4):1059-1087.

Celesti-Grapow L, Pyšek P, Jarošík V and Blasi C 2006. Determinants of native and alien species richness in the urban flora of Rome. *Diversity and Distributions* **12**(5): 490-501.

Chen G and Sun W 2018. The role of botanical gardens in scientific research, conservation, and citizen science. *Plant diversity* **40**(4): 181-188.

Contreras A 2016. *Carica papaya*. *The IUCN Red List of Threatened Species 2016*: e.T20681422A20694916.http://dx.doi.org/10.2305/IUCN.UK.2016-3.RLTS.T20681422A20694916.en.

Contu S 2012. *Acacia auriculiformis*. *The IUCN Red List of Threatened Species 2012*: e.T19891902A19997222.http://dx.doi.org/10.2305/IUCN.UK.2012.RLTS.T19891902A19997222.en.

Cronquist A 1988. *The Evolution and Classification of Flowering* Plants (Second edition). The New York Botanical Z Garden, Bronx, New York, USA: 503-517.

FFI/IUCN SSC Central Asian regional tree Red Listing workshop, Bishkek, Kyrgyzstan (11-13 July 2006) 2007. *Punica granatum*. *The IUCN Red List of Threatened Species 2007*: e.T63531A12687411. https://dx.doi.org/10.2305/IUCN.UK.2007.RLTS.T63531A12687411.en.

Groom A 2012. *Mimosa pudica*. *The IUCN Red List of Threatened Species 2012*: e.T175208A20112058.http://dx.doi.org/10.2305/IUCN.UK.2012.RLTS.T175208A20112058.en

GuhaBakshi DN 1984. *Flora of Murshidabad District West Bengal, India*. Scientific Publishers, Jodhpur, India.

Kitha J and Lyth A 2011. Urban wildscapes and green spaces in Mombasa and their potential contribution to climate change adaptation and mitigation. *Environment and Urbanization* **23**(1): 251-265.

Kowarik I 2011. Novel urban ecosystems, biodiversity, and conservation. *Environmental Pollution* **159**(8-9): 1974-1983.

Kunhamu TK, Ajeesh R and Kumar V. Floristic Analysis of Peri-Urban Home gardens of Southern Kerala, India. *Indian Journal of Ecology* **42**(2): 300-305.

Lansdown RV 2017. *Kyllinga brevifolia* (amended version of 2013 assessment). *The IUCN Red List of Threatened Species 2017*: e.T168653A121917281.http://dx.doi.org/10.2305/IUCN.UK.2017-3.RLTS.T168653A121917281.en.

Lansdown RV and Beentje HJ 2017. *Alternanthera sessilis*. *The IUCN Red List of Threatened Species 2017*: e.T164480A67771620. http://dx.doi.org/10.2305/IUCN.UK.2017-1.RLTS.T164480A67771620.en.

Lansdown RV, Bignoli DJ and Beentje HJ 2018. *Cyperus rotundus*. *The IUCN Red List of Threatened Species 2018*: e.T158183A120153257. http://dx.doi.org/10.2305/IUCN.UK.2018-2.RLTS.T158183A120153257.en.

Loftus C 2014. *Caryota urens*. *The IUCN Red List of Threatened Species 2014*: e.T44393459A44452629. http://dx.doi.org/10.2305

Malick KC 1966. A contribution to the Flora of Purulia district, West Bengal. *Nelumbo* **8**(1): 45-59.

Mallick SN, Ekka NX, Kumar S and Sahu SC 2019. Invasive Alien Flora in and around an Urban Area of India. In *Diversity and Ecology of Invasive Plants*. IntechOpen. DOI: http://dx.doi.org/10.5772/intechopen.88725.

Nehru P, Gnanasekaran G, Karthick NM and Narasimhan D 2012. Angiosperms of Nanmangalam Reserve Forest, an urban forest in metropolitan Chennai, India. *Check List* **8**: 057–076.

Nerlekar AN and Kulkarni DK 2015. The Vetal hills: an urban wilds cape in peril. *Taprobanica* **7**(2): 72-78.

Nerlekar AN, Lapalikar SA, Onkar AA, Laware SL and Mahajan MC 2016. Flora of Fergusson College campus, Pune, India: monitoring changes over half a century. *Journal of Threatened Taxa* **8**(2): 8452-8487.

Page W 1998. *Hyophorbe lagenicaulis*. *The IUCN Red List of Threatened Species 1998*: e.T38580A10126445.https://dx.doi.org/10.2305/IUCN.UK.1998.RLTS.T38580A10126445.en

Prain D 1903. *Bengal Plants*, Calcutta, West Bengal.

Primack RB and Miller-Rushing AJ 2009. The role of botanical gardens in climate change research. *New Phytologist* **182**(2): 303-313.

Rakotoarinivo M and Dransfield J 2012. *Dypsis lutescens*. *The IUCN Red List of Threatened Species 2012*: e.T195960A2436709. http://dx.doi.org/ 10.2305/IUCN. UK.2012. RLTS.T195960A2436709.en.

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Renukarya CK, Kumar HK and Chauhan JB 2015. Studies on the flora of Mahajana PG campus. *Journal of Scientific and Innovative Research* **4**(5): 207-212.

Rivers M 2014. *Delonix regia*. *The IUCN Red List of Threatened Species 2014*: e.T32947A2828337.https://dx.doi.org/10.2305/IUCN.UK.2014-1.RLTS. T32947A2828337.en.

Rivers MC and Mark J 2017. *Tamarindus indica*. *The IUCN Red List of Threatened Species 2017*:e.T62020997A62020999. http://dx.doi.org/10.2305/IUCN.UK.2017-3.RLTS.T62020997A62020999.en.

Smith RM, Thompson K, Hodgson JG, Warren PH and Gaston KJ 2006. Urban domestic gardens (IX): composition and richness of the vascular plant flora, and implications for native biodiversity. *Biological Conservation* **129**(3): 312–322.

Wang M, Li J, Kuang S, He Y, Chen G, Huang Y, Song C, Anderson P and Łowicki D 2020. Plant Diversity Along the Urban–Rural Gradient and Its Relationship with Urbanization Degree in Shanghai, China. *Forests* **11**(2): 171. doi:10.3390/f11020171

World Conservation Monitoring Centre 1998. *Mangifera indica*. *The IUCN Red List of Threatened Species 1998*: e.T31389A9624842. https://dx.doi.org/10.2305/IUCN.UK.1998.RLTS.T31389A9624842.en.

Zari MP 2018. The importance of urban biodiversity: An ecosystem services approach. *International Journal of Biodiversity* **2**(4): 357–360.DOI: 10.15406/bij.2018.02.00087.

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Ethnobotanical Uses of Medicinal Plants in Part of Pauri Garhwal

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Abstract:A study on ethnobotanical uses of medicinal plants was carried out in eight villages in four different altitudinal ranges of Pauri Garhwal. Regarding traditional utilization, about 91 ethno-botanical species viz. 26 tree species, 19 shrubs, 41 herbs, 2 climbers and 1 fern were utilized by the local people in study area. The species like *Quercus leucotrichophora, Grewia optiva, Bauhinia variegate Abrus brachystemon* and *Boehmeria rugulosa* used by local people for food, fodder, edible fruits, fibre, medicinal and for agricultural implements. The local people were keen to provide the information and transferring the indigenous knowledge of medicinal plants from one generation to other. The information obtained from the study can be utilized for conservation, sustainable utilization and management of forest resources from the study area for socio-economic development of the inhabitants and maintaining diversity.

Keywords: Medicinal plants, Trees, Shrubs, Herbs, Ethnobotanical uses, Indigenous knowledge

The Indian Himalayan region (IHR) is very well known throughout the globe due to its representative, unique, natural and socio-economically important flora and fauna. This rich biodiversity is being utilized by the inhabitants of the region for medicine as wild edible food, fodder, fuel and timber in marketing agriculture tools, religious and various other purposes (Samant and Dhar 1997, Samant et al 1998a,b). Forest diversity is the main source of livelihood of the people living in Uttarakhand, Central Himalaya. As per an estimate, over 1600 species of medicinal plants traditionally used in India, more than 50% species comes from the Himalayan region (Uniyal et al 2002). The World Health Organization has estimated that 80% of the developing world relied on their traditional medicines and that of these 85% use plants or their extracts as the active substance (Sheldon et al. 1998).Traditional ethno-botanical studies in recent years have received much attention due to their wide local acceptability and clues for new or lesser known medicinal plant (Tripathi 2000). Indigenous traditional knowledge of medicinal plants of various ethnic communities, where it has been transmitted orally to the next generation and others for centuries, is fast disappearing due to the advent of modern technology and transformation of traditional culture (Gupta 1995).

MATERIAL AND METHODS

The study was carried out in different sites of Amali forest range (East and West range) of Pauri Garhwal. Randomly eight villages in four different altitudinal gradient ranges viz., 1000-1300m (Pabau and Barsudi village), 1300-1600m (Dhor and Kothla village), 1600-1900m (Nautha and Sainji village) and 1900-2200m (Dhulet and Kaprouli village) were selected. The importance regarding the traditional knowledge, local uses of the plants of the study area, containing the information about the local name of the plant, life form, parts used and purpose for which uses was recorded through discussions with the knowledgeable and elderly local people of the study area with the help of predesigned developed questioners. Twelve respondents were selected randomly in each selected village. The different plant samples were collected and identified with the help of local flora (Gaur 1999) and subject expert from S.R.T campus Tehri Garhwal.

RESULTS AND DISCUSSION

A total of 91 species belonging to 88 genera and 44 families have been collected from the study area. The collected species have been described along with botanical names, families, local/common name, part used and uses (Table 1). The maximum number of genera belongs to the family Asteraceae (10) followed by Rosaceae (7). In Asteraceae, genus *Biodens* has the most number of species (2). In Rosaceae, *Prunus* has maximum number of species (2). The family Moraceae was represented by a maximum number of genera (4) and species (5). The ten predominant families in study area are Asteraceae (9 genera and 10 species), followed by Rosaceae (6 genera and 7 species), Moraceae (1 genera and 5 species), Lauraceae and

Table 1. The Ethno-botanical uses of plants in study area

Species and family	Local name	Altitudinal range (m asl)	Life form	Part used	Uses
Agavaceae *Agave Americana*	Ram bans	1050-1258	S	Lf	Leaf fiber used for rope making.
Anacardiaceae *Mangifera indica*	Aam	1226-1523	T	Fr, wd, B, Se, Fl	Fruits of commercial important wood for furniture and construction purposes. Bark in hemorrhage and dried powdered in spices. Resin and seed in diarrhea; flowers useful source of bee-forage in apiary.
Rhus parviflora	Tungla	1050-1782	S	Fr, Lf, Fl	Fruits edible; wood as fuel, Infusion of leaves given in cholera; flowers useful source of bee-forage in apiary.
Asphodelaceae *Aloe vera*	Gheeku-mari	1548-1589	H	wp	Aloe vera extracts for either cosmetic or medicinal purposes. Dietary supplements and used for traditional medicine as a skin treatment.
Amaranthaceae *Amaranthus spinosus*	Kanteli Chauli	1258	H	Lf	Leaves used as vegetables and fodder.
Achyranthes aspera	Chirchra	1675-2005	H	--	Malarial fever, muscular sprains and facilitating delivery and epilepsy
Amaranthus viridis	Chauali	2005-2017	H	Lf	Young shoots and leaves cooked as vegetables
Asteraceae *Eupetorium adenophorum*	Kala bans	1206-2017	H	Lf	Cuts/wounds and skin diseases. Leaf paste is applied externally on wounds, to stop bleeding on open sores and injured portion, pimples and blisters.
Ageratum conyzoides	Gundrya	1548-1609	H	Rt	Plant with the roots of Thalictrum foliolosum made into paste and applied on sores, cuts and skin ailments.
Anaphalis busa	Buglya	1609-1782	H	Lf	Leaf juice applied on bruises, wounds and cuts.
Parthenium hysterophorus	Gajar-ghas	1523-1609	H	St	Remedy for skin inflammation, rheumatic pains, diarrhea and urinary problem. This plant traditionally used for the treatment of migraine headaches, toothaches and fever.
Taraxacum officinale	Dandelion	1675-1782	H	Rt	Root extract used in the treatment of migraine, hepatitis and headache
Galinsoga parviflora	Marchya	1906-2005	H	wp	Plant used as fodder and rubbed on the skin as an antidote of nettle stings.
Biodens bipinnata	Kuru	1906-2005	H	Lf	Vegetables of leaves supposed to be good at the initial stages of leprosy and keeps away from several ailments; leaf juice used in cuts.
Biodens pilosa	Kumur	1906-2022	H	-	Plant extract with honey used in cough and bronchitis; the vegetable of the herb considered useful in leucoderma.
Aster thomsonii	Phulari	1906	H	Lf	Leaf powder taken in indigestion.
Echinops cornigerus	Kantela	1258-1589	H	Rt	Roots edible; root extract given to infants to promote emergence of teeth; roots juice given in fever head as source of bee- forage in apiary.
Berberidaceae *Berberis aristata*	Kingore	1226-1589	S	B, Rt, Fr	Juice from bark of stem or root often known as 'Rasaut' dropped in ophthalmic. Infusion of root given in fever. Fruits edible; bark yields dye.
Berberis lyceum	Kware	1258-1523	S	Rt, Fr	Fruits are edible. Root and stem bark is used tonic and blood purifier. Root is antiseptic upon the fractured bones and utilization for healing of internal wounds.
Betulaceae *Alnus nepalensis*	Utisa	1906-2005	T T	Wd, B	Wood used for carpentry and construction; bark used in local medicinal.
Bombacaceae *Bombax ceiba*	Semal	1050-1206	T T	Fl, Se	Flower buds as vegetables; seed fibers used in stuffing pillows; Gum used to cure digestive disorders.

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Continues Table 1

Species and family	Local name	Altitudinal range (m asl)	Life form	Part used	Uses
Buxaceae *Sarcococca saligna*	Piruli	1906-2005	S	St, Lf	Stem used for making walking- sticks; leaves as green manure; occasionally after warming applied on joint pain
Caesalpinaceae *Bauhinia variegata*	Kachnar	1050-1589	T	Fl, Lf	Flowers used as vegetables and leaves for fodder.
Bauhinia purpurea	Guriyal	1050-1523	T	Fl, B	Flowers buds cooked as vegetable and foliage used as fodder; wood used for agricultural implements; bark used as medicine.
Bauhinia retusa	Semla	1050-1589	T	Lf, wd	Leaves used as fodder; wood as timber and fuel as well as medicine.
Cannabaceae *Cannabis sativa*	Bhang	1906-2005	H	Se, Lf	Seed are used as condiments; seed oil; edible; its leaves and flowers used as an intoxicating agent; Paste of leaf is applied on wisdom tooth.
Commelinaceae *Commelina benghalensis*	Kanjula	2005-2017	H	-	Plant given in dysentery and paste applied on body swelling and ache.
Cucurbitaceae *Trichosanthes tricuspidata*	Indrian	1906-2017	C	Rt, Se	Roots and fruits medicinally, commonly used to relieve bronchitis, asthma, diabetes; Seed paste applied externally on hoops and mouth disease of cattle
Dioscoreaceae *Dioscorea belophylla*	Turar	1206-1675	H	Lf, Tb	Leaves provide fodder. Tubers edible as well as medicinal, relished by wild life.
Dioscorea bulbifera	Ratalu/ Genthi	1548-1700	H	Tb, Fl	Tubers are cooked as vegetable. Dried tubers used as an antiseptic, applied on burns and wounds; Flower occasionally visited by bees.
Dryopteridaceae *Dipalzium esculentum*	Lingura	1548-1782	H	Fe	It is mainly used for vegetables. Lower part is used for bleading of animals.
Euphorbiaceae *Emblica officinalis*	Amla	1050-1609	T	Fr, Lf	Fruits used as edible, Leaves as fodder.
Ricinus communis	Arand	1460-2005	S	Sd	Seed yield fatty oil, commercially known as Coaster oil, used as purgative and laxative.
Ericaceae *Lyonia ovalifolia*	Anyar	1050-2017	T	Se	Skin eruption, worms wounds, seed paste applied on wounds and boils; Fuel
Rhododendron arboreum	Burans	1609-2022	T	Wd, Fl	Wood used for fuel and Charcoal; Flower eaten raw or made into sauce, jellies, jams or refreshing drinks; medicinal (flowers and bark used for digestive and respiratory disorders; fever, headache, wounds) Edible; Fuel; Religious.
Fabaceae *Indigofera cassioides*	Saknya	1782-1906	H	Fl, Lf	Flowers made into vegetables and snacks, often filled in between breads. Leaf flower taken in malarial fever; foliage used as fodder.
Fagaceae *Quercus lucotrichophora*	Banj	1050-2005	T	Wd, Lf, Fr	Wood used for constructions as well as fuel; leaves used as fodder; gum of the tree medicinally used for gonorrheal and digestive disorders: Edible by wild animals; Fuel; Fodder; Timber and Miscellaneous (Agriculture tools, decomposed leaves for organic manure.
Juglandaceae *Juglans regia*	Akhrot	1548-2017	T	Fr, wd, B	Fruits edible and also provide oil; wood is hard for furniture; bark used as dye and as medicine; rind of fruits used to intoxicate fish and for dyeing
Meliaceae *Melia azedarach*	Daikan	1206-1258	T T	Lf, Fr, Se, Fl	Leaves, fruits and seeds are useful in skin diseases as well as in rheumatic pains; Fruits and leaves as antiseptic and fodder; wood useful for household and agricultural implements; flowers useful source of bee-forage in apiary.

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Continues Table 1

Species and family	Local name	Altitudinal range (m asl)	Life form	Part used	Uses
Toona serrata	Toon	1548-2005	T	Lf, B	Timber yielding plant: Leaves as fodder; bark paste applied on ulcers and boils
Menispermaceae *Tinospora sinensis*	Giloei	1226-1523	C	Lf, St	Juice of stem and leaves is used in general debility and urinary troubles; leaves as fodder; extract regarded as an emetic; also used in leprosy; plant decoction given to relieve malarial fever.
Moraceae *Morus serrata*	Shatoot/Kimu	1050-1226	T	Lf, Fr	Leaves as fodder for sheep and goats; Ripe fruits edible; wood used for agricultural implements and other articles.
Ficus hispida	Ghogsha	1050-1206	S	Fr, Lf, B	Young fruits eaten in curries; leaves provide good fodder; bark used as rough fiber.
Ficus Palmata	Bedu	1548-1609	T	Lf, Fl ,Fr	Leaves and twigs for fodder; Fruits delicious in taste, often taken raw with salt or filled inside the bread; fruits are used for digestive disorders.
Ficus religiosa	Peepal	1206-1609	T	Lf	Leaves and branches good fodder for goats; wood used for making charcoal and packing cases; figs and bark medicinal used in bronchitis and skin ailments, regarded as a sacred tree.
Ficus roxburghii	Timla	1206-1589	T	Fr, Lf	Fruits edible, unripe fruits made into vegetables, wood as fuel. Leaves also provide good fodder for cattle. Plants are conserved for its religious significance and utilization.
Musaceae *Musa balbisiana*	Kela	1226-1523	T	Fr	Fruits used as edible, Ornamental
Lamiaceae *Ociumum americanum*	Jangli- tulsi	1906-2005	H	Lf	Leaves used as an insecticide, also made into ' Chutney'
Colobrookia oppositifolia	Bindu	1050-1615	S	Lf	Leaf paste applied on wounds.
Ajuga brachystemon	Neel khanti	1906-2005	H	Wp	The juice of the leaves is used against 'Khasra' and other diseases of children; Juice is given to women in gonorrhea and also used in intermittent fever; Fresh juice of leaves is used as a wound healer; Leaves paste cooked in mustard oil is also applied on head to get relief from chronic headache.
Lauraceae *Neolitsea pallens*	Bilaru, Rasu	2017-2022	S	Wd, Fr	Wood used for construction of various articles. Oil extracted from the fruits used in scabies and eczema.
Cinnamomum tamala	Dalchini	1226-1782	T	B, Lf	Bark and dried leaves used for flavouring tea and various food preparations; bark used as medicine chewed in dyspepsia and throat irritation.
Persea odoratissima	Kaulu	1226-1782	T	Wd	Wood for construction and furniture; plants are used for silk- worm farming.
Lindera pulcherrima	Cheri	2017-2022	T	Lf, Wd	Leaves used as manure; wood for agricultural implements.
Liliaceae *Asparagus racemosus*	Satawari	1258-1548	S S	-	Fodder- given to increase milk yield
Oxalidaceae *Oxalis corniculata*	Khati- mithi	1523-1782	H	Lf, Rt	Leaves taken as salad or cooked as vegetable; Leaves and roots are used to treating dysentery and diarrhea.
Oxalis latifolia	Khatimithi/ Tinpatia	1589-1609	H	Wp	Astringent, Antiseptic and anemia.
Papaveraceae *Argemone Mexicana*	Satyanashi	1523-1609	H	Se, Rt	The seed emetic and narcotic used as medicine;root decoction as wormicide; roots chewed in leucorrhoea

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Continues Table 1

Species and family	Local name	Altitudinal range (m asl)	Life form	Part used	Uses
Pinaceae *Cedrus deodar*	Deodar	1609-2022	T	Wd, St	Aqueous paste of bark used in bowel complaints and piles; wood-oil massaged in lumbago,rheumatic arthritis and urticaria; fuel; Timber
Pinus roxburghii	Chirpine	1206-2005	T	Wd	Saw-dust with honey used in asthma, ulcer and abronchitis; making furniture, doors, flours, windows, boxes etc); Miscellaneous (It provides strength to mud wall, also used in cattle beds). Resin also used in cuts and wounds
Poaceae *Cynodon dactylon*	Dubla	1523-1782	H	Rrt	Root taken in fever and in internal injury
Parthenium hysterophorus	Gajar ghas	1460-1589	H	Sh	*Parthenium hysterophorus* is used to treat diarrhoea, neurologic disorders, dysentery and malaria. This plant traditionally used for the treatment of fevers, migraine and headaches and toothaches.
Sataria viridis	Birali-Ghas	1675-1782	H	Gr	The grains edible and green grass as fodder.
Ranunculaceae *Thalictrum foliolosum*	Meadow- rue	1675-1700	H	Wp	Paste of plant is used in skin disease; Rt is used in Jaundice.
Polygonaceae *Rumex hastatus*	Almora	2005-2017	H H	Lf	Leaf extract applied on wounds and cuts to check bleeding and also believed to relieve from suffering of nettle sting.
Rutaceae *Aegle marmelos*	Bel-patri	1206-1258	T	Fr, Lf, Fl	Fruits pulp eaten raw or made into refreshing drink, Particularly useful in digestive disorders. Leaves offered to Lord Shiva. Flower useful source of bee-forage.
Murraya Koenigii	Gandela	1548-1609	S	Wp	Leaves used for flavoring curries. Leaves made into cutlets. Bark, roots, leaves medicinal, mostly as insecticides; flowers useful source of bee-forage.
Zanthoxylem armatum	Timroo	1206-1548	S	Fr, Lf	Leaves and fruits chewed for mouth wash and tooth care. Walking sticks made from the stem, sometimes kept in the house doors, believed to get rid of all evils; Important source of bee-forage in apiary.
Rosaceae *Cotonester microphyllus*	Wanni	2005-2022	S	Fr, Lf, Rt, Fl	Braches used for making baskets; ripe fruits edible; fuel from wood. Leaf extract and fruits taken in diarrhea; root paste applied on cuts and wounds; flower useful in apiculture.
Prunus cerasoides	Panyyan	1460-2005	T	Fl, B	Bark as psycho medicines and applied for body swelling and contusion other uses for bone dislocation, fracture, burns, cuts, wounds, fever and diarrhea; Edible; Fodder; Religious; flowers useful source of bee-forage. (Plant regarded as sacred, used in several rituals of locals); Braches for walking sticks.
Pyracantha crenulata	Ghingaru	1206-1589	S	Fr, Fr, Fl	Braches used for tool handles; rarely fruits edible; flower useful in apiculture as bee-forage.
Prunus Americana	Chulu	1906-2005	T	Fr, Se	Fruits edible; seed oil edible and also used medicinally in fever and massaged in body pain; the dried fruit pulp used in local brews.
Pyrus pashia	Melu	1226-2005	T	Lf, Fr, Fl	Fruits in digestive disorders; eye complaints; edible (fruits are eaten); Fuel; Religious; Miscellaneous-us; wood made into sticks; flowers used in apiculture)
Prinsepia utilis	Hiamlayan cherry/ Bhikal	1523-1906	S	Se, Rt and Fr,	Seed oil warmed and massaged twice a day in arthritic pain. The paste of root is applied for healing of cuts, wounds and boil; Seed oil edible, Plant used in rituals and religious ceremonies; Ripe fruits eaten. Seed oil used for massaging rheumatic joints.

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Continues Table 1

Species and family	Local name	Altitudinal range (m asl)	Life form	Part used	Uses
Pyrus pashia	Melu	1226-2005	T	Lf, Fr, Fl	Fruits in digestive disorders; eye complaints; edible (fruits are eaten); Fuel; Religious; Miscellaneous-us; wood made into sticks; flowers used in apiculture)
Prinsepia utilis	Hiamlayan cherry/ Bhikal	1523-1906	S	Se, Rt and Fr,	Seed oil warmed and massaged twice a day in arthritic pain. The paste of root is applied for healing of cuts, wounds and boil; Seed oil edible, Plant used in rituals and religious ceremonies; Ripe fruits eaten. Seed oil used for massaging rheumatic joints.
Rosa macrophylla	Bangulab	1523-2022	S	Fl	Fresh juice flower is used in Earache.
Rubiaceae *Rubus ellipticus*	Hisaar	1206-1005	S	Fr, L	Root extract used is local beverages as intoxicating ingredient; other uses for dysentery, malaria, stomache and worms; Edible; Miscellaneous; (flower useful in apiculture as bee-forage).
Salicaceae *Bergonia picta*	Patharchatta	1906-2005	H H	Lf	Young leaves occasionally cooked as vegetable.
Saxifragaceae *Berginia ciliate*	Silpara/Pashanb heda	1460-1906	H	Rh, Lf	Supposed to be highly medicinal; rhizomatous part used as tonic; also used in digestive; dried leaves adulterated with tea. Root parts used for stone problems.
Solanaceae *Datura stramonium*	Dhatura	1206-1589	H	Lf	Fresh leaves tied on wounds for early cure, dried leaves smoked for intoxication; Asthma, burns, ulcers, headaches, sores.
Solanum surattense	Kateli	1548-1609	H	Fl	Flower used for stimulant, diuretic, laxative and febrifuge.
Solanum nigrum	Makoi	1782-2005	H	Wp	Juice of whole plant is administered orally in fever; paste made of leaves, black pepper and goat milk is applied over boil and pimples; Cooked leaves also given in skin diseases. Fruits edible used to treat eye diseases, dysentery and fever; occasionally roots added to the local beverages.
Urticaceae *Debregeasia salicifolia*	Syanru/ Tushaira	1906-2017	H	B, Fr	Plant provides good fodder; bark yields strong fiber for ropes and cordages; fruits edible; plaster made from the bark for bone- fracture
Debregeasia longifolia	Tusara	1206-1609	S	B	Plant is a good fodder; bark yields strong fiber; bark for bone- fracture.
Urtica dioca	Kandali	1050-2022	H	St, Se	Stem yield strong fiber- mat weaving, ropes, seed oil edible as well as for curing skin ailments.
Valerianaceae *Valeriana jatamansi*	Sumaya/ Balchhari	1675-1700	H	Rt	Roots used as an aphrodisiac and in mental disorders; as well as local beverage to promote aroma. Dried roots also used as an incense and insecticide. Plant used in rituals and various religious ceremonies.
Verbenaceae *Lantana camara*	Kuri	1206-2005	S	Lf	Leaves are used in healing wounds, cuts and ulcer; ringworm, skin diseases, malaria and insecticidal.
Permna barbeta	Bakhara	1615-1700	S	Wd, Fl	Wood used as fuel; leaves as fodder; Plant decoction taken in rheumatic- arthritis; flowers as source of bee- forage.
Zingiberaceae *Hedychium spicatum*	Van –haldi	1615-1782	H H	Tu	Used in asthma and with saw dust of deodar used in tuberculosis.

***(**T= Tree, S= Shrub, H= Herb, C= Climber, Fr = Fern, Fr = Fruit, Fl= Flower, Se= Seed, Rt = Root, S= Shoot, Wp= whole plant, Tu= Tuber, B= bark, Br= Branches, Lf= Leaf, Wd= Wood, St= Stem, Br= Branches, Rh= Rhizomes)

Poaceae (4 genera and 4 species), Amaranthes (2 genera, 3 species), Caesalpinaceae (1 genera, 3 species), Rutaceae (3 genera, 3 species), Lamiaceae (3 genera, 3 species), Solanaceae (3 genera, 3 species) and Urticaceae (3 genera, 3 species).

Out of total species studied there are 28 tree species *viz*; *Mangifera indica, Alnus nepalensis, Bombax ceiba, Bauhinia variegate, Bauhinia purpurea, Bauhinia retusa, Emblica officinalis, Lyonia ovalifolia, Rhododendron arboreum, Quercus leucotrichophora, Juglans regia, Melia azedarach, Toona serrata, Morus serrata, Ficus palmata, Ficus religiosa, Ficus roxburghii, Musa balbisiana, Ficus palmata, Cinnamomum tamala, Persea odoratissima, Lindera pulcherrima, Cedrus deodara, Pinus roxburghii, Agele marmelos, Prunus cerasoides, Prunus americana* and *Pyrus pashia.* In addition 19 species of shrubs *viz;Agave americana, Rhus parviflora, Berberis aristata, Berberis lyceum, Sarcococca saligna, Ricinus communis, Ficus hispida, Colobrookia oppositifolia, Neolitsea pallens, Asparagus racemosus, Murraya koenigii, Zanthoxylem armatum, Cotoneaster microphyllus, Pyracantha crenulata, Prinsepia utilis, Rosa macrophylla, Rubus ellipticus, Lantana camara* and *Premna barbeta.* In herbs, there are 41 species viz; *Aloe vera, Amaranthus spinosus, Achyranthes aspera, Amaranthes viridis, Eupetorium adenophorum, Ageratum conyzoides, Anaphalis busa, Parthenium hysterophorus, Taraxacum officinale, Galinsoga parviflora, Biodens bipinnata, Biodens pilosa, Aster thomsonii, Echinops cornigerus, Cannabis sativa, Commelina benghalensis, Discorea belophylla, Discorea bulbifera, Diplazium esculentum, Ocimum americanum, Ajuga brachystemon, Oxalis corniculata, Oxalis latifolia, Argemone mexicana, Cynodon dactylon, Pennisetum orientale, Parthenium hysterophorus, Sataria viridis, Thalictrum foliolosum, Rumex hastatus, Berginia ciliata, Datura stramonium, Solanum surattense, Solanum nigrum, Debregeasia salicifolia, Urtica dioca, Valeriana jatamansi* and *Hedychium spicatum.* Two species of climbers were recorded from the areai.e., *Trichosanthes tricuspidata* and *Tinospora sinensis.*

Analysis of life form (Fig. 1) of plants documented shows that trees share the largest proportion with 28 species belonging to 15 families, 19 shrubs belonging to 14 families, herbs of 41 species belonging to 19 families, 2 climbers and 1 fern species were being used by local people as food, fodder, medicine, edible, fibre and for agriculture implements. The most usable parts were leaves (37 spp.) followed by fruits (19 spp.) and wood (11 spp.), bark (10 spp.) and flowers (15 spp.), roots (11 spp.), seeds (9spp.) and stem and fibre (3 spp., each), twigs (2 spp.) whole plant (5 spp.), gum and resin (1 spp.) (Fig. 2).

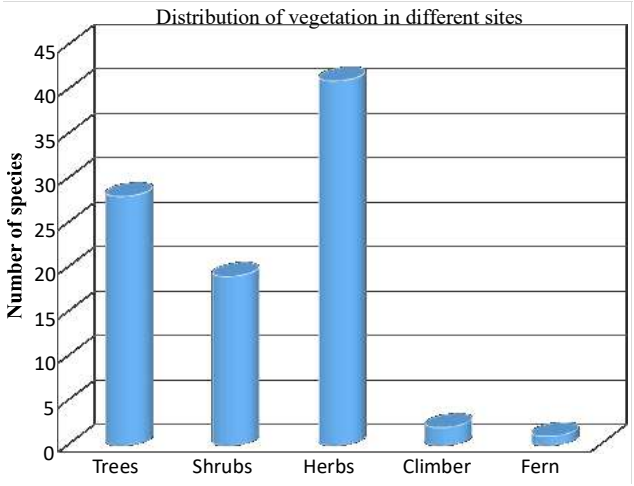
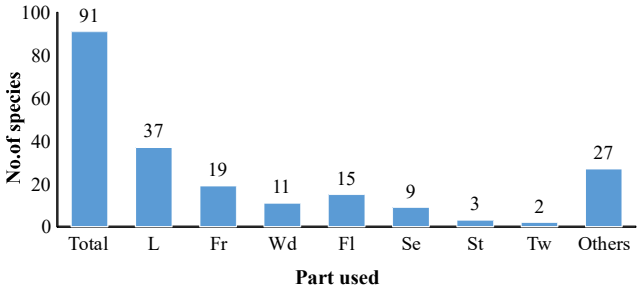


Fig. 1. Distribution of vegetation in different sites



(L= Leaves, Fr= Fruits, wd= wood, Fl= Flowers, Se= Seeds, St= Stem, Tw= Twigs and others=others purposes including; Bark, Roots, whole plant, gum and resin)

Fig. 2. Different plant parts used by local people

Amongst 96 respondents interviewed, 16% male and 75% female respondents were using the plants for ethno botanical purposes. A total of 91 plants of ethno-botanical use were selected after conducting the survey and having discussion with people of different age group. During the survey it was found that most of the women of the study area use medicinal plants for various therapeutic purposes in their day-to-day life for primary healthcare. The majorities of women respondents shared the information and were keen to transfer indigenous knowledge of medicinal plants from one generation to next generation. It was also observed that the young women had less knowledge on indigenous uses of plants in comparison to the old women.

The study revealed that local people depend on a number of plants for their daily needs. Among 91 ethno-medicinal plants, most of the plants were found nearby villages, wasteland and forest area. In the altitudinal range between 1000-2200m various trees, shrubs, herbs and climbers are chiefly used for curing diseases such as stomach pain, fever, diabetes cold and cough, bleeding and

wounds and insect bite in nearby villages. Plants used are tabulated in order of species, local name, part used and uses. People in this region are dependent on forest resources for medicine, food and fuel. Similar studies conducted by Chauhan et al. (2017) revealed that a total of 79 species belonging to 33 genera of medicinal plants growing in Tehri Garhwal. Tiwari et al. (2016) reported 89 plant species belonging to 36 families from Bharsar (Pauri Garhwal) in which the highest ethno medicinal species found from Asteraceae family (17 species). However, other studies have also achieved the similar results that Asteraceae family had more number of ethno medicinal plants in Pauri Garhwal (Pala et al. 2010, Kapkoti et al. 2014, Baunthiyal and Priyanka 2016). Bohra et al. (2017) recorded 59 plant species from 35 families used as wild edible plants, used by the rural communities of Ramnagar region. Rawat (2016) recorded a total of 53 plant species distributed in 41 families were documented that were used in treating various ailments of the local communities of Thalisain block of Pauri Garhwal district. Out of the total plant species 49% were herbs, 26% trees, 23% shrubs and 2% climber. Similar study conducted by Kapkoti et al. (2014) at Kumaun region revealed 28 ethno-medicinal plant species by local people to cure various ailments and the plant part used for medicine preparation was root, leaves, bark, flowers, rhizome, fruit, bud, stem and whole plant and other authors documented approximately 375 species of medicinal uses from the different parts of Garhwal Himalaya (Uniyal and Shiva 2005, Kumar et al. 2011, Tiwari and Ansari 2014).

CONCLUSION

A total of ninety one ethno botanical plant species belong to eighty eight genera from forty four families were recorded. Out of total species used for ethno botanical value, majority was herbs (forty one species) followed by twenty seven trees species and twenty species of shrubs. The ethno botanical study shows that the study area is rich in medicinal plants. The local people have a good ethno botanical knowledge in using plant resources and developed their own traditional system of using plants for medicinal uses. Specially, the elderly people of a community and the local traditional healers have greater knowledge on medicinal plants. But the youngsters showed less interest in traditional practices mainly due to less recognition of traditional healers and easy availability of modern medicines and instant effect. Because of which the practice of using plants and plants parts for medicinal use is decreasing. Hence, the emphasis should be given for the systematically documenting and cataloguing this vast knowledge about plants and their beneficial uses before it is lost forever.

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REFERENCES

Baunthiyal M and Priyanka 2016. An ethno botanical study of medicinal plant of Ghurdauri region, Uttarakhand, India. *Journal of Medicinal Plants Studies* **4**(5): 200-205.

Bohra N, Tiwari LM and Tiwari A 2017. Ethno botany of wild edible plants traditionally used by the local people in the Ramnagar region from Nainital District, Uttarakhand, India. *Biolife* **5**(1): 12-19.

Chauhan PS, Bisht S and Ahmed S 2017. Traditional & Ethno botanical uses of medicinal trees in District Tehri Garhwal. *International Journal of Ayurvedic and Herbal Medicine* **7**(1): 2442-2448.

Gaur RD 1999. *Flora of district Garhwal Northwest Himalaya*. Transmedia Publication, Srinagar Garhwal, India. 811p.

Gupta SP 1995. Study on plants during Ethnological research. In: *A Manual of Ethno-botany* Jain, S.K. (ed.), Scientific Publishers, Jodhpur (India). 9-18 pp.

Kapkoti B, Lodhiyal N and Lodhiyal LS 2014. Ethno medicinal plants and their uses by van panchayat people in Nainital of Kumaun region, Uttarakhand. *Journal of Biology and Life Science* **2**(2): 526-532.

Kumar K, Sheikh MA and Bussmann WR 2011. Ethono-medicinal and ecological status of plants in Garhwal Himalaya, India. *Journal of Ethno biology and Ethno medicine* **7**: 32.

Pala AN, Negi AK and Todaria NP 2010. Traditional uses of medicinal plants of Pauri Garhwal, Uttarakhand. *Nature and Science* **8**(6): 57-61.

Rawat VS 2016. Medicinal plants and sustainable livelihood in Pauri district of Garhwal Himalaya, Uttarakhand, India. *International Journal of Bioassays* **5**(6): 4589-4592.

Samant SS and Dhar U 1997. Diversity, endemism and economic potential of wild edible plants of Indian Himalaya. *International Journal of Sustainable Development. World Ecology* **4**: 179-191.

Samant SS, Dhar U and Palni LMS 1998b. *Medicinal Plants of Indian Himalaya: Diversity Distribution Potential Values.* Gyanodaya Prakashan, Nainital. p. 163.

Samant SS, Dhar U and Rawal RS 1998a. Biodiversity status of a protected area of West Himalaya, 1-Askot wildlife sanctuary. *International Journal of Sustainable Development. World Ecology* **5**: 194-203.

Sheldon JW, Balick M and Laird S 1998. Medicinal plants utilization and conservation. *Advance in Economic Botany, New York* **98**(12): 29-31.

Tiwari AP and Ansari AA 2014. Ethno medicinal uses of plants among the tribals of Jashpur District, Chhattisgarh. *Journal of Non Timber Forest Products* **21**(2): 137-143.

Tiwari D, Upadhyay S and Paliwal A 2016. Survey of Ethno-medicinal plants of Bharsar. *International Journal of Agricultural* **6**(6): 329-350.

Tripathi YC 2000. Ethno-botanical treasure of tribal Rajasthan. *Journal of Non Timber Forest Products* **7**(1-2): 77-84.

Uniyal B and Shiva V 2005. Traditional knowledge on medicinal plants among rural women of the Garhwal Himalaya, India. *Journal of Traditional Knowledge* **4**(3): 259-266.

Uniyal SK, Awasthi A and Rawat GS 2002. Current status and distribution of commercially exploited medicinal and aromatic plants in upper Gori Valley, Kumaon Himalaya, and Uttaranchal. *Current Science* **82**(10): 1246-1252.

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Aeroallergen Sensitizations with Special Reference to Fungi Sensitization among the Community of Sultan Idris Education University, Malaysia

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Abstract: The present study is aimed to profile the prevalence and determine the risk of aeroallergen sensitization including fungi on gender, ethnicity, and age groups. 225 of the university community population were interviewed using a standard questionnaire by allergists to collect information on demographic including gender, ethnicity, and age. To confirm the prevalence of the aeroallergens sensitization, the gold standard procedure, i.e. skin prick testing was performed using commercial aeroallergens. Of the subjects, 93 (41.3%) were categorised as atopic. The most prevalent positive SPT among the general and the atopic population were house dust mites, (32.4%; 78.5%), followed by German cockroach (20%; 48.3%), fungal (7.55%; 18.2%), and cat dander (4.8%; 11.8%) respectively. The prevalence of fungi sensitization among the atopic population is doubled to the general population and considerably high compared to the World Allergy report. Among the 17 fungal sensitized subjects, 9 (52.9%) were monosensitized to *Aspergillus fumigatus*, 4 (23.5%) to *Penicillium notatum*, 2 (11.8%) to *Candida albicans*, and one (5.9%) to *Alternaria alternata*. One (5.9%) subject was oligosensitized to both *Alternaria alternata* and *Aspergillus fumigatus*. Male subjects were with the higher risk to fungi sensitization compared to female, Chinese ethnicity subjects to other ethnicities, and subjects with ≥20 years of age to other age groups. Sensitization is high to both *Aspergillus fumigatus* and *Penicillium notatum*. Thus, it is an indicator not to be taken lightly as these fungi are also highly prevalent at UPSI and have been associated with the sick building syndrome.

Keywords: Indoor aeroallergen sensitization, Fungi sensitization, Risk group sensitization

The incidence of allergic diseases has been on the rise in recent decades all over the world (Sharma et al 2012, Soegiarto et al 2019). Aeroallergens are various airborne substances or inhalants, such as pollen, spores, and other biological or non-biological airborne particles that can cause allergic disorders. Inhalation or cutaneous contact with aeroallergens can trigger a release of proteins in the form of an allergic reaction on the skin and mucous membranes (Chapman 2008). Aeroallergens play a great role in the pathogenesis of respiratory allergic diseases. Pollens, molds, and pets are the main sources of allergens, the number and types of aeroallergens an individual is sensitized to vary across geographic regions (Assarehzadegan et al 2013, Ahmed et al 2019). Sensitization to aeroallergens is the most important factor causing allergic symptoms such as allergic rhinitis (Alvarez Cuesta et al 2006). Many studies have shown that the distribution and pattern of aeroallergens are significantly different from one country to another (Bousquet et al 2007). Identification of the most common aeroallergens to which the patients are sensitized has an important role in the diagnosis and treatment of allergic symptoms. Selecting the most appropriate panel of allergen extracts for diagnostic testing and finding the best formulation of allergen immunotherapy depends on information about the most important aeroallergens in a specific area. Likewise, allergen avoidance cannot be properly achieved without identifying the allergens that are associated with allergic symptoms for every patient (Aburuz et al 2011).

Fungi are ubiquitous and, as a consequence of this, sensitization to fungi can be found throughout the world. The exact prevalence of mold sensitization is not known but is estimated to range from 3 to 10% in the general population, 12 to 42% of the atopic patients (Wiszniewska et al 2013). Fungi of the genera i.e. *Mucor*, *Penicillium*, *Aspergillus*, *Rhizopus*, *Alternaria,* and *Cladosporium* dominate the fungi isolated from dust mites which are the indoor fungi (Sabariego et al 2012). Allergens of indoor fungi are present in the air space throughout the year. Sensitivity is mostly detected to the genera of *Alternaria*, *Cladosporium*, *Aspergillus*, *Penicillium,* and *Fusarium*. In the tropical and other hot, humid regions, spore counts typically exceed

pollen counts by 100-fold. In Malaysia, studies among allergic rhinitis patients reported the prevalence of *Aspergillus* and *Penicillium* sensitization were 21.2 and 16% respectively (Hamilos 2010). House dust mites (HDM) have been described as important allergen sources causing respiratory allergies, such as asthma and rhinitis. More than 30 allergens from HDM have been described are responsible for over 50% of IgE reactivity in patients sensitized to HDM (Resende et al 2019). Clinical studies in patients demonstrated that allergy to HDM and cat allergens were the most common aeroallergens in Malaysia (Lim et al 2015). One study suggested that sensitization to one allergen (monosensitization) versus sensitization to multiple allergens (polysensitization) constitute two different phenotypes of allergic rhinitis (Ciprandi & Cirillo 2011). Moreover, polysensitization seems to be associated with a more severe form of respiratory allergy (Migueres et al 2009). Understanding sensitization patterns in certain geographic areas helps target specific interventions like allergen reduction and/or avoidance and encourages the use of specific immunotherapy towards the most common allergens (Ciprandi et al 2008, Casset & Braun 2010). Due to the lack of published studies on sensitization towards aeroallergens in Malaysia, the prevalence of common aeroallergens is still not fully understood in this region.

MATERIAL AND METHODS

There was a total of 225 subjects made up of students, lecturers, supporting staff, and volunteers undergoing SPTs to common aeroallergens for evaluation of allergy. The inclusion criteria were that the subject must be between 18-60 years of age and able to provide self consent for participation in the study. The exclusion criteria were pregnant women and those who drew negative results in the histamine test. All the subjects also completed a questionnaire. In this study, 6 commercial fungi allergen extracts were included namely; *Alternaria alternata*, *Aspergillus fumigatus*, *Candida albicans*, *Aspergillus niger*, *Mucor mucedo*, and *Penicilliumnotatum* purchased f rom Inmunotek, a pharmaceutical company based in Madrid. Allergens of SPT routinely used for allergy testing comprising of environmental insect allergens German cockroach (*Blattella germanica*), house dust mites (HDM) (*Dermatophagoides pteronyssinus* and *Dermatophagoides farinae*), and animal dander (cat dander) were also included. The prevalence of immunoglobulin E (IgE) to various common aeroallergens was determined by the skin-prick test (SPT) performed by two trained investigators following the recommendations of the European Academy of Allergy and Clinical Immunology (Mbatchou Ngahane et al 2016).Skin prick testing relies on the introduction of a very small amount of allergen extract into the epidermis using a sterile lancet along with the negative control (saline) and positive control (Histamine) (10 mg/mL). Results of the skin prick testing were examined after 15 mins of testing. The diameters of the resulting wheal and erythema in mm were recorded. By convention, a positive test is in which the mean of the two wheal diameters is at least 3 mm, greater than the negative control (saline). The atopic population was defined as having at least one positive to the test. Monosensitization was defined as sensitization to one of the four aeroallergens groups, namely; HDM, Cockroach, Cat Dander, and Fungi. Oligosensitizationrefers to sensitization to 2–3 groups. and polysensitization to all the 4 groups. This study was approved by the Ethical Committee of Universiti Pendidikan Sultan Idris (code:2019-005-01) and informed consent was obtained from all the participants.Data were analyzed using IBM SPSS Statistics version 23 (Armonk, NY, USA: IBM Corp). Descriptive statistics were presented as frequencies, mean, and standard deviation while the inferential statistics involved correlation and odds-ratio for risk factor analysis. Group differences were studied using the chi-squared test for categorical variables or independent t-test for continuous variables.

RESULTS AND DISCUSSION

Of the 225 general subjects (167 females, 58 males, the age range of 18-60 years), 93 (41.3%) had responded to at least one aeroallergen and epithet as the atopic population.

General population: The most prevalent positive SPT was house dust mites (78%), followed by German cockroach (48.3%), fungal (18.2%), and cat dander (11.8%). The fungi sensitization prevalence in the general population was 7.55%. Among the 17 fungal sensitized subjects, 9 (52.9%) were sensitized only to *Aspergillus fumigatus*, 4 (23.5%) to *Penicillium notatum,* 2 (11.8%) to *Candida albicans*, and one (5.9%) to *Alternaria alternata*. One (5.9%) subject was sensitized to both *Alternaria alternata* and *Aspergillus fumigatus* (Table 1).

The prevalence of HDM sensitization (78%) in this study is within the range demonstrated among the adult population of Southeast Asian countries, reported to be 80% for Malaysia, 33.3%-68.5% for Singapore, 64.7% for Thailand, and the Philippines showed the prevalence was 33.3%-97%. The present study indicates higher value compared to other of the recent studies conducted among office workers in Malaysia (Lim et al 2015) with the prevalence of *D. pteronyssinus, D. farinae* were 50.3% and 49.0% respectively. Several HDM surveys suggested that *Dermatophagoides* species are an important source for the allergic sensitization, but *Blomia tropicalis* has recently been

identified as the most common and abundant species of HDM (Ahmed et al 2019). The prevalence of fungi sensitization (18.9%) in this study is relatively low compared to 72.8% among the Filipinos (Navarro et al 2009, Navarro & Lim-Jurado 2018). There is a great discrepancy between studies about allergies affecting male subjects more than the female. The male subjects showed a high prevalence (46.55%) of sensitization to all the allergens tested in this study in comparison to the female (39.52%). The male subjects also showed high sensitization to HDM and cat dander, in line with the previous study conducted in Malaysia in 2015, among Malaysia's office workers (Siti Nadzrah et al 2015, Lim et al 2015). This study also supported Psenka (2015), findings that demonstrated the male exhibit higher sensitivity to 11 common allergens including mold. Ahmed et al (2019) revealed male is more sensitive to common environmental aeroallergens than female.In Vietnam, where sensitization to house dust mites is common in both rural and urban areas, specific rates for HDM *D. pteronyssinus* to male 16.5%, female 10.6%, and for *D. farinae,* male15.3% and female 6.3% (Lâm et al 2014). Some studies concluded that the allergy prevalence found to be more among females than males as reported by a meta-analysis study that reviewed 591 studies (Kelly & Gangur 2009). In the contrast, a huge study involving 14 million blood tests showed that males exhibit higher sensitivity to 11 common allergens including mold (Psenka 2015). Among different ethnicities subjects, Indian ethnicity subjects showed the highest sensitization (35.0%) to HDM. The Malay ethnicity demonstrated high sensitization to cockroach (22.2%) and cat dander (7.1%). Subjects from the Chinese ethnicity were highly sensitized to fungi (25.0%) compared to others. The subjects with age group ≤20 years showed the highest sensitization to HDM (38.0%) and cat dander (4.7%), while the age group 21-30 was highly prevalent to cockroach (21.3%) and fungi (9.2%) (Table 1). It is interesting to note that the age group ≥31 years old did not show a high prevalence of any aeroallergen compared to other age groups.

Understanding how groups with high risk differ from other groups with lower risk is an important step that can lead to an understanding of aetiology. Racial disparities are present in many facets of health and disease, allergy and asthma are no exceptions (Chen et al 2018). Genetics is unlikely to be the sole or major cause of the observed differences (Wegienka et al 2016). Some studies suggested disparity in allergic sensitization by race might be primarily a result of environmental factors rather than genetic differences (Yang et al 2008). In this study, the high prevalence of fungi among Chinese subjects may due to environmental factors especially many recent studies reported that in China the overall incidence of invasive fungal continued to rise especially *Aspergillus* have propagated in recent years. The drastic socioeconomic lifestyle transformation among Chinese people may have altered the epidemiological characteristics of fungal infections in the country (Chen et al 2016, 2018). However, in another study which was conducted in Singapore Chinese ethnicity subjects also showed high fungal sensitization compared to Malay, Indian, and other ethnicities (Goh et al 2017). Chinese subjects showed significant risk between atopic and general population OR= 1.33; 95% CI: (0.962-1.848). Generaly in the allergy systematic review studies, subjects within the ages of 2 and 17 years demonstrated sensitization to 1 or more allergens. From the age of 18 onwards, mold sensitization steadily declined in patients after the age of 12 (Psenka 2015). This is similar to our results in which the age group ≤ 20 showed high sensitization to both HDM and cat dander. In this study, the age group ≤ 20 has significant risk between atopic and general population OR=1.750 95% CI: 1.413 - 2.167.

Table 1. Demographical prevalence of aeroallergens sensitization among the general population

Parameter		General population (n)	Fungi sensitized subjects (%)	HDM sensitized subjects (%)	Cockroach sensitized subjects (%)	Cat dander sensitized subjects (%)
Gender	Male	58	18.9	41.3*	20.6	6.8
	Female	167	3.5	29.3	19.7	4.1
Ethnicity	Malay	153	5.8	33.3	22.2*	7.1*
	Chinese	12	25.0*	33.3	8.3	0
	Indian	20	5	35.0*	10	0
	Others	40	10	27.5	20	0
Age	≤ 20	63	6.3	38.0*	19	4.7*
	21-30	131	9.2*	32.0	21.3*	3.0
	≥31	31	3.2	22.5	16.1	3.0

*Ranked as the highest

Degree of sensitization: Among the general population, 53 3.56%) were monosensitized, 37 (14.44%) oligosensitized, and 3 (1.33%) polysensitized. Polysensitization as evidenced by SPT is common among the general population worldwide. Based on the studied population by Miguires et al (2014), reported monosensitization was between 16.2 and 19.6%, 12.8 to 25.3% oligosensitization, and 38.8% polysensitized. The sensitization degree disparities between these studies due to the definition of mono-, oligo-, and polysensitization. In our study, we are referring to the allergens' groups, whereas Miguires et al (2014) to the allergens in the test panel.

Atopic population: Among the atopic population, there is an increment of allergy prevalence as compared to the general population for the most common allergen (house dust mites, 32.4 to 78.5%; German cockroach, 20 to 48.3%; cat dander, 4.8 to 11.8% and fungi, 7.5 to 18.2%). Similar house dust mites prevalence result was demonstrated by Gendeh et al (2000) among their rhinitis patients (72%) compared to the general population (22.2%). HDM sensitization is also highly related to atopic patients with asthma with mean of 76% (range 50 – 90%) and more than 80% of asthmatic and rhinitis patients (Sinniah and Thakachy 2014).The female atopic population showed a higher prevalence compared to males (70.99%: 29.01%). Subjects from Malay ethnicity showed the highest sensitization to cockroach allergen, whereas subjects from Chinese ethnicity showed the highest sensitization to fungi and HDM. SPT found highest in the age group 21-30 years old followed by ≤20, and ≥31(Table 2).

Degree of sensitization: Among the atopic subjects, 53 (57%) were monosensitized, 37 (39.7%) oligosensitized, and 3 (3.22%) polysensitized. Interestingly, all the polysensitized were male subjects. Other studies revealed a higher prevalence of polysensitization (from 31.0% to 74.3%) among allergic rhinitis patients. The discrepancy in the degree of prevalence between this study as reported by other studies may be due to fewer allergens were included in the test kit panel. Nevertheless, other factors such as the allergen extracts are varied markedly from one country to another. Age groups are also to be considered as polysensitized increased with age (Fasce et al 2007).

Fungal sensitization: Seventeen subjects (18.2%) found to be positive to at least one fungal allergen. Among the fungi sensitized subjects, the highest sensitization was to *Aspergillus fumigatus* (n=9, 58.8%) followed by *Penicillium notatum* (n=4, 23.5%), *Alternaria alternata,*and *Candida albicans* (n=2, 11.7%). No positive reactivity for both *Aspergillus niger,* and *Mucor mucedo*as as presented in Table 3.

Gender: In the general population, the male demonstrated a higher prevalence compared to females. The prevalent showed 2.15 folds higher in males of the atopic population compared to the general population (40.7%: 18.9%). Among the female, it was even greater up to 2.57 folds (3.5%: 9.0%) in the atopic population (Table 4).

Table 3. SPT reactivity to a panel of fungi allergens among the atopic population

Allergen	Number positive (n=17)	Percent positive (%)
All fungi allergens		
Alternaria alternata	2	11.7
Aspergillus fumigatus	10	58.8
Candida albicans	2	11.7
Aspergillus niger	0	0
Mucor mucedo	0	0
Penicillium notatum	4	23.5

Table 2. Demographical prevalence of aeroallergens sensitization among the atopic population

Parameter		Fungi sensitized subjects (N=17)		HDM sensitized subjects (N= 73)		Cockroach sensitized subjects (N=45)		Cat dander sensitized subjects (N= 11)	
		n	(%)	n	(%)	n	(%)	n	(%)
Gender	Male	11	40.7	24	88.8*	12	44.4	4	14.8
	Female	6	9.0	49	74.2	33	50	7	10.6
Ethnicity	Malay	9	14	51	79.6	34	53.1*	11	17.1*
	Chinese	3	75*	4	100*	1	25	0	0
	Indian	1	11.1	7	77.7	2	22.2	0	0
	Others	4	25	11	68.7	8	50	0	0
Age	≤ 20	4	14.8	24	88.8*	12	44.4	3	11.1
	21-30	12	21.4*	42	75	28	50*	4	7.1
	≥31	1	10	7	70	5	50*	4	40*

*Ranked as the highest

Ethnicity*:* Chinese subjects in the general population were higher prevalent for fungal sensitization (25%) followed by other ethnicities (10%), Malay (5.8%), the least was Indian (5%). Among the atopic population, the highest prevalence was also among the Chinese subjects (75%) with 3 folds higher than the general population. Other ethnicity subjects showed 25% prevalent among the atopic population and 2.5 folds higher than the general population. Indian ethnicity prevalent was the least (11.1%) among the atopic population and 2.2 folds higher compared to the general population (Table 4).

Age group: Subjects in 21-30 years age group was the highest fungal sensitized (21.4%) with 2.32 folds higher compared to the general population (9.2%) (Table 4). The incidence of fungal allergy ranges from 6 to 24% in the general population (Simon-Nobbe et al 2008). In this study, the prevalence of fungal allergy was 7.55% among the general population and 18.27% among the atopic population. Many of systematic review studies reported the highest prevalence of fungi sensitization in Spain (20%), the lowest in Portugal (3%) (Twaroch et al 2015). In this study fungi sensitization prevalence is high compared to prevalence in many European cities (Newson et al 2014) and also higher than Turkey 14.8% (Hamilos 2010), and relatively less compared to the asthmatic population in Africa countries 23% (Kwizera et al 2019). The results of fungi sensitization prevalence in this study nearly similar to the prevalence in Singapore and Iran (19%). The latter has subtropical weather conditions while the climate of the south is tropical (Kidon et al 2004, Moghtaderi et al 2017). Chinese ethnicity subjects have higher reactivity to SPT to both fungal and house dust mite (HDM) allergens. This could be extensive exposure to HDM in most Chinese households. According to many studies which reported that HDM considers as major allergens in overall China (Zheng et al 2015, Zhang & Zhang 2019). The individuals in the age group 21-30 years showed the highest sensitization (5.33%), whereas the age group ≥ 31 years were the least likely to have fungi sensitization (Table 4). This agrees with the data from the European Community Respiratory Health Survey (ECRHS) which demonstrated that among adults aged 20–44 years within the same population, fungi sensitization ranged from 0.2 to 14.4% (Bousquet et al 2007). Uysal et al (2016) also reported that the number of sensitized allergens in the majority of children, who have been sensitized until the age of 4, rises by time and detected at age 10 and 18 years. Sensitization to some fungi species tends to decrease with age, following the general recognition that atopic asthma is more common in younger patients. However, the frequency of *Aspergillus fumigatus* did not decrease with age, most likely because sensitization to this species is associated with severe persistent asthma with long disease duration (Fukutomi & Taniguchi 2015). Among fungi sensitized subjects 9 were mono-sensitized to *Aspergillus fumigates* which was also highly detected at UPSI buildings, reported in our previous study (Hadi et al 2019). Therefore, *Aspergillus* could be considered as a potential and hazardous aeroallergen that could elicit serious upper respiratory tract infection among UPSI community. *Aspergillus* sp., the dominating genera (Barathy et al 2020) is also known as one of the major causes of the disease among the pathogenic Aspergilli. The frequency of *Aspergillus fumigatus* sensitization did not decrease with age, most likely because sensitization to this species is associated with severe persistent asthma with long disease duration (Fairs et al 2010).

Table 4. Prevalence offungi sensitized subjects by gender, ethnicity and age groups in the general and atopic populations

Patient groups according to	Per cent of the general population (N=225)	Per cent of the atopic population (N=93)
Sex		
Male	11 (18.96)	11 (40.74)
Female	6 (3.59)	6 (9.09)
Ethnicity		
Malay	9 (5.88)	9 (14.06)
Chinese	3 (25.0)	3 (75.0)
Indian	1 (5.0)	1 (11.1)
Others	4 (10.0)	4 (25.0)
Age (years)		
≤ 20	4 (6.34)	4 (14.81)
21–30	12 (9.02)	12 (21.42)
≥ 31	1 (3.33)	1 (10.00)

Degree of sensitization: Among 17 fungal sensitized subjects 6 (35.29%) were mono-sensitized only to fungi group 8 (47.06%) were oligo-sensitized to two to three groups, while 3 (17.65%) were poly-sensitized to all aeroallergen groups (Fig. 1). Prevalence on polysensitization among AR patients was reported in the range of 27.5 to 74.3% (Ciprandi et al 2008, Migueres et al 2009, Didier et al 2010, Baatenburg et al 2011). Many studies confirmed that polysensitized subjects are more likely to have a more severe and persistent respiratory allergic disease (Ciprandi et al 2008, Ciprandi & Cirillo 2011, Gelardi et al 2015).

In this study male subjects with fungi sensitization are more at risk compared to the female OR= 1.688; 95% CI: (1.234 - 2.307), *r*-value 0.573**; OR= 1.100 95% CI: (1.019 - 1.187) *r*-value 0.168 (Table 5). The Chinese ethnicity subjects are more at risk compared to other ethnicities OR=

Table 5. Risk factors for fungi sensitized subjects, including gender, ethnicity, and age groups

		Fungi sensitized subjects			
		General population (N=225, n=17)		Atopic population (N=93, n=17)	
		OR (95% CI)	*r*-values	OR (95% CI)	*r*-values
Gender	Male	1.234 (1.090 - 1.398)	0.385**	1.688 (1.234 - 2.307)	0.573**
	Female	1.037 (1.007 - 1.068)	0.098	1.100 (1.019 - 1.187)	0.168
Ethnicity	Malay	1.063 (1.021 - 1.105)	0.140*	1.164 (1.054 - 1.285)	0.220*
	Chinese	1.333 (0.962 - 1.848)	0.490**	4.000 (0.733 - 21.838)	0.861**
	Indian	1.053 (0.952 - 1.164)	0.214**	1.125 (0.893 - 1.417)	.319**
	Other	1.111 (1.002 - 1.232)	0.289**	1.333 (1.005 - 1.769)	0.465**
Age groups	≤ 20	1.068 (1.001 - 1.139)	0.216**	1.174 (1.003 - 1.374)	0.331**
	21-30	1.099 (1.042 - 1.160)	0.197**	0.543 (0.445 - 0.663)	0.313**
	≥ 31	1.034 (0.968 - 1.106)	0.170*	1.111 (0.904 -1.366)	0.300**

*P ≥ 0.05 **P ≥ 0.01

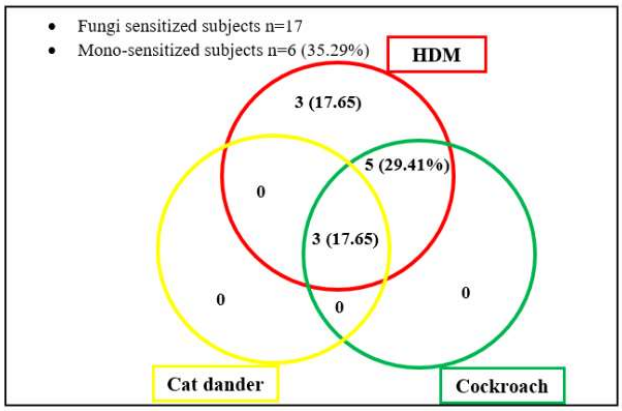

Fig. 1. Degree of sensitizations among fungi sensitized subjects

4.000; 95% CI: (0.733 - 21.838) *r*-value 0.861**. Subjects within the age between 21-30 years are more at risk followed by subjects within the age ≤ 20, OR= 0.543; 95% CI: (0.445 - 0.663), *r*-value 0.313**; OR= 1.174; 95% CI: (1.003 - 1.374), *r*-value 0.331** respectively (Table5).

Rate of sensitization to fungi is also reported as significantly high among the male than female specifically to *Cladosporium* and *Aspergillus* (Ezeamuzie et al 2000). The prevalence of the Chinese ethnicity fungi sensitization is aligned with the incidence of invasive fungal infections that have continued to rise in China as reported recently (Chen et al 2018). Similarly, the prevalence of *Cladosporium* (60%) was reported among subjects within 8-15 years (Ezeamuzie et al 2000).

CONCLUSION

The SPT results showed a significant proportion of participants are sensitized to common aeroallergens with a high incidence of sensitization to house dust mites (HDM).The prevalence of fungi sensitization is 7.55% among the general population and 18.27% among the atopic population. Males with fungi sensitization are more at risk compared to the females as Chinese ethnicity subjects to other ethnicities, and subjects within the age between 21-30 years to other age groups. Prevalence of mono-, oligo-, and polysensitization varies but male subjects were more likely to be polysensitized compared to the female. *Asp. fumigatus* is considered the most causative of sensitization among fungal species. This study implicates that understanding the allergenicity prevalence of the most common indoor aeroallergens can better help to identify patients' sensitization and support immunotherapy for them. Subsequently, enhancing the wellbeing and reducing the medical costs. Further studies are recommended to clarify the role of mono or oligo-, and polysensitization in the development and severity of respiratory allergic conditions. Mechanisms of the Development of Allergy (MeDALL) suggested that monosensitization and polysensitization represent two distinct phenotypes with differences in symptoms and biomarkers.

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REFERENCES

Aburuz S, Bulatova N and Tawalbeh M 2011. Skin prick test reactivity to aeroallergens in Jordanian allergic rhinitis patients. *East Mediterr Health Journal* **17**(7): 604-10.

Ahmed H, Ospina MB, Sideri K and Vliagoftis H 2019. Retrospective

analysis of aeroallergen's sensitization patterns in Edmonton, Canada. Allergy, *Asthma and Clinical Immunology* **15**(1): 1-6.

Alvarez Cuesta E, Bousquet J, Canonica GW, Durham SR, Malling HJ and Valovirta E 2006. Standards for practical allergen-specific immunotherapy. *Allergy* **61**(82): 1-3.

Assarehzadegan MA, Shakurnia A and Amini A 2013. The most common aeroallergens in a tropical region in Southwestern Iran. *World Allergy Organization Journal* **6**(1): 1-7.

Baatenburg de Jong A, Dikkeschei LD and Brand PL 2011. Sensitization patterns to food and inhalant allergens in childhood: A comparison of nonsensitized, monosensitized, and polysensitized children. *Pediatric Allergy and Immunology* **22**(2): 166-171.

Barathy S, Vimali M, Sivaruban T and Srinivasan P 2020. Leaf litter degradation by microbes and micro invertebrates in mid reaches stream of Eastern Ghats. *Indian Journal of Ecology* **47**(3): 881-883.

Bousquet PJ, Chinn S, Janson C, Kogevinas M, Burney P and Jarvis D 2007. Geographical variation in the prevalence of positive skin tests to environmental aeroallergens in the European Community Respiratory Health Survey I. *Allergy* **62**(3): 301-309.

Casset A and Braun JJ 2010. Relation entre allergènes de l'environnement intérieur, sensibilisation et symptômes de rhinite et asthme allergiques. *Revue Des Maladies Respiratoires* **27**(8): 913-920.

Chapman MD 2008. Allergen nomenclature. *Clinical Allergy and Immunology* **21**: 47-58.

Chen M, Xu Y, Hong N, Yang Y, Lei W, Du L and Liao W 2018. Epidemiology of fungal infections in China. *Frontiers of Medicine* **12**(1): 58-75.

Chen Y, Lu ZY, Jin Y, Han L and Huang LY 2016. Progress of research on azole resistance in *Aspergillus fumigatus*. *Zhonghua Liu Xing Bing Xue Za Zhi Zhonghua Liuxingbingxue Zazhi* **37**(12): 1687-1692.

Ciprandi G, Alesina R, Ariano R, Aurnia P, Borrelli P, Cadario G and Castiglioni G 2008. Characteristics of patients with allergic polysensitization: the POLISMAIL study. *European Annals of Allergy and Clinical Immunology* **40**(3): 77-83.

Ciprandi G and Cirillo I 2011. Monosensitization and polysensitization in allergic rhinitis. *European Journal of Internal Medicine* **22**(6): 75-79.

Didier A, Chartier A and Demonet G 2010. Specific sublingual immunotherapy: for which profiles of patients in practice? Midterm analysis of ODISSEE (observatory of the indication and management of respiratory allergies [rhinitis and/or conjunctivitis and/or allergic asthma] by specific sublingual immunotherapy). *Revue Francaise D Allergologie* **50**(5): 426-433.

Ezeamuzie CI, Al-Ali S, Khan M, Hijazi Z, Dowaisan A, Thomson MS and Georgi J 2000. IgE-mediated sensitization to mould allergens among patients with allergic respiratory diseases in a desert environment. *International Archives of Allergy and Immunology* **121**(4): 300-307.

Fairs A, Agbetile J, Hargadon B, Bourne M, Monteiro WR, Brightling CE and Pashley CH 2010. IgE sensitization to *Aspergillus fumigatus* is associated with reduced lung function in asthma. *American Journal of Respiratory and Critical Care Medicine* **182**(11): 1362-1368.

Fasce L, Tosca MA, Baroffio M, Olcese R and Ciprandi G 2007. Atopy in wheezing infants always starts with monosensitization. In *Allergy and Asthma Proceedings* **28**(4): 449-453.

Fukutomi Y and Taniguchi M 2015. Sensitization to fungal allergens: Resolved and unresolved issues. *Allergology International* **64**(4): 321-331.

Gelardi M, Ciprandi G, Incorvaia C, Buttafava S, Leo E, Iannuzzi L and Frati F 2015. Allergic rhinitis phenotypes based on mono-allergy or poly-allergy. *Inflammation Research* **64**(6): 373-375.

Gendeh BS, Murad S, Razi AM, Abdullah N, Mohamed AS and Kadir KA 2000. Skin prick test reactivity to foods in adult Malaysians with rhinitis. *Otolaryngology-Head and Neck Surgery* **122**(5): 758-762.

Goh KJ, Yii ACA, Lapperre TS, Chan AKW, Chew FT, Chotirmall SH and Koh MS 2017. Sensitization to *Aspergillus* species is associated with frequent exacerbations in severe asthma. *Journal of Asthma and Allergy* **10**: 131-140.

Hadi G, Abdullah MS and Misnan R 2019. Protein profile of the most common fungi at Sultan Idris Education University, Malaysia. *International Journal of Research in Pharmaceutical Sciences* **10**(2): 1233-1237.

Hamilos DL 2010. Allergic fungal rhinitis and rhinosinusitis. *Proceedings of the American Thoracic Society* **7**(3): 245-252.

Kelly C and Gangur V 2009. Sex disparity in food allergy: evidence from the PubMed database. *Journal of Allergy*, 2009: 1-7.

Kidon MI, See Y, Goh A, Chay OM and Balakrishnan A 2004. Aeroallergen sensitization in pediatric allergic rhinitis in Singapore: Is air-conditioning a factor in the tropics? *Pediatric Allergy and Immunology* **15**(4): 340-343.

Kwizera R, Musaazi J, Meya DB, Worodria W, Bwanga F, Kajumbula H and Denning DW 2019. Burden of fungal asthma in Africa: A systematic review and meta-analysis. *PLoS ONE* **14**(5): 1-17.

Lâm HT, Ekerljung L, Bjerg A, Tường NV, Lundbäck B and Rönmark E 2014. Sensitization to airborne allergens among adults and its impact on allergic symptoms: a population survey in northern Vietnam. *Clinical and Translational Allergy* **4**(1): 1-6.

Lim FL, Hashim Z, Than LTL, Said SM, Hashim JH and Norbäck D 2015. Asthma, airway symptoms and rhinitis in office workers in Malaysia: Associations with house dust mite (HDM) allergy, cat allergy and levels of house dust mite allergens in office dust. *PLoS ONE* **10**(4): 1-21.

Mbatchou Ngahane BH, Noah D, Nganda Motto M, Mapoure Njankouo Y and Njock LR 2016. Sensitization to common aeroallergens in a population of young adults in a sub-Saharan Africa setting: A cross-sectional study. *Allergy, Asthma and Clinical Immunology* **12**(1): 1-6.

Migueres M, Dakhil,J, Delageneste R, Schwartz C, Pech-Ormières C, Petit IL and Demonet G 2009. Skin sensitisation profiles of outpatients with symptoms of respiratory allergies. *Revue Des Maladies Respiratoires* **26**(5): 514-520.

Moghtaderi M, Teshnizi SH and Farjadian S 2017. Sensitization to common allergens among patients with allergies in major Iranian cities. *Epidemiology and Health* **39:** 1-10.

Nadzrah YS, Zulkiflee AB and Prepageran N 2015. Common aeroallergens by skin prick test among the population in two different regions. *Primary Health Care Open Access* **5**(03): 1-6.

Navarro A, Colas C, Anton E, Conde J, Dávila I, Dordal MT and Montoro J 2009. Epidemiology of allergic rhinitis in allergy consultations in Spain: Alergologica-2005. *J Investig Allergol Clin Immunol* **19**(2): 7-13.

Navarro-Locsin CG and Lim-Jurado M 2018. Aeroallergen sensitization and associated comorbid diseases of an adult Filipino population with allergic rhinitis. *Asia Pacific Allergy* **8**(3): 1-25

Newson RB, Van Ree R, Forsberg B, Janson C, Lötvall J, Dahlén SE and Kowalski ML 2014. Geographical variation in the prevalence of sensitization to common aeroallergens in adults: the GA2LEN survey. *Allergy* **69**(5): 643-651.

Psenka J 2015. *Dr. Psenka's seasonal allergy solution*, New York, NY: Rodale, p. 294

Resende RDO, Ynoue LH, Miranda JS, de Almeida KC, Silva DADO, Sopelete MC and Taketomi EA 2019. IgE, IgG1, and IgG4 reactivity to *dermatophagoides pteronyssinus* glycosylated extract in allergic patients. *BioMed Research International 2019*.

Sabariego S, Bouso V and Pérez-Badia R 2012. Comparative study of airborne Alternaria conidia levels in two cities in Castilla-La Mancha (Central Spain), and correlations with weather-related variables. *Annals of Agricultural and Environmental Medicine* **19**(2): 227-232.

Sharma R, Gaur SN, Singh VP and Singh AB 2012. Association between indoor fungi in New Delhi homes and sensitization in children with respiratory allergy. *Medical Mycology* **50**(3): 281-290.

Simon-Nobbe B, Denk U, Pöll V, Rid R and Breitenbach M 2008. The spectrum of fungal allergy. *International Archives of Allergy and Immunology* **145**(1): 58-86.

Sinniah D and Thakachy SS 2014. Meta-analysis: Spectrum of HDM allergic rhinitis and asthma in Malaysia. *Clinical and Translational Allergy* **4**(1):1-1.

Soegiarto G, Mai Shihah A, Damayanti LA, Suseno A and Effendi C 2019. The prevalence of allergic diseases in school children of a metropolitan city in Indonesia shows a similar pattern to that of developed countries. *Asia Pacific Allergy* **9**(2): 1-10.

Twaroch TE, Curin M, Valenta R and Swoboda 2015. Mold allergens in respiratory allergy: From structure to therapy. *Allergy, Asthma and Immunology Research* **7**(3): 205-220.

Uysal P, Erge D and Yenigün A 2016. Clinical characteristics of fungal sensitization in children with allergic respiratory diseases. *Meandros Medical and Dental Journal* **17**(2):74-82.

Wegienka G, Johnson CC and Zoratti E 2016. *HHS Public Access***13**(3): 255-261.

Wiszniewska M, Tymoszuk D, Nowakowska-Swirta E, Palczynski C and Walusiak-Skorupa J 2013. Mould sensitisation among bakers and farmers with work-related respiratory symptoms. *Industrial Health* **51**(3): 51-275.

Yang JJ, Burchard EG, Choudhry S, Johnson CC, Ownby DR, Favro D and Krajenta R 2008. Differences in allergic sensitization by self-reported race and genetic ancestry. *Journal of Allergy and Clinical Immunology* **122**(4): 820-827.

Zhang Y and Zhang L 2019. Increasing prevalence of allergic rhinitis in China. *Allergy, Asthma & Immunology Research* **11**(2): 156-169.

Zheng YW, Lai XX, Zhao DY, Zhang CQ, Chen JJ, Zhang L and Spangfort DM 2015. Indoor allergen levels and household distributions in nine cities across China. *Biomedical and Environmental Sciences* **28**(10): 709-717.

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Studies on Safety Evaluation of Carbosulfan on the Predator, *Chrysoperla zastrowi sillemi* Esben-Peterson

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Abstract: The toxicity of carbosulfan to the chrysopids, *Chrysoperla zastrowi sillemi* Esben-Peterson is assessed in laboratory as well as field conditions. Lesser ovicidal action was observed at the effective field dose at Carbosulfan @ 250 g a.i. ha^{-1} recording 80.5 and 89.5 per cent mortality after 24 and 48 Hours of treatment. All the tested concentrations caused significant grub mortality when subjected to oral feeding and dry film methods. The recommended dose showed 58.0, 78.0 and 90.0 per cent in oral feeding method and 64.0, 86.0 and 98.0 per cent mortality in dry film method at 12, 24 and 48 HAT. Carbosulfan was not safe to adult green lace wings when assessed through contamination method with an adult longevity of 6.60 days and fecundity rate per five females being 90.60 eggs. In the field, the adults recorded a reduction in population from 6.0 before treatment to 4.0 on the first day after treatment, but rebounded to almost the original population @ 5.0 on third day after treatment at the recommended dose at carbosulfan @250 g a.i. ha^{-1}. The study suggested the toxicity of carbosulfan 25 EC to chrysopids, but the recommended dose can be used in case of severe infestation of pest owing to its capability to manage brinjal pests efficiently.

Keywords: Carbosulfan, Brinjal, Toxicity, Green lace wing, *Chrysoperla zastrowi sillemi*

Green lacewing, *Chrysoperla zastrowi sillemi* (Esben Peterson) (Neuroptera: Chrysopidae) has long been considered as an important natural predator because of its potential to control a variety of soft bodied insects like aphids, coccids, mealybugs, thrips, psyllids, whiteflies, and eggs and larvae of many lepidopteran pests and mites occurring on various crops. Chrysopids are the most intensively studied predators because of their wide geographical distribution, broad habitats with high relative frequency of occurrence, good searching ability and easy rearing in the laboratory (Henry et al 2010). Most of the adult chrysopids are non-predatory but their larval instars are predatory. The chrysopids are emerging as potent biocontrol agents against mealybugs and aphids. However, further research is needed to ascertain their efficiency in the integrated pest management programmes (Pappas et al 2011).

Brinjal eggplant (*Solanum melongena* L.) is a warm-weather crop mostly cultivated in tropical and subtropical regions of the world. The insect pests of brinjal are quite complex which indirectly contribute towards low yield. Brinjal is attacked by more than 36 pests from the time of its planting till harvest (Regupathy et al., 2014), which includes leaf hopper, *Amrasca biguttula biguttula* (Ishida.), whitefly, *Bemisia tabaci* (Genn.), aphid, *Aphis gossypii* (Glover.), and shoot and fruit borer, *Leucinodes orbonalis* (Guen.). *Chrysoperla zastrowi sillemi* is a major predator of sucking pests as well as larva of lepidopterans infesting brinjal. Insecticides provide an acceptable solution to overcome these pests, as they are highly effective, rapid in curative action and adaptable to most situations, flexible in meeting changing agronomic conditions and relatively economical. Carbosulfan 25 EC is one of the broad-spectrum insecticides for the management of sucking and chewing pests in brinjal ecosystem (Sheeba Jasmine 2002). Though insecticides are an important component of Integrated Pest Management (IPM), their usage has become both extensive and intensive and have created serious upset and imbalance in the arthropod complex and some insecticides show toxicity to the predators especially *Chrysoperla zastrowi sillemi* (Thangavel et al 2014).

Natural occurrence of *Chrysoperla* sp. in field is rare due to frequent use of non-selective agrochemicals (*Nasreen et al* 2005). The impact of synthetic pesticides on beneficial arthropods and the human health risks posed by exposure to these chemicals are issues of growing concern. To mitigate these adverse effects, choice of selective insecticide, dosage, or timing of insecticide application can be a viable option. Biological control and selective insecticides proved to be compatible tactics in Integrated Pest Management (IPM) programs. Hence protection and preservation of these beneficial insects are indispensable. With a view to generate information on the safety of carbosulfan to *C. z. sillemi*, studies were conducted to evaluate the effect of carbosulfan on eggs, larva and adults of *C. z. sillemi* under lab conditions and adult activity under field condition.

MATERIAL AND METHODS

The laboratory studies were carried out at the Department of Entomology, Tamil Nadu Agricultural University, Coimbatore. The field study was conducted at a farmer's holding, Urumandampalayam village, Vellakinaru, Coimbatore, on the brinjal variety CO_2.

Laboratory Studies

Effect of carbosulfan on the eggs of *C. z. sillemi:* Laboratory studies were conducted to assess the effect of carbosulfan on the eggs of *C. z. sillemi* (Krishnamoorthy 1985). The eggs along with stalk collected on brown paper strips were sprayed with various dilutions using an atomizer. Each treatment was replicated five times with 200 eggs per treatment. Untreated check was maintained by spraying distilled water. The number of grubs hatched from each treatment was recorded and per cent hatchability was worked out by the formula,

$$\text{Per cent hatchability} = \frac{\text{No. of grubs hatched}}{\text{Total number of eggs}} \times 100$$

Effect of Carbosulfan on the Grubs of *C. z. sillemi*

Larval feeding method: Eggs of *C. cephalonica* were exposed to UV radiation of 15W capacity for 15 minutes to kill the embryos and then sprayed with different concentrations of the insecticide with an atomizer. The treated eggs were shade dried for 15 minutes and then transferred to test tubes (1cc / test tube) of size 2.0 x 15 cm. The eggs were sprayed with distilled water for untreated control. Second instar grubs of *C. z. sillemi* were transferred to these test tubes at the rate of 10 per test tube. After complete feeding of the treated eggs, the grubs were provided with untreated C*orcyra* eggs until pupation. Observations were made on the grub mortality 12, 24 and 48 hours after treatment (Preetha et al 2009).

Dry film method: The bioassay method described by McCutchen and Plapp (1988) was adopted with modifications. In this method the different concentrations were obtained by dissolving 0.2, 0.4 and 0.8 ml of carbosulfan and 0.2 ml of dimethoate as check in 100 ml of analytical grade acetone. Glass scintillation vials of 20 ml capacity with 1 mm thickness were evenly coated with 1 ml of acetone solutions of insecticide formulations and dried by rolling for few seconds. Second instar predatory lacewing grubs were released into the vials at 10 per vial and covered with muslin cloth. Mortality observations were taken at 12, 24 and 48 hours after treatment. After 24 hours exposure of the grubs, 1 cc of *C. cephalonica* eggs were given as feed to the grubs. Per cent mortality of the grubs was worked

Effect of carbosulfan on the adults of *C. C. z. sillemi:* Five pairs of freshly emerged *C. z. sillemi* were placed in separate plastic containers. The adults were fed with 10 per cent sucrose solution containing different concentrations of carbosulfan formulation. In the untreated check the adults were fed with 10 per cent sucrose solution alone. The eggs laid in each treatment were collected daily by keeping a brown paper sheet of size 21 x 6 cm along the inner side of the plastic container. Observations were made on the adult longevity and fecundity by recording the number of days the adults were alive and number of eggs laid per five females (Rajeshwaran and Santharam 2004).

Field studies: The study was carried out in a replicated and randomized field experiment at Urumandampalayam village, Vellakinaru, Coimbatore, on the brinjal variety CO-2. Three sprays of carbosulfan@ 250, 500 and 1000 g a.i. ha^{-1} and standard check dimethoate @ 300 g a.i. ha^{-1} were given separately on the crop at an interval of 14 days. The control plots were sparayed with water. The first spraying was given at 10 days after transplanting using pneumatic knapsack sprayer with the fluid rate was 500 l ha^{-1} and subsequent two applications were made at 14 days interval.

Statistical analysis: The data were transformed to $\sqrt{X+0.5}$ and analysed by completely randomized design. The treatment mean values of the experiment were compared using Duncan's Multiple Range Test (DMRT) (Gomez and Gomez, 1984). The corrected per cent mortality for lab studies was worked out by using Abbott's correction (Abbott, 1925). The values of the corrected per cent mortality were transformed using arc sine transformation for normalisation of data.

RESULTS AND DISCUSSION

Ovicidal action: The per cent hatchability was maximum in untreated check (85 and 93 % at 24 and 48 HAT), whereas the recommended dose of carbosulfan @ 250 g a.i.ha^{-1} recorded 80.5 and 89.5 per cent hatchability at 24 and 48 HAT. Consequently, the mortality percent was only 19.5 and 11.5 % at 24 and 48 HAT for the recommended dose of carbosulfan ensuring its safety to chrysopids (Table 1). But the other doses carbosulfan 25 EC @ 500 g a.i. ha^{-1} and 1000 g a.i.ha^{-1} recorded 72.5 and 65.0 percent hatchability at 24 HAT and 84.0 and 75.5 percent hatchability at 48HAT. However, the standard dimethoate recorded 73.0 and 85.5 per cent hatchability at 24 and 48 HAT.

Larval feeding method: The results of the larval feeding of carbosulfan 25 EC was listed in Table 2. The results revealed that carbosulfan at all the doses caused grub mortality to an extent of 76 per cent for carbosulfan at 1000 g a.i.ha^{-1} after 12 hours of treatment (HAT). However, at 48 HAT, except control (28%) all the treatments recorded higher mortality of 90, 94, 98 and 98 per cent in carbosulfan 25 EC at 250, 500 and 1000 g a.i. ha^{-1} and dimethoate 30EC @ 300 g a.i. ha^{-1}.

Nevertheless, the recommended dose of carbosulfan @ 250 g a.i.ha^{-1} recorded only 58 per cent at 12 HAT, which increased to 72 and 90 percent at 24 and 48 HAT.

Dry film method: All the doses of carbosulfan caused significant grub mortality (Table 2). The highest mortality (98%) was in carbosulfan 1000 g a.i.ha^{-1} followed by dimethoate (84%), carbosulfan 500 and 250 g a.i.ha^{-1} (82 and 64 per cent) at 12 HAT. Mortality increased at 48 HAT for the treatments equally affecting the grubs with the mortality ranged from 98 to 100 per cent. However, the recommended dose of carbosulfan @ 250 g a.i. ha^{-1} recorded 64 percent mortality, which jumped up to 86.0 and 98.0 per cent at 24 and 48 HAT. The standard check was also unsafe recording 84, 90 and 100 per cent mortality.

Adult: The adult longevity was maximum of 16.8 days in untreated check, while it was 6.6, 3.6, and 1.2 days in carbosulfan at 250, 500 and 1000 g a.i.ha^{-1} respectively and 3.4 days in the standard check dimethoate (Table 1). Significantly more number of eggs were laid in untreated check (414.80 eggs per five females). Carbosulfan at different doses *viz.*, (250, 500 and 1000 g a.i.ha^{-1}) recorded 90.60, 42.8 and 19.2 eggs per five females respectively. The standard check, dimethoate recorded 40.6 eggs per five females.

Field studies: The pre-treatment population of chrysopids ranged from 5.3 to 6.3 per 10 plants before spraying (Table 3). Carbosulfan at higher dose (1000 g.a.i.ha^{-1}) recorded minimum number of 2.0, 2.8, 4.0 and 4.8 on 1, 3, 7 and 14 DAT. The field dose of Carbosulfan @ 250 g a.i.ha^{-1}, recorded 4.0, 5.0, 6.0 and 9.0 chrysopids at 1, 3, 7 and 14 DAT.

Table 1. Effect of carbosulfan 25 EC on the eggs and adults of *Chrysoperla z. sillemi*

T.No	Treatments	Eggs				Adult	
		24 HAT		48 HAT		Adult longevity (days)	No. of eggs laid per 5 females
		Hatchability (%)	Mortality (%)	Hatchability (%)	Mortality (%)		
T_1	Carbosulfan @ 250 g a.i.ha^{-1}	80.5^{b}(63.79)	19.5^{b}(26.20)	89.5^{b}(71.09)	11.5^{b}(19.82)	6.60^{b}(2.66)	90.60^{b}(9.54)
T_2	Carbosulfan @ 500 g a.i.ha^{-1}	72.5^{c}(58.37)	27.5^{c}(31.63)	84.0^{d}(66.43)	16.0^{d}(24.49)	3.60^{c}(2.02)	42.80^{c}(6.58)
T_3	Carbosulfan @ 1000 g a.i.ha^{-1}	65.0^{d}(53.73)	35.0^{d}(36.27)	75.5^{e}(60.33)	24.5^{e}(29.66)	1.20^{d}(1.30)	19.20^{e}(4.44)
T_4	Dimethoate @ 300 g a.i.ha^{-1}	73.0^{c}(58.69)	27.0^{c}(31.30)	85.5^{c}(67.62)	14.5^{c}(22.46)	3.40^{c}(1.97)	40.60^{d}(6.41)
T_5	Untreated control	85.0^{a}(67.22)	15.0^{a}(22.77)	93.0^{a}(74.69)	7.0^{a}(15.31)	16.8^{a}(4.15)	414.80^{a}(20.38)

HAT - Hours after treatment; In a column means followed by a common letter are not significantly different by DMRT (p = 0.05)

Table 2. Effect of carbosulfan 25 EC on the grubs of *C.z. sillemi* by larval feeding and dry film method

Treatments	Mortality %					
	Dry film method			Oral feeding method		
	12 HAT	24 HAT	48 HAT	12 HAT	24 HAT	48 HAT
Carbosulfan @ 250 g a.i.ha^{-1}	58.0^{b} (49.60)	72.0^{b} (58.05)	90.0^{b} (71.58)	64.0^{b} (53.13)	86.0^{b} (68.03)	98.0^{b} (82.08)
Carbosulfan @ 500 g a.i.ha^{-1}	68.0^{c} (55.55)	78.0^{c} (62.03)	94.0^{c} (75.86)	82.0^{c} (64.90)	88.0^{c} (69.74)	98.0^{b} (82.08)
Carbosulfan @ 1000 g a.i.ha^{-1}	76.0^{e} (60.67)	88.0^{e} (69.74)	98.0^{d} (82.08)	98.0^{d} (82.08)	100.0^{e} (86.96)	100.0^{c} (86.96)
Dimethoate @ 300 g a.i.ha^{-1}	70.0^{d} (66.27)	82.0^{d} (64.90)	98.0^{d} (82.08)	84.0^{c} (66.27)	90.0^{d} (71.58)	100.0^{c} (86.96)
Untreated control	4.0^{a} (11.46)	13.00^{a} (21.12)	28.0^{a} (32.26)	0.0^{a} (0.22)	8.00^{a} (16.4)	22.0^{a} (27.97)

HAT - Hours after treatment; In a column means followed by a common letter are not significantly different by DMRT (p = 0.05)

Table 3. Toxicity of carbosulfan 25 EC to chrysopids in brinjal ecosystem

T. No	Treatments	Number per 10 plants				
		PTC	1 DAT	3 DAT	7 DAT	14 DAT
T_1	Carbosulfan @ 250 g a.i.ha^{-1}	6.0^{a} (2.54)	4.0^{b} (2.11)	5.0^{b} (2.33)	6.0^{b} (2.54)	9.0^{a} (3.08)
T_2	Carbosulfan @ 500 g a.i.ha^{-1}	6.3^{a} (2.59)	3.8^{b} (2.05)	4.3^{b} (2.17)	5.3^{b} (2.39)	6.0^{bc} (2.54)
T_3	Carbosulfan @ 1000 g a.i.ha^{-1}	5.3^{a} (2.39)	2.0^{c} (1.56)	2.8^{c} (1.79)	4.0^{c} (2.11)	4.8^{c} (2.27)
T_4	Dimethoate @ 300 g a.i.ha^{-1}	5.3^{a} (2.39)	3.5^{b} (1.97)	5.0^{b} (2.33)	5.8^{b} (2.49)	9.3^{b} (3.12)
T_5	Untreated control	6.0^{a} (2.54)	7.0^{a} (2.73)	8.8^{a} (3.04)	8.8^{a} (3.04)	9.3^{a} (3.12)

HAT - Hours after treatment; In a column means followed by a common letter are not significantly different by DMRT (p = 0.05)

Carbosulfan 25 EC @ 250 g a.i.ha^{-1} was on par with the untreated check, followed by dimethoate 30 EC @ 300 g a.i.ha^{-1} (9.3 per 10 plants) and carbosulfan 25 EC @ 500 g a.i.ha^{-1}(6.0 per 10 plants) which were on par followed by the maximum dose of carbosulfan (4.8 per 10 plants) (1000 g a.i.ha^{-1}) on 14 DAT.

CONCLUSION

The chemical in general is unsafe for *C. zillemi zastrowi* with highest toxicity recorded in the higher doses (500 and 1000 g a.i.ha^{-1}). The field dosage of carbosulfan @ 250 g a.i.ha^{-1} recorded less ovicidal action, recording 80.5 and 89.5 per cent mortality after 24 and 48 Hours of treatment. and comparatively higher percent larval hatchability of 58.0 and 64.0 per cent at 12 HAT in oral feeding and dry contamination method. The adults demonstrated an adult longevity of 6.60 days and fecundity rate per five females being 90.60 eggs. Moreover, the recommended dose of carbosulfan showed steady increase of 5.0, 6.0 and 9.0 chrysopids on 3, 7 and 14 days after spray under field conditions, after a slight decrement of 4.0 on the first day of spray from 6.0 before spray. Therefore, the field dose of carbosulfan 25 EC @ 200 g a.i. ha^{-1} is recommended when there is a severe outbreak of brinjal pests as the chemical is very efficient in managing them.

REFERENCES

Abbott WS 1925. A method of computing the effectiveness of an insecticide. *Journal of Economic Entomology* **18**: 265-267.

Gomez KA and Gomez AA 1984. *Statistical procedures for Agricultural research.* Wley International Science Publications. John Wiley and sons, New Delhi.

Henry CS, Brooks SJ and Johnson JB 2010. The most important lacewing species in Indian agricultural crops, *Chrysoperla sillemi* (Esben-Petersen), is a subspecies of *Chrysoperla zastrowi* (Esben-Petersen) (Neuroptera: Chrysopidae). *Journal of Natural History* **44**(41-42): 2543-2555

Krishnamoorthy A 1985. Effects of several pesticides on the eggs, larvae and adults of green lace wing, *Chrysopa scelestes* (Banks). *Entomon* **10**(1): 21-28.

McCutchen BF and Plapp FN 988. Monitoring procedure for resistance to synthetic pyrethroids in tobacco bollworm larvae. **In**: *Proceeding of Beltwide Cotton Prodn. Research Conference,* New Orleans, Jan 3-8, 1988, Nat. Cotton Council of America, Memphis Tenn. pp 356-358.

Nasreen A, Ashraf M, Mustafa G and Khan RR 2007. Mortality rates of five commercial insecticides on *Chrysoperla carnea* (stephens) (chrysopidae: neuroptera). *Pakistan Journal of Agricultural Sciences* **44**(2): 266-27.

Pappas ML, Broufas GD and Koveos DS 2011. Chrysopid predators and their role in biological control. *Journal of Entomology* **8**(3): 301-326.

Preetha G, Stanley J, Manoharan T, Chandrasekaran S and Kuttalam S 2009. Toxicity of imidacloprid and diafenthiuron to *Chrysoperla zastrowi sillemi* (Stephens) (Neuroptera: Chrysopidae) in the laboratory conditions. *Journal of Plant Protection Research* **49**(3): 290-296.

Rajeshwaran J and Santharam G 2004. Evaluation of toxicity of carbosulfan to eggs, larvae and adults of green lacewing, *Chrysoperla zastrowi sillemi* (Stephens) (Neuroptera: Chrysopidae). *Journal of Biological Control* **18**(2): 2 11-214.

Regupathy A, Palanisamy S, Chandramohan N and Gunathilagaraj K 2014. *A guide on crop pests*. Sheeba publishers, Coimbatore. 264p.

Sheeba Jasmine R 2002. *Evaluation of carbosulfan (Marshal®) 25 EC against cotton and brinjal sucking pests and brinjal shoot and fruit borer*. M.Sc.(Ag.). Thesis, Tamil Nadu Agricultural University, Coimbatore.

Thangavel K, Baskaran RK and Baby Rani W 2014. Safety evaluation of Emamectin benzoate 5 WG against green lacewing, *Chrysoperla zastrowi sillemi* (Esben-Petersen). *National Symposium on Emerging Trrends in Eco-friendly Insect Pest Management* January 22-24, 2014 (In commemoration of 100 Years of Entomological Research in TNAU).

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Taxonomic and Ecological Studies on Trematode Parasite *Euclinostomum heterostomum* (Clinostomidae: Euclinostominae) from Freshwater Fishes of River Tawi of Jammu Region (J & K)

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Abstract: The study was conducted during 2016-18 to ascertain the taxonomic status of trematode parasite *Euclinostomum heterostomum* along with the various physicochemical parameters affecting parasitic infestation in freshwater fishes of river Tawi. A total of 690 fishes comprising *Labeo rohita*, *Tor putitora, Channa punctatus, Puntius sophore*, *Mystus bleekeri*, *Xenentodon cancilia* and *Oreochromis mossambicus* were examined and 240 specimens of parasites were recovered. The trematode parasite revealed characteristics like elongated body, rudimentary anterior sucker, sub terminal acetabulum, 7-12 caecal diverticulae, paired testes positioned in the posterior part of the body and inter-testicular ovary. High prevalence percentage was 37.38 and 33.64% for first and second year respectively and the lowest in winter. The maximum mean intensity values was during winter season (5.5 and 2.85). Fluctuations were observed in various physicochemical parameters *viz.,* water temperature (9º to 30ºcelsius), dissolved oxygen (5.5to 18.6 mg/L), free carbon dioxide (0 to 12.5) mg/L), carbonates (0 to 41.0 mg/L) and bicarbonates (107.1 to 241.4 mg/L) which revealed that the rate of parasitic infestation was positively correlated with water temperature, carbon dioxide, bicarbonates and negatively with pH, dissolved oxygen and carbonates.

Keywords: Fish, *Euclinostomum heterostomum*, Parasite, Trematode

Fish being one of the best sources of animal protein fulfills about 25% of the world's protein requirement. Due to the intensification of this sector and lack of management practices, fishes are prone to many diseases of which 80% are of parasitic origin and are prevalent in warm water fishes. Such diseases pose a threat to fish culture by affecting the production as well as to the humans which come in contact with zoonotic parasites. The eggs and the juveniles of most of the parasites are released in the water bodies in which they enter the intermediate hosts which are vital for the completion of their life cycle. Many of the trematode parasites flourishing in contaminated water bodies enter the human food chain by the intake of infected fish thus resulting in zoonosis (Doligalska and Donskow 2003, Nithiuthai et al 2004). Parasites cause heavy mortality in fishes by affecting the growth rate and weight loss prior and after the disease outbreak (Ayotunde et al 2007, Kayis et al 2009 and Gulelat et al 2013). Amongst the trematodes, the digeneans are the major parasites of the teleosts and most of them exist as endoparasites with several digenetic trematodes (Clinostomidae) recorded by numerous workers across the world (Hadid and Lofty 2007, Abd Al Aal et al 2008). Most of the trematode parasites from fishes remain unidentified due to poor collection techniques and lack of the taxonomic literature. The trematode parasite *Euclinostomum heterostomum* is a common parasite of Piscivorous birds in several parts of Europe, Asia and Africa. In addition to the previous studies on the life cycle of *E. heterostomum* there have been many frequent reports of adult and metacercarial forms of *E. heterostomum* from freshwater fishes by several workers across the globe (Vankara et al 2011, Senapin et al 2014, Britz et al 2015, Athokpam et al 2016 and Abro et al 2016). Trematodes are the most diverse type of fish parasites and are in larval or adult forms in majority of the fish species. A few species of *Euclinostomum* have been reported from Jammu in the past *viz., E. reticulatum* and *E. jammuensis.* The present study, however, encompasses a detailed investigation with respect to taxonomy of a trematode parasite *E. heterostomum* and effect of various physicochemical parameters on the parasitic infestation.

MATERIAL AND METHODS

The fishes collected from river Tawi (32º 47 North and 74º 43 East) with proper aeration for further processing. All the internal organs were examined carefully for the trematode parasite *E. heterostomum*.

Processing of parasites: The trematode parasites thus recovered were fixed in Carnoy's fixative for 10-15 minutes followed by dehydration in various alcoholic grades from 30-70% alcohol each for the duration of 10 minutes. The parasites were stained in aceto-alum carmine depending upon the thickness of the parasite after which they were

subjected to higher alcoholic grades. This was followed by final washings (twice) in absolute alcohol. The specimens were micro photographed and drawings were made and sizes of the various organs were recorded by micrometry.

Ecological parameters: Prevalence and mean intensity were calculated.

$$\text{Prevalence}=\frac{\text{Total number of hosts infected}}{\text{Total number of hosts examined}} \times 100$$

$$\text{Mean intensity}=\frac{\text{Total number of parasites}}{\text{Total number of infected hosts examined}}$$

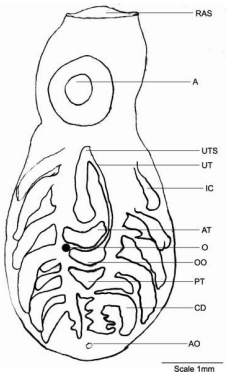
p- values were also determined using PAST software.

Physicochemical parameters: The water temperature was recorded from depth of 10.12 cm in water for two minutes (APHA 2000). The pH determined by using a pH meter (Hanna model). The dissolved oxygen was determined by using Sodium Azide modification of Winkler's method (APHA 2000). Free carbon dioxide and carbonates and bicarbonates were calculated (APHA 2000). The standard techniques of A.P.H.A. (2000) has been used for estimation of carbonates and bicarbonates.

RESULTS AND DISCUSSION

The body shape of the fluke varied from elongated to oval or spherical to filamentous, with two suckers, one of them being rudimentary or absent. Oral rudimentary sucker was supported by a collar fold of the body. Acetabulum was well developed, pharynx was primitive type provided with bifurcated intestines which have blind caeca that open at the anal opening at the posterior most end of the body. The long caeca which may be simple or diverticular were mostly present in the lower half of the body. A pair of testes and a single ovary was present. Size, distribution and form of uterus and vitellaria were variable. The metacercarial fluke recovered in the present study measured 5.84 and 2.75 mm in length and width, with anterior rudimentary sucker formed by a fold of the collar wall. However, the ventral sucker is well developed measuring 1.17 mm. Anterior and posterior testes were 0.25 x 0.65 mm and 0.30 x 0.57 mm respectively. Ovary which was intertesticular measured 0.25 x 0.60 mm. Long lateral caecal diverticulae extend upto the posterior end of the body and are mostly unbranched except one or two. The number of caecal diverticulae ranged from 7-12.

The present trematode parasite were recovered in large numbers from the intestines of *Labeo rohita* and *Channa punctatus* measured 5.84 x 2.75 mm. The presence of a well-developed oral sucker was recorded in the earlier report (Rudolphi 1809) but has been observed to be rudimentary in the present study. The disappearance of the anterior sucker might have occurred due to evolution in which the parasites do not need to hold fast to its host due to easy availability of food. The acetabulum is well developed and shares close similarity with the previous report (Rudolphi 1809), however, the ventral sucker of the present parasite is larger than that of *E. bhagavantami* (Ukoli 1966) and *E. minutes* (Bhutta and Khan 1975). The size of the ovary, however, shows resemblance to *E. minutes* which is quite smaller than that of *E. heterostomum* and *E. bhagavantami*. The number of intestinal diverticulae (caecal diverticulae) that are present in the lower half of the body is however, similar to previous reports of *E. heterostomum* (7-12) and *E. reticulatum* (6-13) reported by Rudolphi (1809) and Pandoh (1992) respectively (Table 1). The intestinal diverticulae in *E.bhagavantami* range from 9-12, whereas in *E. minutes* are 15. The present species closely resemble previous reports of *E. reticulatum* (Rudolphi 1809) and Purivirojkul and Sumontha (2013). This species bears many resemblances with *Euclinotomum heterostomum* (Abro et al 2016, Caffara et al 2016) which was characterized by the presence of a slipper shaped body, oral invagination forming a collar like structure, body narrow after the anterior sucker region and was widest in the gonadal region, intestines bifurcate in the posterior region forming the blind caeca, intertesticular ovary, connection between intestinal caeca and excretory pore is not well demarcated. *E. heterostomum* from the muscles of osphronemid fishes *viz., T. vitatta, B. splendens, B. imbellis* was larger than the present parasite and was provided with a sub terminal oral sucker (Purivirojkul and Sumontha 2013). The ventral sucker of the parasite reported by Purivirojkul and Sumontha (2013) shared close resemblance to present parasite with testes and ovary larger than present studies. Since, most of the characteristics of the present parasite bear a close resemblance with *E. heterostomum*, hence the parasite is identified as *E. heterostomum* which is a clinostomid parasite reported from freshwater fishes of Jammu.



RAS: Rudimentary Anterior Sucker, A: Acetabulum, UTS: Uterine Sac, UT: Uterus, IC: Intestinal Caeca, AT: Anterior Testes, O: Ovary, OO: Ootype, PT: Posterior Testes, CD: Caecal Diverticula, AO: Anal Opening

Fig. 1. *Euclinostomum heterostomum* (5x x 4x)

Seasonality: A total of 690 fishes were examined for a period of two years and 240 parasites were recovered with maximum prevalence in spring season during both the years. During the first year, highest prevalence percentage was witnessed during the spring season (37.38%) and lowest in winter (5.7%) (Table 2). Similar pattern was recorded during the second year (33.64% and 8.64%, Table 3). However, during both the years, maximum mean intensity were during the winter season (5.5 and 2.85) which might be due to the previous infestation by the parasite which has increased the number of parasites present on a single fish specimen. Shareef and Abidi (2015) also witnessed highest values in spring and lowest values in winter. However for some other parasites, highest infestation rates were in autumn season and least values in early spring (Alkhuzaie et al 2019) which might be due to the difference in the climatic conditions depending upon the topography.The rate of parasitic infestation depends upon various physicochemical parameters which are highly variable depending upon the topographical conditions. During both the years trematode parasite *Euclinostomum heterostomum* flourished during the spring season which was due to the fact that due to the

Table 1. Comparative measurements of *Euclinostomum heterostomum* with other species of *Euclinostomum* (in mm)

Particulars	*E. heterostomum* (Rudolphi 1809)	*E. bhagavantami* (Ukoli 1966)	*E. minutus* (Bhutta and Khan 1975)	*E. reticulatum* (Sudan 1979)	*E. reticulatum* (Pandoh 1992)	*E. heterostomum* (Purivirojkul and Sumontha 2013)	*E. heterostomum* present species
Mean body size	5.65-7.975 x 2.29-2.925	12.7 x 3.37	4.484-6.66 x 1.66-2.424	6.72-7.50 x 2.56-2.96	6.40-10.08 x 1.76-3.26	5.78-7.77 x 2.25-2.73	5.84 x 2.75
Oral sucker	0.24-0.231 x 0.310-0.210	-	0.235-0.392 x 0.245-0.392	0.20-0.28 x 0.22-0.36	0.19-0.32 x 0.24-0.48	0.199 x 0.264	Rudimentary
Ventral sucker	0.85-1.9 x 0.75-1.7	0.53 x 0.380	0.235-0.392 x 0.245 -0.39	1.10-1.30 x 1.04-1.28	0.96-1.47 x 0.96-1.76	0.978 x 0.930	1.17
Number of diverticula	7-12	9-12	15	7-12	6-13	10-12	7-12
Ovary	0.6 -0.72 x .1-0.15	0.6 x 0.26	0.245-0.333x 0.235-0.393	0.13-0.18 x 0.16-0.19	0.09-0.20 x 0.08-0.24	0.179 x 0.148	0.25 x 0.60
Anterior testes	--	--	--	0.20-0.24 x 0.60-0.71	0.48-1.20 x 0.08-0.24	0.13 x 0.179	0.25 x 0.65
Posterior testes	--	--		0.16-0.32 x 0.50-0.56	0.40-1.12 x 0.19-0.40	0.530 x 0.680	0.30 x 0.57
Hosts	--	--	Birds	*Channa punctatus*	*Channa punctatus*	*Trichopsis vittata, Betta splendens, Betta imbellis*	*Labeo* sp., *Channa punctatus*
Location	-	-	Pakistan	Jammu (J & K), India	Jammu (J & K), India	Israel	Jammu (J & K), India

Table 2. Infection patterns of *Euclinostomum heterostomum* in fishes (2016-17)

Season	Total No. of fish	No. of fish infected	p value	Significance	No. of parasites	Prevalence (%)	Mean intensity
Spring	99	37	0.015	S	57	37.38	1.54
Summer	86	25	0.000	HS	37	29.06	1.48
Autumn	79	6	0.000	HS	17	7.5	2.83
Winter	69	4	0.000	HS	22	5.7	5.5
Total	333	72			133		

Table 3. Infection patterns of Euclinostomum heterostomum in fishes (2017-18)

Season	Total No. of fish	No. of fish infected	p value	Significance	No. of parasites	Prevalence (%)	Mean intensity
Spring	107	36	0.001	HS	43	33.64	1.19
Summer	77	25	0.434	NS	31	32.46	1.24
Autumn	92	8	0.000	HS	13	8.69	1.62
Winter	81	7	0.000	HS	20	8.64	2.85
Total	357	76			107		

congenial water conditions and availability of intermediate hosts in abundance that required for the completing the life cycle (Kundu et al 2015). However, these intermediate hosts start decreasing on moving to winter through summer season. Out of the total 690 fishes examined, 148 were infected with *Euclinostomum heterostomum* and 240 parasites were recovered. Of these, 48 fishes of *Labeo rohita* and *Channa punctatus* were most infected (Table 4).

Physicochemical parameters: The parasitic infestation also depends on the climatic changes and hence an attempt has been made to study the relationship of parasitic infestation with physicochemical parameters. The water temperature showed wide fluctuations from 9º to 30º C (Table 5), which affects the seasonal rate of parasitic infestation and a decreasing trend was found from summer to winter season. When water temperature rises from spring to summer, the oxygen carrying capacity of water is reduced thereby creating stressful conditions for the fishes and making them more susceptible to parasitic infestations. Similar fluctuations in water temperature have been put forward by earlier workers (Sharma et al 2017, Shehata et al 2018 and Joshua et al 2018). DO values showed fluctuations from 5.5 to 18.6 (Table 5) minimum during summer months because warm water cannot hold high amounts of oxygen. Moreover, during summer, the decomposition of organic matter is high thus more of the carbon dioxide is released into the water. During summer, the temperature of water increases that decreases the dissolved oxygen and free carbon dioxide increases due to the release of carbon dioxide from the bottom and photosynthetic activity of phytoplankton is low, overnight respiration of zooplanktons is high and hence the dissolved oxygen is minimal. Since, there exists an inverse relationship between dissolved oxygen and carbon dioxide, hence during summer when the dissolved oxygen is least,

Table 4. Host wise monthly pattern of infection

Particulars	Total No. of fish	No. of fish infected	No. of parasites recovered	*Labeo rohita*		*Tor putitora*		*Channa punctatus*		Others*	
				E	I	*E*	I	*E*	I	E	I
November	29	3	7	10	1	7	0	3	2	9	0
December	31	4	7	8	2	7	1	10	1	6	0
January	19	0	5	6	0	5	0	3	0	5	0
February	19	0	10	9	0	7	0	1	0	2	0
March	34	11	19	6	6	8	0	5	5	15	0
April	29	11	20	8	5	6	1	4	4	9	1
May	36	15	18	12	2	8	1	2	2	14	10
June	33	12	15	9	3	8	3	6	3	10	3
July	29	11	13	11	2	10	1	3	3	5	5
August	24	2	9	9	1	9	0	3	1	3	0
September	25	2	5	10	1	5	0	5	1	5	0
October	32	2	5	7	0	5	2	6	0	14	0
November	22	2	7	6	0	6	0	4	0	8	2
December	24	1	7	9	1	5	0	3	0	7	0
January	30	1	5	10	0	8	0	7	1	5	0
February	27	5	8	5	3	8	0	4	2	10	0
March	38	8	11	8	2	8	1	6	4	16	1
April	32	12	15	9	6	6	0	8	6	9	0
May	37	16	17	7	6	6	2	4	4	20	4
June	29	14	18	10	2	7	3	6	4	6	5
July	20	8	9	10	2	5	2	3	2	2	2
August	28	3	4	7	1	10	1	4	1	7	0
September	33	3	3	9	1	9	1	2	1	13	0
October	30	2	3	5	1	5	0	4	1	16	0
Total	690	148	240	200	48	168	19	106	48	216	33

*Others: *Puntius sophore*, *Mystus bleekeri*, *Xenentodon cancilia* and *Oreochromis mossambicus;* E: Examined, I : Infected

carbon dioxide values are high and the rate of infestation is highest. These findings were similar to Puinyabati et al (2013), Ahmed (2017) and Sharma et al (2017). However, these findings are in contradiction to Yousuf and Irfan (2018) who witnessed highest dissolved oxygen values in spring season which might be due to the fact that during winter season most of the water bodies in Kashmir remains frozen thus no uptake of oxygen occurs from air and hence the oxygen can be taken up by the atmosphere only when the ice melts during the spring. Moreover, during winter, photosynthesis occurs to a minimal extent due to which negligible amounts of oxygen are added to the water body.

The pH ranged from 7.0 to 8.2 (Table 5), minimum in summer and maximum during winter (alkaline pH). Moreover, during summer, free carbon dioxide is more due to the influx from ground water and leaching of rocks hence pH values are low. Similar findings were put forward by Gandotra et al (2008). There exists a direct relationship between pH values and dissolved oxygen as recorded in the present study and hence slightly alkaline pH was observed during winter months when the values of dissolved oxygen were also high and parasites showed a negative correlation with pH, most parasitic incidence was when the pH was slightly alkaline. When pH started shifting towards the higher alkalinity, there was decline in the parasitic prevalence (winter). The carbon dioxide values varied from 0 in winter months to 12.5 in summer months (Table 5). This is because most of the carbon dioxide is added to the water body due to the decomposition of the organic matter or respiration of plants and animals which is high in summer months, yet, carbon dioxide accumulation occurs at the bottom of water bodies which rises to the surface in the form of bubbles. In summer, the rate of biological oxidation is on increase, therefore levels of free carbon dioxide in water are maximum because elevated water temperature favours the dissolution of carbon dioxide. High concentration of carbon dioxide lowers the pH by reducing the dissolved oxygen. Free carbon dioxide showed a positive correlation with the number of parasites, highest in summer which results in complete absence of carbonates and hence low pH; hence it is evident

carbon dioxide

Table 5. Showing various physicochemical parameters that determine the rate of infestation (Mean ±SD)

Months	Water temperature (ºC)	pH	DO (mg/l)	FCO_2 (mg/l)	Carbonates (mg/l)	Bicarbonates (mg/l)
November	18.2±0.75	7.90±0.14	11.20±0.42	6.0±0.60	0	158.20±6.90
December	16.50±0.31	8.20±0.25	16.0±0.25	0	25.0±0.31	156.80±4.20
January	16±0.52	8.10±0.36	18.0±0.84	0	41.0±0.25	202.0±9.60
February	14±0.25	7.70±0.16	14.20±0.24	6.50±0.18	0	212.40±8.80
March	20.2±0.42	7.90±0.14	15.10±0.36	7.90±0.21	0	211.30±7.60
April	27.5±0.56	7.50±0.35	8.80±0.29	7.50±0.36	0	238.30±3.45
May	27.0±0.31	7.30±0.43	6.90±0.46	8.0±0.57	0	241.40±2.15
June	29.80±0.34	7.0±0.25	5.50±0.58	10.0±0.69	0	223.0±2.64
July	27.50±0.34	7.40±0.47	7.40±0.47	9.50±0.16	0	196.40±2.16
August	26.20±0.43	7.80±0.18	7.80±0.24	7.50±0.36	0	160.30±3.31
September	25.0±1.00	7.70±0.16	8.80±0.64	7.50±0.58	0	140.20±2.32
October	21.0±0.58	7.90±0.39	10.0±0.25	6.80±0.34	0	117.10±1.50
November	19.20±0.41	7.50±0.16	11.50±0.39	6.0±0.31	0	124.40±3.32
December	14.0±0.61	8.00±0.25	16.50±0.55	0	24.0±1.31	134.60±4.04
January	9.0±0.62	8.20±0.64	18.60±0.29	0	41.0±0.54	155.40±2.61
February	18.2.0±0.62	7.40±0.24	15.50±0.54	6.10±0.51	0	180.40±1.45
March	22.1±0.80	7.7±0.40	13.4±0.47	8.5±0.36	0	197.4±3.73
April	24.5±0.63	7.6±0.24	9.3±0.71	9.8±0.14	0	212.6±8.71
May	27.5±0.43	7.5±0.18	8.1±0.29	12.5±0.43	0	234.8±5.45
June	30±0.93	7.5±0.34	6.8±0.41	12.0±0.25	0	212.7±2.98
July	29.4±0.49	7.3±0.29	7.7±0.36	10.0±0.41	0	187.2±3.73
August	28.2±0.24	7.7±0.23	8.8±0.21	9.0±0.25	0	180.1±4.60
September	25.5±0.51	7.6±0.52	9.7±0.18	8.5±0.14	0	109.5±0.67
October	25.5±0.78	7.8±0.68	10.1±0.60	8.0±0.52	0	107.1±3.32

that pH bears a direct relation with carbonates and an inverse relation with FCO2. Moreover, increased diffusion of carbon dioxide from the atmosphere into the surface of the water body results in increased partial pressure of carbon dioxide and reduced pH (Tiwary and Thakur 2012).

Carbonates were present during winters at all the stations and parasites show a negative relation with higher carbon dioxide as maximum were during seasons when the carbon dioxide content in the water body was almost negligible. The carbonates fluctuated from 0 to 41.0 (Table 5). However, bicarbonates showed fluctuations from 107.1 to 241.4 mg L^{-1} (Table 5). The bicarbonates are higher during summer due to the increase in the decomposition process by an increase in the temperature. Since free carbon dioxide and carbonates are inversely proportional, hence carbonates were present only in the winter months (December and January) when the amount of free carbon dioxide was nil and hence carbonate values were high. The bicarbonates were found throughout the year but maximum during the spring season when the rate of decomposition is very high.

CONCLUSIONS

This study highlights the taxonomic characteristics of the trematode parasite *E. heterostomum* which is reported for the first time from Jammu region. The incidence of this parasite was observed in relation to the physicochemical parameters which revealed that the rate of parasitic infestation was positively correlated with water temperature, carbon dioxide, bicarbonates and negatively with pH, dissolved oxygen and carbonates. Steps should be taken to minimise the fluctuations in fish farms and keeping the conditions congenial for fish that will boost the fish production.

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REFERENCES

Abd Al Aal Z, Amer OH, Badawy AII and El- Ashram AMM 2008. Digenetic trematodes of the little erget, *Egretta garzetta* and possibility of transmission to *Oreochromis niloticus* at El-abbassa fish farms, Egypt. Proceeding of the *8th International Symposium on Tilapia in Aquaculture,* pp 1351-1364.

Abro MM, Dharejo AM, Khan MM and Birmani NA 2016. *Euclinostomum heterostomum* (Rud., 1809) Travassos, 1928 (Trematode: Clinostomidae: Euclinostominae): A new record in avian host little cormorant (Aves: Phalacrocoracidae) of Pakistan. *Journal of advances in Biology and Biotechnology* **8**(1): 1-5.

Ahmed F 2017. *Studies on the ectoparasitic fauna of fishes of district poonch of Jammu and Kashmir*. Ph.D. Thesis submitted to University of Jammu.

Alkhuzaie SS, Moyed ALS and Alsaadawi MA 2019. Studies on soil nematodes in Al-Muthanna Province, Iraq. *Indian Journal of Ecology* **46**(3): 640:642.

APHA 2000. Standard methods for the examination of water and wastewater: 20th edition. *Choice Reviews Online* **37**: 2737-2792.

Athokpam VD, Jyrwa DB and Tandon V 2016. Utilizing ribosomal DNA gene marker regions to characterize the metacercariae (Trematoda: Digenea) parasitizing piscine intermediate hosts in Manipur, Northeast India. *Journal of Parasitic Diseases* **40**(2): 330-338.

Ayotunde EO, Change ST and Okey IR 2007. Parasitological examination and food composition in the gut of feral Africa carp, *Labeo coubie* in the cross river, South Eastern Nigeria. *African Journal of Biotechnology* **6**: 625-630.

Bhutta MS and Khan D 1975. Digenetic trematodes of vertebrates from Pakistan. *Bulletin Department of Zoology University of Punjab* **8**: 1-175.

Britz J, Saayman JE and Van As JG 2015. Anatomy of the metacercaria and adult of *Euclinostomum heterostomum* (Rudolphi, 1809) Trematoda: Clinostomatidae. *South African Journal of Zoology* **19**(2): 91-96.

Caffara M, Locke SA, Cristanini C, Davidovich N, Markovich MP and Fioravanti ML 2016. Combined morphometric and molecular approach to identifying metacercariae of *Euclinostomum heterostomum* (Digenea: Clinostomidae). *Journal of Parasitology* **102**(2): 239-248.

Doligalska M and Donskow K 2003. Environmental contamination with helminth infective stages implicated in water and foodborne diseases. *Acta Microbiologica Polonica* **52**: 45-56.

Gandotra R, Sharma JP, Hina and Andotra P 2008. Evaluation of water quality of river Tawi with reference to physico chemical parameters of district Jammu (J & K) India. *Current world Environment* **3**(1): 55-56.

Gulelat Y, Eshetu Y, Asmare K and Bekele J 2013. Study on parasitic helminthes infecting three fish species from koka reservoir, Ethopia. *Ethiopian Journal of Science and Technology* **36**: 73-80.

Hadid SM and Lotfy HS 2007. Some studies on the helminth parasites of the buff backed heron (*Ardeola ibis ibis*) with special reference to its role in transmission of *Clinostomum complanatum* in Beni Suef Governorate. Proceeding of the *5th Scientific Conference,* Pp 135-141.

Joshua NA, Idumah OO, Nkwuda NG and Chijioke A 2018. Seasonal variation in physicochemical parameters and its relationship with zooplankton abundance in river Asu, Nigeria. Indian *Journal of Ecology* **45**(1): 60-65.

Kayis S, Ozcelep T, Capkin E and Altinok I 2009. Protozoan and metazoan parasites of cultured fish in turkey and their applied treatments. *Israeli Journal of Aquaculture Bamidgeh* **61**: 93-102.

Kundu I, Bandyopadhyay PK and Mandal DR 2015. Prevalence of helminth parasites infecting *Channa punctatus* Bloch, 1793 from Nadia district of West Bengal. *Journal of Agriculture and Veterinary Science* **8**(8):41-46.

Nithiuthai S, Malinee T, Anantaphruti, Waikagul J and Gajadhar A 2004. Waterborne helminthiasis. *Veterinary Parasitology* **1-2**: 167-193.

Pandoh BR 1992. *Ecological studies on trematodes of some aquatic vertebrates of Jammu Province*. Ph.D. Thesis submitted to University of Jammu.

Puinyabati H, Shomorendra M and Kar D 2013. Correlation of water's physicochemical characteristics and trematode parasites of *Channa punctata* (Bloch) in Awangsoi lake, Manipur, India. *Journal of Applied and Natural Science* **5**(1): 190-193.

PurivirojkulW and Sumontha M 2013. *Euclinostomum heterostomum* (Rudolphi, 1809) metacercarial infection in three osphronemid fish species. *Journal of Science education and Technology* **10**(1): 97-102.

Rudolphi CA 1809. *Entozoorum sive vermium intestinalium*. Historia naturalis. **1,** (Amsteold.).

Senapin S, Phiwasaiya K, Laosinchai P, Kowasupat C and Ruenwongsa P 2014. Phylogenetic analysis of parasitic trematodes of the genus *Euclinostomum* found in *Trichopsis* and Betta fish. *Journal of Parasitology* **100**: 368-371.

Shareef PAM and Abidi SMA 2015. Studies on the epidemiology and histopathology of *Euclinostomum heterostomum* (Trematoda: Digenea) infection in *Channa punctata* from North India. *Archieves of Polish Fisheries* **23**: 133-140.

Sharma KK, Kour S and Sharma K 2017. Seasonal variations in physicochemical parameters of Dilli pond Sainik Colony J & K. *International Journal of Applied Research* **3**(7): 686-691.

Shehata SM, Ramadan AM, Ghanem MH, Abdelhadi YM and Radwan MK 2018. Impact of the stresses environmental condition on the prevalence of parasite in freshwater aquaculture. *Journal of fisheries Sciences* **12**(2): 1-19.

Sudan OS 1979. *Studies on trematode fauna of Jammu province*. Ph.D. thesis submitted to the University of Jammu.

Tiwary CB and Thakur K 2012. Effect of pH upon copepoda and Cladocera under laboratory conditions. *Indian Journal of Ecology* **39**(1): 44-47.

Ukoli FMA 1966. On *Euclinostomum heterostomum* (Rudolphi, 1809). *Journal of Helminthology* **40**: 227-234.

Vankara A, Mani G and Vijaylakshmi C 2011. A report on various digenetic metacercariase from the freshwater fishes of river Godavari, Rajahmundry. *Journal of Parasitic Diseases* **35**(2): 177-185.

Yousuf AR and Irfan J 2018. Seasonal variations in physicochemical characteristics of Dal lake, Kashmir. *Indian Journal of Ecology* **45**(1): 33-43.

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Dynamics of a Fractional Stage Structured Predator-Prey model with Prey Refuge

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Abstract: In this paper, a stage structured fractional predator-prey model with a prey refuge is investigated in terms of existence and uniqueness, positivity and boundedness of the solutions. It is called satge structured because prey population is composition of matured and immatured prey. Sufficient conditions are derived for existence and stability of various points of equilibrium. Finally theoretical results are strengthen with the help of numerical results obtained by using Trapezoidal Based Homotopy Perturbation Method.

Keywords: Predator-prey model, prey refuge, Caputo fractional derivative, Trapezoidal Based Homotopy Perturbation Method, Lyapunov function.

Predator-prey model is an effective tool in mathematical ecology for the understanding of interacting populations and from the past few decades their applications in understanding the dynamics of interaction in various fields like business, finance, defence, criminology, epidemiology etc. are phenomenal (Hsieh and Hsiao 2008, Malleson and Evans 2014, Xu 2014). In the real world, we observe that the life span of most of the predators and preys may be distributed over two or more stages. So, many mathematical biologist have contributed towards the study of stage structured predator-prey models (W. Wang and Chen 1997, Cui et al 2000, Cui and Takeuchi 2006 and Zhang et al 2000). Like the other predator-prey models, stage structured models are also influenced by the factor like predator harvesting, prey refuge, disease in prey/predator, delay etc.(Gourley and Kuang 2004, Liu and Beretta 2006, You and Yuan, 2011, Zhang et al 2013, Xu 2014, Naji and Majeed 2016, Mortoja et al 2018).

In the study of predator-prey dynamics, prey refuge is used as an effective tool to prevent the prey population from extinction (González-Olivares and Ramos-Jiliberto 2003, Kar 2005, Huang et al 2006, Ma et al 2009, Ma 2010, Ma et al 2013, Tang et al 2014, Tripathi et al 2015 and Wei and Fu 2016). In a logistics predator-prey system, Ma et al (2013) has introduced the refuge term for the first time and investigated the model

$$\dot{x}(t) = rx(1-\frac{x}{k}) - c(1-m)xy$$
$$\dot{y}(t) = ec(1-m)xy - dy$$

where $x(t)$, $y(t)$ denote the density of prey and predator population respectively. In this model $mx, m \in [0,1)$ is the refuge term. Due to this, term only $(1-m)x$ of the prey population will be available for predation. In (Kar 2005), Kar studied the dynamical behavior of predator-prey system incorporating Holling type-II functional response and a prey refuge. In (Huang et al 2006), authors investigated the influence of prey refuge on a predator-prey model with Holling type-III functional response. (Tripathi et al 2015) examined the dynamical behavior of predator-prey system incorporating Beddington-DeAngelis type functional response and a prey refuge. When prey population is infected by some disease then prey refuge play a very important role in saving the population from extinction and this can be observed in the articles (Wang and Ma 2012 and Pal and Samanta 2013). On the other hand, fractional calculus is gaining new pace among the researchers due to its more realistic interpretation of physical phenomena. In case of fractional evolution equation, the function holds the information about the past memory and this is one of the necessary features one would look for while studying evolution equations. So, mathematical biologists have started investigating all forms of traditional order predator-prey models incorporating fractional derivatives (Aziz-Alaoui 2002, Ahmed et al 2007, Ahmed & Elgazzar 2007, Das & Gupta 2011, Rivero et al 2011, Javidi & Nyamoradi 2013, Rihan et al 2015, Vargas-De-León 2015, Elsadany & Matouk 2015, Hong et al 2017 and Baishya & Jaipala 2018).

In this paper, we have analyzed a fractional stage structured predator-prey model with prey refuge in terms of existence and uniqueness, boundedness and positivity of solutions. Existence of various equilibrium points and their stability are investigated in qualitative as well as quantitative manner. The theoretical results are validated with the help of Trapezoidal based Homotopy Perturbation Method (Diethelm et al 2002, Baishya & Jaipala 2018).

MATERIAL AND METHODS

Priliminaries: In this section, we present some preliminary results (Podlubny, 1999) from fractional calculus and those results are applied in the subsequent sections to validate various results.

Definition 1: The Riemann-Liouville fractional integral operator J^{α} of order $\alpha \geq 0$ of a function $f \in C_{\mu}, \mu \geq -1$ is defined as $J^{\alpha}f(t) = \frac{1}{\lambda(\alpha)}\int_0^t (t-\tau)^{(}\alpha-1)f(\tau)d\tau,\ \alpha > 0,$ $J^0 f(t) = f(t).$

Definition 2: Caputo fractional derivative of order α for a real valued function $f \in C^n[t_0, +\infty)$ is defined as

$$D^{\alpha}f(t) = \frac{1}{\lambda(n-\alpha)}\int_0^t \frac{f^{(n)}(x)}{(t-\tau)^{(\alpha-n+1)}}d\tau$$

where the fractional derivative of order α is such that

$n-1<\alpha<n$ of $f(t), t>0$.

In particular if $0<\alpha<1$ then,

$$D^{\alpha}f(t)=\frac{1}{\lambda(1-\alpha)}\int_0^t \frac{f^{'}(x)}{(t-\tau)^{\alpha}}d\tau$$

Lemma 1 (Li et al., 2010) Consider the system

$$D_t^{\alpha}x(t)=f(t,x), t>t_0 \qquad (1)$$

with the initial condition $x(t_0)$ *where* $0<\alpha\leq 1$ and $f:[t_0,\infty]\times\Omega\to R^n, \Omega\in R^n$. If f(t,x) satisfies the locally Lipchitz condition with respect to x, then there exists a unique solution of equation 1 on $[t_0,\infty)\times\Omega$.

Lemma 2 (Odibat & Shawagfeh, 2007)Let $0<\alpha\leq 1$. Soppose that $f(t)\in C[a,b]$ and $D_t^{\alpha}f(t)\in C[a,b]$. If $D_t^{\alpha}f(t)\geq 0\forall t\in(a,b)$, then $f(t)$ is nondecreasing function for each $t\in[a,b]$. If $D_t^{\alpha}f(t)\leq 0\forall t\in(a,b)$, then $f(t)$ is nonincreasing function for each $t\in[a,b]$.

Lemma 3 (Hong et al., 2017) Let $f(t)$ be a continuous function on $[t_0,+\infty)$ and satisfying

$$D_t^{\alpha}f(t)\leq -\lambda f(t)+\mu, f(t_0)=f_{t_0}$$

where $0<\alpha\leq 1$, $(\lambda,\mu)\in R^2$ and $\lambda\neq 0$ and $t_0\geq 0$ is the initial time. Then

$$f(t)\leq (f(t_0)-\frac{\mu}{\lambda})E_{\alpha}[\lambda(t-t_0)^{\alpha}]+\frac{\mu}{\lambda}$$

Lemma 4 (Vargas-De-León, 2015) Let $x(t)\in\mathbb{R}_+$ be a continuous and derivable function. Then for any time instant $t>t_0$,

$$D_t^{\alpha}[x(t)-x^*-x^*\ln\frac{x(t)}{x^*}]\leq(1-\frac{x^*}{x})D_t^{\alpha}x(t), \quad \alpha\in(0,1)$$

(x^*,y^*,z^*) is the point of equilibrium.

Model Formulation

In this modelling the following hypothesis are embraced:

1. The immatured prey grows exponentially completely depending on its parents i.e. matured prey with a growth rate r.
2. There is intraspecific competition between the individuals of mature as well as immature prey population.
3. The preys have the hiding facilities to protect themselves from the predators with a refuge rate $0<m<1$. Because of this only $(1-m)x$ prey population will be available for predation.
4. There is intraspecific competition between the individuals of predator population.
5. The nature of interaction between predators and preys is represented by Holling Type-I functional response.
6. Fractional order α of derivatives are of Caputo sense with $0<\alpha\leq 1$.

The proposed fractional mathematical model is as follows:

$$\begin{aligned}
&\frac{d^{\alpha}x}{dt^{\alpha}}=ry-c_1x^2-d_1x-bx-\lambda_1(1-m)xz\\
&\frac{d^{\alpha}y}{dt^{\alpha}}=bx-c_2y^2-d_2y-\lambda_2(1-m)yz\\
&\frac{D^{\alpha}z}{dt^{\alpha}}=e_1\lambda_1(1-m)xz+e_2\lambda_2(1-m)yz\\
&-c_3z^2-d_3z
\end{aligned} \qquad (2)$$

with initial condition$x(t_0)>0, y(t_0)>0, z(t_0)>0$ where t_0 is the initial time. All the parameters $r, c_1, d_1, b, \lambda_1, m, c_2, d_2, \lambda_2, e_1, e_2, c_3, d_3$ are all positive and there biological meaning is given in Table 1.

Table 1. Biological meaning of symblos

r	intrinsic growth rate of immature prey depending on parents
c_1	Intraspecific competition rate between immature prey population
d_1	natural death rate of immature prey population
b	grownup rate of immature prey population
λ_1	attack rate of predator to immature prey population
c_2	Intraspecific competition rate between mature prey population
d_2	natural death rate of mature prey population
λ_2	attack rate of predator to mature prey population
e_1	conversion factor of predator after consuming immature prey with $0<e_1<1$
e_2	conversion factor of predator after consuming mature prey with $0<e_2<1$
c_3	Intraspecific competition rate between predator population
d_3	natural death rate of predator population
M	prey refuge term

Existence and Uniqueness

In this section we have established that the solution of the system (2) exists and also unique.

Theorem 1: The solutions of the system (2) exist and is unique.

Proof. With the support of the lemma 1, we shall investigate the existence and uniqueness of solution of system (2).

Let $\xi=(x,y,z), \bar{\xi}=(\bar{x},\bar{y},\bar{z})\in\Omega$ be arbitrary.

Let,

$F(\xi)=ry-c_1x^2-d_1x-bx-\lambda_1(1-m)xz,$

$G(\xi)=bx-c_2y^2-d_2y-\lambda_2(1-m)yz$

And

$H(\xi)=e_1\lambda_1(1-m)xz+e_2\lambda_2(1-m)yz-c_3z^2-d_3z.$

Then it follows that

$$\begin{aligned}
&\left\|L(\xi)-L(\bar{\xi})\right\|\\
&=|F(\xi)-F(\bar{\xi})|+|G(\xi)-G(\bar{\xi})|\\
&+|H(\xi)-H(\bar{\xi})|\\
&=|ry-c_1x^2-d_1x-b_n-\lambda_1(1-m)xz\\
&-r\bar{y}+c_1\bar{x}^2+d_1\bar{x}+b\bar{x}-\lambda_1(1-m)\bar{x}\bar{z}|\\
&+|bx-c_2y^2-d_2y-\lambda_2(1-m)yz\\
&-b\bar{x}+c_2\bar{y}^2+d_2\bar{y}+\lambda_2(1-m)\bar{y}\bar{z})|\\
&+|e_1\lambda_1(1-m)xz+e_2\lambda_2(1-m)yz-\lambda_3z^2\\
&-d_3z-e_1\lambda_1(1-m)\bar{x}\bar{z}-e_2\lambda_2(1-m)\bar{y}\bar{z}\\
&+\lambda_3\bar{z}^2+d_3\bar{z}|\\
&=|r(y-\bar{y})-c_1(x^2-\bar{x}^2)-d_1(x-\bar{x})\\
&-b(x-\bar{x})-\lambda_1(1-m)(xz-\bar{x}\bar{z}|\\
&+|b(x-\bar{x})-c_2(y^2-\bar{y}^2)-d_2(y-\bar{y})
\end{aligned}$$

$-\lambda_2(1-m)(yz-\bar{y}\bar{z})$
$+|e\lambda_1(1-m)(xz-\bar{x}\bar{z})+e_2\lambda_2(1-m)(yz-\bar{y}\bar{z})$
$-\lambda_3(z^2-\bar{z}^2)-d_3(z-\bar{z})|$
If $\Omega=\{(x,y,z)\in R^3: max\{|x|,|y|,|z|\}$
$\leq M\}$ then
$\left|\left|L(\xi)-L(\bar{\xi})\right|\right|$
$\leq((2Mc_1+d_1+2b)+Mr_1(1-m)(1$
$+e_1))|x-\bar{x}|+(r+2Mc_2+d_2+r_2M(1$
$+e_2)(1-m))|y-\bar{y}|+(c_3+2Md_3+Mr_1(1$
$-m)(1+e_1)+Mr_2(1+e_2)(1-m))|z-\bar{z}|$
Let
$\sigma=max\{2Mc_1+d_1+2b+Mr_1(1-m)(1$
$+e_1),r+2Mc_2+d_2+Mr_2(1-m)(1+e_2),$
$c_3+2Md_3+Mr_1(1-m)(1+e_1)+Mr_2(1$
$+e_2)(1-m)\}$
$\therefore ||L(\xi)-L(\bar{\xi})||\leq\sigma||\xi-\bar{\xi}||$
As $L(\alpha)$ satisfies Lipschitz condition, the solution (x,y,z) of the system (2) is unique.

Positivity

In the biological system it is essential to ensure that all the solutions are non-negative. Let $\Omega_+=\{x,y,z)\in\Omega: x,y,z\in R_+\}$ where R_+ represents set of non-negative real numbers. First let us show that $x(t)\geq 0 \quad all\ t\in[t_0,T]$ If possible, let us assume that there exist t_2 such that $x(t_2)<0, y(t)\geq 0, z(t)\geq 0$
Now $x(t_0)>0, x(t_2)<0$ implies that there exists some $t_1\in(t_0,T]$ such that $x(t_1)=0$, but $y(t_1)\geq 0, z(t_1)\geq 0$
From the first equation of system (2) , we have
$$D_t^\alpha x(t_1)=ry(t_1)\geq 0$$
From the Lemma 2 it implies that $x(t_2)=0$ which contradicts the assumption that
$$x(t_2)<0$$
$\therefore x(t)\geq 0\ \forall\ t\in[t_0,T]$ Similarly, we can show that $y(t)\geq 0, z(t)\geq 0 \quad \forall\ t\in[t_0,T]$.

Boundedness

Theorem 2: The solution of the system (2) is uniformly bounded in the region

$$\lambda=\{(x,y,z)\in\Omega_+: x+y+z\leq\frac{(\mu-d_1)^2}{4c_1\mu}+\epsilon,\epsilon>0\}$$

Proof. Let us define a function
$$W(t)=x(t)+y(t)+z(t)$$
$D_t^\alpha W(t)+\mu W(t)$
$=ry-c_1x^2-d_1x-bx-\lambda_1(1-m)xz$
$+bx-c_2y^2-d_2y-\lambda_2(1-m)yz$
$+e_1\lambda_1(1-m)xz+e_2\lambda_2(1-m)yz-c_3z^2$
$-d_3z+\mu(x+y+z)$
$\leq ry-c_1x^2+e_1\lambda_1(1-m)xz+e_2\lambda_2(1$
$-m)yz-d_1x-d_2y-d_3z+\mu(x+y+z)$
$-\lambda_1(1-m)xz-\lambda_2(1-m)yz$
$=(\mu-d_1-c_1x)x+(\mu-d_2+r)y$
$+(\mu-d_3)z-(1-e_1)\lambda_1(1-m)xz-(1$
$-e_2)\lambda_2(1-m)yz$
$<(\mu-d_1-c_1x)x+(\mu-d_2+r)y$
$+(\mu-d_3)z$
If $g(x)=(\mu-d_1-c_1x)x$ then
$g'(x)=(\mu-d_1-c_1x)+x(-c_1)$.
As $g''(x)=-2c_1<0$ therefore $g(x)$ is maximum at $x=\frac{\mu-d_1}{2c_1}$.
So,
$D_t^\alpha W(t)+\mu W(t)$
$\leq(\mu-d_1-c_1(\frac{\mu-d_1}{2c_1}))(\frac{\mu-d_1}{2c_1})-(d_2-r$
$-\mu)y-(d_3-\mu)z$
If $\mu<min\{d_2-r,d_3\}$,
Then $D_t^\alpha W(t)+\mu W(t)\leq\left(\frac{\mu-d_1}{2}\right)\left(\frac{\mu-d_1}{2c_1}\right)$
$=(\frac{(\mu-d_1)^2}{4c_1})$
or $D_t^\alpha W(t)+\mu W(t)\leq\psi, \psi=(\frac{(\mu-d_1)^2}{4c_1})$
By Lemma 3
$W(t)\leq(W(t_0)-\frac{\psi}{\mu})E_\alpha[-\mu(t-t_0)^\alpha]$
$+\frac{\psi}{\mu}W(t)$
$\leq(W(t_0)-\frac{(\mu-d_1)^2}{4c_1\mu}]E_\alpha[-\mu(t-t_0)^\alpha]$
$+\frac{(\mu-d_1)^2}{4c_1\mu}\rightarrow\frac{(\mu-d_1)^2}{4c_1\mu}\ as\ t\rightarrow\infty$
$\therefore$ The solution of the system is uniformly bounded in the region.
$$\lambda=\{(x,y,z)\in\Omega_+: x+y+z\leq\frac{(\mu-d_1)^2}{4c_1\mu}+\epsilon,\epsilon>0\}$$

RESULT AND DISCUSSION

Existence of Points of Equiliblium

This section deals with the sufficient conditions for the existence of various points of equlibrium. The system 1 has at most three biologically feasible equilibrium points viz. $E_i, i=0,1,2$.

1. Trivial $E_0=(0,0,0)$ always exists.
2. Predator extinct equilibrium point is $E_1=(\bar{x},\bar{y},0)$.

Here $\bar{x}=\frac{c_2\bar{y}^2+d_2\bar{y}}{b}$ and $\bar{y}$ is the positive root od the equation
$$A\bar{y}^3+B\bar{y}^2+C\bar{y}+D=0$$
where $A=c_1c_2^2,\quad B=2d_2c_1c_2,$
$C=bd_1c_2+d_2^2c_1+b^2c_2,$
$D=b^2d_2+bd_1d_2-rb^2.$
So there exists unique positive root only if $d_1d_2<b(r-d_2)$
3. Coexitence equilibrium point is (x^*,y^*,z^*).

Here, $x^*=-\frac{y(\lambda_2d_3(m-1)+c_3(d_2+c_2y)+\lambda_2^2e_2(m-1)^2y)}{\lambda_1\lambda_2e_1(m-1)^2y-bc_3}$
$$z^*=\frac{bd_3+(m-1)y(\lambda_1d_2e_1+b\lambda_2e_2+\lambda_1c_2e_1y)}{\lambda_1\lambda_2e_1(m-1)^2y-bc_3}$$
and y^* is a positive root of the equation $A_1(y^*)^3+A_2(y^*)^2+A_3y^*+A_4=0$
where,
$A_1=(c_2c_3+\lambda_2^2e_2(m-1)^2)(\lambda_2^2c_1e_2(m-1)^2$
$+c_2(c_1c_3+\lambda_1^2e_1(m-1)^2))$

$A_2 = \lambda_1\, e_1\, (m-1)\text{^}2\, (\lambda_1\, d_2\, (2c_2\, c_3 + \lambda_2\text{^}2\, e_2\, (m - 1)\text{^}2) - \lambda_2\, (\lambda_2\text{^}2\, e_2\, (m-1)\text{^}2\, (b + d_1) + c_2\, (c_3\, (b + d_1) - \lambda_1\, d_3\, (m-1)))) + (c_2\, c_3 + \lambda_2\text{^}2\, e_2\, (m-1)\text{^}2)(2c_1\, (d_2\, c_3 + \lambda_2\, d_3\, (m-1)) + b\lambda_1\lambda_2 e_2 (m-1)^2) - \lambda_1^2\lambda_2^2 e_1^2 (m-1)^4 r$

$A_3 = \lambda_2 d_2 (m-1)(d_3(2c_1c_3 + \lambda_1^2 e_1(m-1)^2) - \lambda_1 c_3 (m-1)(e_1(b+d_1) - be_2)) - \lambda_1 d_3 (m-1)(\lambda_2^2 e_1 (m-1)^2 (b+d_1) - b(c_2c_3 + 2\lambda_2^2 e_2 (m-1)^2)) + c_3 d_2^2 (c_1c_3 + \lambda_1^2 e_1 (m-1)^2) + bc_3((b+d_1)(c_2c_3 + \lambda_2^2 e_2 (m-1)^2) + 2\lambda_1\lambda_2 e_1 (m-1)^2 r) + \lambda_2^2 d_3^2 c_1 (m-1)^2$

$A_4 = b(c_3 d_3 (m-1)(\lambda_2(b+d_1) + \lambda_1 d_2) + \lambda_1\lambda_2 d_3^2 (m-1)^2 + c_3^2 (d_2(b+d_1) - br))$

Interior equilibrium point exists if $A_4 < 0$ with ($A_2 > 0$ or $A_3 < 0$)

and $m < 1 - \frac{bd_3}{y(\lambda_1 d_2 e_1 + b\lambda_2 e_2 + \lambda_1 c_2 e_1 y)}$ and $m > 1 - \sqrt{\frac{bc_3}{\lambda_1\lambda_2 e_1 y}}$

or

$A_4 < 0$ with ($A_2 > 0$ or $A_3 < 0$) and $m > 1 - \frac{bd_3}{y(\lambda_1 d_2 e_1 + b\lambda_2 e_2 + \lambda_1 c_2 e_1 y)}$ and $m < 1 - \sqrt{\frac{bc_3}{\lambda_1\lambda_2 e_1 y}}$.

Local Stability of Points of Equiliblium

Theorem 4: Trivial equilibrium point E_0 is unstable only if $bd_2 + d_1 d_2 < rb$

Proof. Eigen value of the Jacobian matrix at E_0 are $\lambda_1 = -d_3$,

$\lambda_2 = \frac{1}{2}(-b - d_1 - d_2 - \sqrt{(b+d_1+d_2)^2 - 4(bd_2 + d_1 d_2 - br)})$,

$\lambda_3 = \frac{1}{2}(-b - d_1 - d_2 + \sqrt{(b+d_1+d_2)^2 - 4(bd_2 + d_1 d_2 - br)})$. $|arg(\lambda_1)| = \pi > \frac{\alpha\pi}{2}$, for $0 < \alpha \leq 1$. If $bd_2 + d_1 d_2 < rb$ then $|arg(\lambda_2)| = \pi > \frac{\alpha\pi}{2}$ and $|arg(\lambda_3)| = 0 < \frac{\alpha\pi}{2}$. Therefore, trivial equilibrium point if unstable only if $bd_2 + d_1 d_2 < rb$.

Theorem 5: Predator extinct equilibrium point is stable if

$m > 1 - \frac{d_3}{(\lambda_1 e_1 x^* + \lambda_2 e_2 y^*)}$ and

$(d_2 + 2c_2 y^*)(b + d_1 + 2c_1 x^*) > br$

Proof. Eigen value at E_1 are

$\lambda_1 = -d_3 + \lambda_1 e_1 (1-m) x^* + \lambda_2 e_2 (1-m) y^*$,

$\lambda_2 = \frac{1}{2}(-b - d_1 - d_2 - 2c_1 x^* - 2c_2 y^* - P)$,

$\lambda_3 = \frac{1}{2}(-b - d_1 - d_2 - 2c_1 x^* - 2c_2 y^* + P)$

$P = \sqrt{(b+d_1+d_2+2c_1x^*+2c_2y^*)^2 - 4\begin{pmatrix} bd_2+2d_2c_1x^*+2d_1c_2y^*+d_1 \\ d_2+b(-r)+4c_1c_2x^*y^*+2bc_2y^* \end{pmatrix}}$

If $m > 1 - \frac{d_3}{(\lambda_1 e_1 x^* + \lambda_2 e_2 y^*)}$ and $(d_2 + 2c_2 y^*)(b + d_1 + 2c_1 x^*) > br$ then $|arg(\lambda_1)| = \pi$ and $|arg(\lambda_3)| = \pi$ and these are the condition for stability of predator extinct equilbrium.

Global Stability of fixed points

Theorem 6: The coexistence equilibrium point is globally stable if the conditions

(i) $c_1 e_1 > \frac{re_1}{x}(\frac{1}{2} - \frac{y^*}{x^*}) + \frac{be_2}{2y}$

and (ii) $c_2 e_2 > \frac{re_1}{2x} + \frac{be_2}{y}(\frac{1}{2} - \frac{x^*}{y^*})$ are satisfied.

Proof. Let us consider the positive definite function

$$V(t) = e_1 x_1(t) + e_2 y_1(t) + z_1(t)$$

Where $x_1(t) = x - x^* - x^* ln\frac{x}{x^*}$,

$y_1(t) = y - y^* - y^* ln\frac{y}{y^*}$,

$z_1(t) = z - z^* - z^* ln\frac{z}{z^*}$.

Then,

$D_t^\alpha V(t) \leq e_1\left(1 - \frac{x^*}{x}\right) D_t^\alpha x + e_2\left(1 - \frac{y^*}{y}\right) D_t^\alpha y + (1 - \frac{z^*}{z}) D_t^\alpha z$

$= e_1(\frac{x-x^*}{x})[ry - c_1x^2 - d_1x - bx - \lambda_1(1-m)xz] + e_2(\frac{y-y^*}{y})[bx - c_2y^2 - d_2y - \lambda_2(1-m)yz] + (\frac{z-z^*}{z})[e_1\lambda_1(1-m)xz + e_2\lambda_2(1-m)yz - c_3z^2 - d_3z]$

$= e_1(x-x^*)[\frac{\lambda y}{x} - c_1x - d_1 - b - \lambda_1(1-m)z] + e_2(y-y^*)[\frac{bx}{y} - c_2y - d_2 - \lambda_2(1-m)z] + z$

From system 2, first, second and third equation respectively yield

$d_1 + b = -(c_1x^* + \lambda_1(1-m)z^*) + \frac{ry^*}{x^*}$, $d_2 = \frac{bx^*}{y^*} - c_2y^* - d_2 - \lambda_2(1-m)z^*$

$d_3 = c_3z^* - e_1\lambda_1(1-m)x^* - e_2\lambda_2(1-m)y^*$

Simple computation gives,

$\frac{d^\alpha V}{dt^\alpha} \leq e_1(x-x^*)(\frac{ry}{x} - c_1x - \lambda_1(1-m)z + c_1x^* + \lambda_1(1-m)z^* - \frac{ry^*}{x^*}) + e_2(y - y^*)(\frac{bx}{y} - c_2y\lambda_2(1-m)z + c_2y^* + \lambda_2(1-m)z^* - \frac{bx^*}{y^*}) + (z-z^*)(e_1\lambda_1(1-m)x + e_2\lambda_2(1-m)y - c_3z + c_3z^* - e_1\lambda_1(1-m)x^* - e_2\lambda_2(1-m)y^*)$

$= e_1(x-x^*)(-c_1(x-x^*) - \lambda_1(1-m)(z-z^*) + r\left(\frac{y}{x} - \frac{y^*}{x^*}\right)) + e_2(y-y^*)(-c_2(y-y^*) - \lambda_2(1-m)(z-z^*) + b(\frac{x}{y} - \frac{x^*}{y^*} + (z-z^*)[e_1\lambda_1(1-m)(x-x^*) + e_2\lambda_2(1-m)(y-y^*) - c_3(z-z^*)]$

$= -c_1e_1(x-x^*)^2 - c_2e_2(y-y^*)^2 - c_3(z-z^*)^2 + (x-x^*)re_1\frac{yx^* - xy^*}{xx^*} + (y-y^*)be_2\frac{xy^* - yx^*}{yy^*}$

$$\leq -(c_1e_1 - \frac{re_1}{2x} + \frac{re_1y^*}{xx^*} - \frac{be_2}{2y})(x - x^*)^2$$
$$-(c_2e_2 - \frac{re_1}{2x} + \frac{be_2x^*}{yy^*} - \frac{be_2}{2y})(y - y^*)^2$$
$$-c_3(z - z^*)^2$$

Therefore, global stability demands

$$c_1e_1 > \frac{re_1}{x}(\frac{1}{2} - \frac{y^*}{x^*}) + \frac{be_2}{2y}$$

and $c_2e_2 > \frac{re_1}{2x} + \frac{be_2}{y}(\frac{1}{2} - \frac{x^*}{y^*})$

Numerical Analysis

In this section model 2 is integrated numerically by using Trapezoidal Based Homotopy Perturbation method for various sets of parameter values.

1. **Trivial Equilibrium:** The parameters values are given as:$r = 2; c_1 = 0.1; d_1 = 0.4;$ $b = 0.4; \lambda_1 = 0.5; c_2 = 0.1; d_2 = 0.5; \lambda_2 = 0.2; e_1 = 0.2; m = 0.7; e_2 = 0.4; c_3 = 0.1; d_3 = 0.3$. The condition $bd_2 + d_1d_2 + b(-r) = -0.4 < 0$ is satisfied. At the point E_0 eigenvalues of the Jacobian matrix are $\{-1.55692, -0.3, 0.256918\}$. This shows that the equilibrium point $E_0(0,0,0)$ is a unstable.

For parameter values $r = 1; c_1 = 0.1; d_1 = 0.5; b = 0.3; \lambda_1 = 0.5; c_2 = 0.1; d_2 = 0.6; \lambda_2 = 0.2; e_1 = 0.2; m = 0.7; e_2 = 0.4; c_3 = 0.1; d_3 = 0.3$ the eigen value is $-1.25678, -0.3, -0.143224$ because for these values $bd_2 + d_1d_2 + b(-r) = 0.18 > 0$. We consider the initial cpopulation as $x_0 = 1, y_0 = 2, z_0 = 2$. The convergence of the solutions to the point of equilibrium $E_0(0,0,0)$ is shown in Figure 1 for different values of α.

2. **Predator Extinct Equilibrium:** Parameters values are taken as $r = 4; c_1 = 0.1; d_1 = 0.5; b = 0.3; \lambda_1 = 0.5; c_2 = 0.1; d_2 = 0.6; \lambda_2 = 0.2; e_1 = 0.2; m = 0.7; e_2 = 0.4; c_3 = 0.1; d_3 = 0.3$. For these values the condition $(bd_2 + d_1d_2 + b(-r) = -0.72 < 0$. So there exists unique predator extinct equiliblun point $E_1(6.42671, 2.31791, 0)$. At this point of equilibrium $-d_3 + \lambda_1e_1(1 - m)x^* + \lambda_2e_2(1 - m)y^* = -2.78318 < 0$ and $(d_2 + 2c_2y^*)(b + d_1 + 2c_1x^*) - br = 1.01793 > 0$. Eigenvalues of Jacobian matrix at point of Equilibrium E_1 are $\lambda_1 = -2.78318, \lambda_2 = -0.365744, \lambda_3 = -0.0515689$.Therefore $|\arg(\lambda_1)| = |\arg(\lambda_2)| = |\arg(\lambda_3)| = \pi > \alpha\pi/2$ for $0 < \alpha \leq 1$. The E_1 is a stable focus as shown in Figure 1.

3. **Interior Equilibrium:** For parameter values $r = 4; c_1 = 0.05; d_1 = 0.5; b = 1; \lambda_1 = 0.5; c_2 = 0.1; d_2 = 0.6; \lambda_2 = 0.2; e_1 = 0.2; m = 0.7; e_2 = 0.4; c_3 = 0.1; d_3 = 0.7$, $A_1 = 0.0000116917$, $A_2 = 0.000056916 > 0$, $A_4 = -0.03919 < 0$. Also $m < 1 - \frac{bd_3}{y(\lambda_1d_2e_1 + b\lambda_2e_2 + \lambda_1c_2e_1y)} = 0.716968$ and $m > 1 - \sqrt{\frac{bc_3}{\lambda_1\lambda_2e_1y}} = 0.30034$. Therefore interior equilibrium point $E_2(16.8761, 10.214, 0.514201)$ exists. At this point of equilibrium, conditions for global stability are satisfied. Figure 3 and 4 show the stability profile of the point of equilibrium.

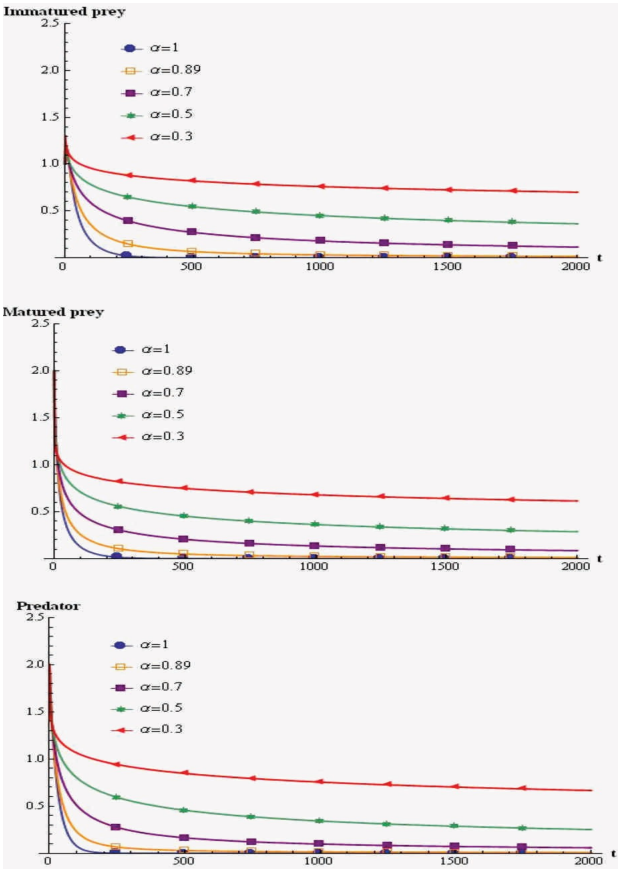

Fig. 1. Stability of trivial equilibrium for different values of α

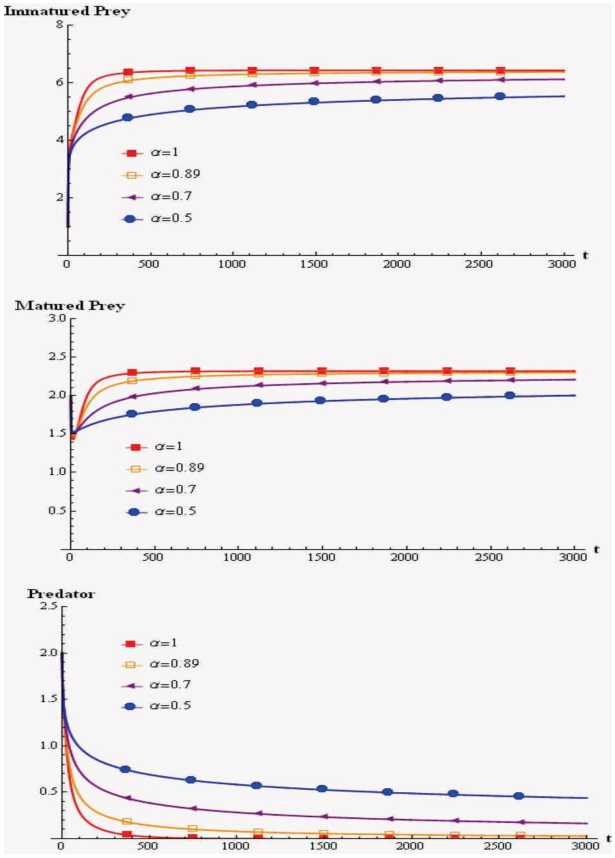

Fig. 2. Stability of predator extinct equilibrium for different values of α

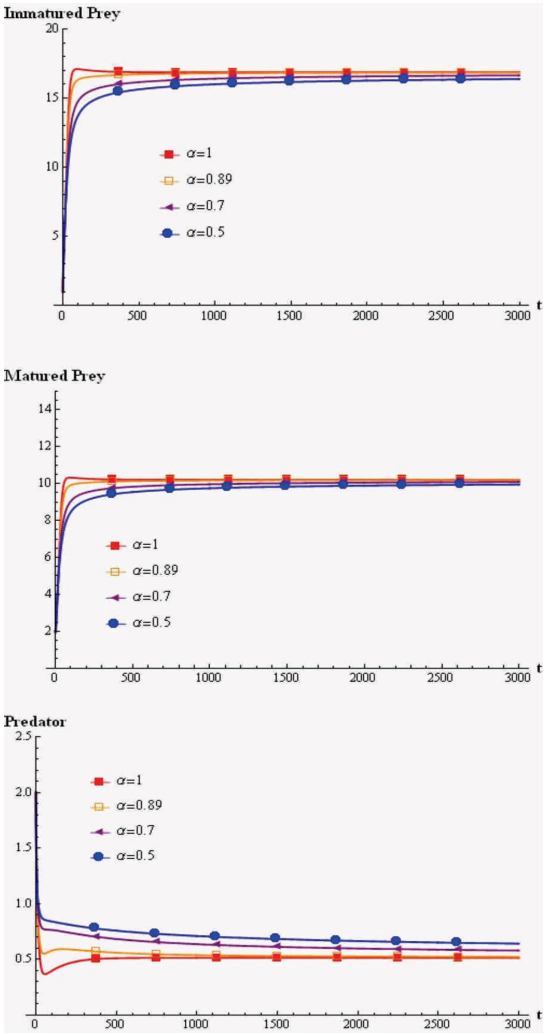

Fig. 3. Stability of coexistence equilibrium for different values of α

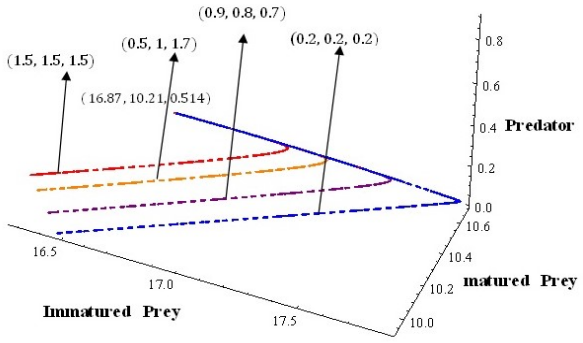

Fig. 4. Global Stability of coexistence equilibrium for different initial conditions

CONCLUSION

In this paper, we have analyzed the dynamics of a stage structured fractional predator-prey model incorporating prey refuge. We establish the existence and uniqueness, positivity and uniform boundedness of the solutions. Sufficient conditions for existence of points of equilibrium, their local and global stability are discussed. It is observed that prey refuge has remarkable influence in existence of coexistence equilibrium and stability of predator extinct equilibrium. Numerical analysis shown in this paper completely support the analytical results. It is seen that speed of convergence of the flow towards the point of equilibrium depends on the order of fractional derivatives. Speed of convergence increases as order of fractional derivative α increases $(0 < \alpha \leq 1)$.

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REFERENCES

Ahmed E and Elgazzar AS 2007. On fractional order differential equations model for nonlocal epidemics. *Physica A: Statistical Mechanics and Its Applications* **379**(2): 607-614.

Ahmed E, El-Sayed AMA and El-Saka HAA 2007. Equilibrium points, stability and numerical solutions of fractional-order predator–prey and rabies models. *Journal of Mathematical Analysis and Application* **325**(1): 542-553.

Aziz-Alaoui MA 2002. Study of a Leslie–Gower-type tritrophic population model. *Chaos, Solitons & Fractals* **14**(8): 1275–1293.

Baishya C and Jaipala 2018. Numerical solution of fractional predator-prey model by trapezoidal based homotopy perturbation method. *International Journal of Mathematical Archive* **9**(3): 2229-5046.

Cui Jingan, Chen L and Wang W 2000. The effect of dispersal on population growth with stage-structure. *Computers & Mathematics with Applications* **39**(1): 91-102.

Cui Jingan and Takeuchi Y 2006. A predator–prey system with a stage structure for the prey. *Mathematical and Computer Modelling* **44**(11): 1126–1132.

Das S and Gupta PK 2011. A mathematical model on fractional Lotka–Volterra equations. *Journal of Theoretical Biology* **277**(1): 1–6.

Diethelm K, Ford NJ and Freed AD 2002. A Predictor-Corrector Approach for the Numerical Solution of Fractional Differential Equations. *Nonlinear Dynamics* **29**(1): 3–22.

Elsadany AA and Matouk AE 2015. Dynamical behaviors of fractional-order Lotka–Volterra predator–prey model and its discretization. *Journal of Applied Mathematics and Computing* **49**(1): 269-283.

González-Olivares E and Ramos-Jiliberto R 2003. Dynamic consequences of prey refuges in a simple model system: More prey, fewer predators and enhanced stability. *Ecological Modelling* **166**(1): 135-146

Gourley SA and Kuang Y 2004. A stage structured predator-prey model and its dependence on maturation delay and death rate. *Journal of Mathematical Biology* **49**(2): 188-200.

Hong-Li Li, Zhang L, Hu C, Jiang Y-L and Teng Z 2017. Dynamical analysis of a fractional-order predator-prey model incorporating a prey refuge. *Journal of Applied Mathematics and Computing* **54**(1): 435-449.

Hsieh Y-H and Hsiao C-K 2008. Predator–prey model with disease infection in both populations. *Mathematical Medicine and Biology: A Journal of the IMA* **25**(3): 247-266.

Huang Y, Chen F and Zhong L 2006. Stability analysis of a prey–predator model with holling type III response function incorporating a prey refuge. *Applied Mathematics and Computation* **182**(1): 672-683

Javidi M and Nyamoradi N 2013. Dynamic analysis of a fractional order prey–predator interaction with harvesting. *Applied Mathematical Modelling* **37**(20): 8946-8956.

Kar TK 2005. Stability analysis of a prey-predator model incorporating a prey refuge. *Communications in Nonlinear Science and Numerical Simulations* **10**: 681-691.

Li Y, Chen Y and Podlubny I 2010. Stability of fractional-order nonlinear dynamic systems: Lyapunov direct method and generalized Mittag–Leffler stability. *Computers & Mathematics with Applications* **59**(5): 1810-1821.

Liu S and Beretta E 2006. A Stage-Structured Predator-Prey Model of Beddington-DeAngelis Type. *SIAM Journal on Applied Mathematics* **66**(4): 1101-1129.

Ma Z 2010. *The research of predator-prey models incorporating prey refuges.* Ph.D. Thesis, Lanzhou University.

Ma Z, Chen F, Wu C and Chen W 2013. Dynamic behaviors of a Lotka-Volterra predator-prey model incorporating a prey refuge and predator mutual interference. *Applied Mathematica and Computation***219***:* 7945–7953.

Ma Z, Li W, Zhao Y, Wang W, Zhang H and Li Z 2009. Effects of prey refuges on a predator-prey model with a class of functional responses: The role of refuges. *Mathematical Biosciences* **218**(2): 73-79.

Malleson N and Evans A 2014. Agent-Based Models to Predict Crime at Places. *Encyclopedia of Criminology and Criminal Justice* **2014**: 41-48.

Mortoja SG, Panja P and Mondal SK 2018. Dynamics of a predator-prey model with stage-structure on both species and anti-predator behavior. *Informatics in Medicine Unlocked* **10**: 50-57.

Naji RK and Majeed SJ 2016. *The Dynamical Analysis of a Prey-Predator Model with a Refuge-Stage Structure Prey Population*. International Journal of Differential Equations. Article ID 2010464

Odibat ZM and Shawagfeh NT 2007. Generalized Taylor's formula. *Applied Mathematics and Computation* **186**(1): 286–293.

Pa AK and Samanta GP 2013. A Ratio-dependent Eco-epidemiological Model Incorporating a Prey Refuge. *Universal Journal of Applied Mathematics* **1**(2): 86-100.

Podlubny I 1999. *Fractional Differential Equations*, Vol.198, Academic Press, USA.

Rihan FA, Lakshmanan S, Hashish AH, Rakkiyappan R and Ahmed E 2015. Fractional-order delayed predator–prey systems with Holling type-II functional response. *Nonlinear Dynamics* **80**(1): 777–789.

Rivero M, Trujillo JJ, Vázquez L and Velasco MP 2011. Fractional dynamics of populations. *Applied Mathematics and Computation* **218**(3): 1089–1095.

Tang G, Tang S and Cheke RA 2014. Global analysis of a Holling type II predator–prey model with a constant prey refuge. *Nonlinear Dynamics* **76**(1): 635–647.

Tripathi J P, Abbas S and Thakur M 2015. A density dependent delayed predator-prey model with Beddington-DeAngelis type function response incorporating a prey refuge. *Communications in Nonlinear Science and Numerical Simulations***22**: 427–450.

Tripathi JP, Tyagi S and Abbas S 2018. Dynamical analysis of a predator-prey interaction model with time delay and prey refuge. *Nonautonomous Dynamical Systems***5**(1): 138–151.

Vargas-De-León C 2015. Volterra-type Lyapunov functions for fractional-order epidemic systems. *Communications in Nonlinear Science and Numerical Simulations* **24**: 75–85.

Wang S and Ma Z 2012. Analysis of an Ecoepidemiological Model with Prey Refuges. *Journal of Applied Mathematics* **2012**: 1–16.

Wang W and Chen L 1997. A predator-prey system with stage-structure for predator. *Computers & Mathematics with Applications***33**(8): 83–91.

Wei F and Fu Q 2016. Hopf bifurcation and stability for predator–prey systems with Beddington–DeAngelis type functional response and stage structure for prey incorporating refuge. *Applied Mathematical Modelling* **40**(1): 126–134.

Xu R and Zhang S H 2013. Modelling and analysis of a delayed predator-prey model with disease in the predator. *Applied Mathematics and Computation* **224**: 372–386.

Xu S 2014. Dynamics of a general prey–predator model with prey-stage structure and diffusive effects. *Computers & Mathematics with Applications* **68**(3): 405–423.

You H and Yuan R 2011. A stage-structured predator-prey model with two delays due to juvenile maturation. *Acta Mathematicae Applicatae Sinica, English Series*.

Zhang X, Chen L and Neumann A U 2000. The stage-structured predator–prey model and optimal harvesting policy. *Mathematical Biosciences* **168**(2): 201–210.

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Production Potential of Soybean Based Cropping Sequence under Resource Conservation Technologies

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Abstract: The field investigation was undertaken during *kharif* and *rabi* season of 2014-15 and 2015-16 at VNMKV, Parbhani to study effect of tillage and nutrient levels on soybean based cropping sequence. Treatment consists of twelve treatment combinations comprising two tillage practices (minimum tillage, conventional tillage) and two cropping systems (soybean-*rabi* sorghum, soybean-wheat) in main plot, three levels of nutrients (75, 100 and 125 per cent RDF) in sub plot for soybean in *kharif* and after that for *rabi* sorghum and wheat in *rabi* season were assigned in a split-split plot design. Practice of conventional tillage with 125 RDF applications to soybean, *rabi* sorghum and wheat improved the yields, soybean equivalent yield, production efficiency of soybean based cropping system. Soybean-wheat cropping systems augmented the soybean equivalent yield and production efficiency of soybean based cropping system while land use efficiency was higher in soybean-*rabi* sorghum cropping systems.

Keywords: Conventional tillage, Minimum tillage, Nutrient levels, Rabi sorghum, Soybean, Wheat

Soybean-wheat and soybean-*rabi* sorghum are the most dominant cropping systems on the Vertisols of Central India. Cultivation of soybean in rainy season (June to October) has witnessed a phenomenal growth in the last two decades in the region while wheat or *rabi* sorghum in winter season (November to April) has a considerable potential due to congenial climate. Besides including a legume (soybean) in sequence with a cereal crop (wheat or *rabi* sorghum) may prove beneficial for long term productivity and sustainability of the system. Rotation of soybean and wheat is practiced on 4.5 million ha on the Vertisols of Central India but the mean yields are only 0.9 t and 1.7 t ha^{-1}, respectively due to limited knowledge of resource conservation technologies. Adoption of the RCT's offers newer opportunities of better livelihood for the resource poor small and marginal farmers. At the same time, these technologies are generating alternative sources of productivity growth through diversification and intensification of production systems. The combination of RCT working in synergy is commonly referred as conservation agriculture. Presently there is a need to develop more efficient resource conservation technologies to sustain productivity of different crops and cropping systems without diminishing soil environment while resource conservation practices is a must for higher crop productivity.

The resource conservation technologies primarily focus on resource savings through minimal tillage, ensuring soil nutrients and moisture conservation through crop residues and growth of cover crops adoption of spatial and temporal crop sequencing and practiced on more than 80 million ha. Introduction of RCT was an important breakthrough for sustaining productivity, natural resource base and economic growth of the farmers. Issues of conservation have assumed importance in view of widespread resource degradation problems and the need to reduce production costs, increase profitability and make agriculture more competitive. Introduction of RCT in soybean based cropping system was an important breakthrough for sustaining productivity, natural resource base and economic growth of the farmers. These pro-sustainable technologies and the practices therein have been long practiced by the farmers in the Indo- Gangetic Plains but got eroded in recent times. With squeezing net returns and increasing threats of sustainability, the viability of rice-wheat farming is looming large. These issues are being discussed and concerns are being raised by the planners and policy makers. Considerable efforts are being made to popularize and increase the adoption of RCTs in the region. In the absence of specific information however, the policies and efforts are inadequate and ineffective to achieve the desired results in this direction. It is therefore, imperative now to promote alternative technologies that would help conserve the much needed but gradually depleting natural resources while boosting productivity growth in the long-run by maintaining soil health and production environment. As a part of this strategy, resource conserving technologies play a major role in sustaining and enhancing the productivity of soybean based cropping system. Keeping this view this project was designed to identify a feasible and economically viable soybean based cropping system under RCTs that

could benefit the farmers as well as researchers in this locality. Therefore keeping these facts in view, the present studies were planned to investigate the idea about soybean based cropping system for the area.

MATERIAL AND METHODS

The experiments were conducted at Vasantrao Naik Marathwada Krishi Vidyapeeth, Parbhani (MS), during *kharif* and *rabi* season of 2014-15 and 2015-16. The topography of the experimental field was fairly uniform and levelled. The soil was clayey in texture and slightly alkaline in reaction having low in organic carbon, available nitrogen and phosphorus, but marginally high in available potassium. The climate of Parbhani is semi-arid and characterized by three distinct seasons *viz.,* summer being hot and dry during March to May, warm and humid monsoon in June to October and winter with mild cold from November to February. Most of the rainfall received from south-west monsoon during June to October with mean annual normal precipitation of 964 mm received in 66.84 rainy days. Treatment consists of twelve treatment combinations comprising two tillage practices minimum tillage (*kharif*- 1 moghda + 1 harrowing, *rabi*- 2 harrowing) conventional tillage (*kharif*- 1 ploughing + 1 moghda + 1 harrowing, *rabi*-1 moghda + 2 harrowing) and two soybean-based cropping systems (soybean-*rabi* sorghum, soybean-wheat) in main plot, three nutrient levels (125,100,75 per cent RDF) in sub plot for soybean in *kharif* season and *rabi* sorghum, wheat in *rabi* season. The treatments were assigned in a split-split plot design with three replications.

Certified seed for each crop under experimentation was used. Sowing was undertaken after receipt of sufficient rains during *kharif* season by drilling method. The distance between two rows was kept 45 cm while intra row distance was 5 cm for soybean crop in *kharif*. The seed rate used for soybean c.v. MAUS-71 was 62.5 kg ha^{-1}. During *rabi* season the seed rate used for *rabi* sorghum c.v. SPV-1595 10 kg ha^{-1}. The distance in between two rows was 45 cm and in between two plants was 15 cm and in case of wheat the seed rate used wheat c.v. NAIW-301 100 kg ha^{-1}. The distance in between two rows was 22.5 cm. The recommended dose of fertilizer (RDF) used for soybean was 30: 60: 30 kg N, P_2O_5 and K_2O ha^{-1} respectively. Full dose of N, P_2O_5 and K_2O was applied at the time of sowing as basal dose to soybean crop. In *rabi* season also the *rabi* sorghum and wheat crop received fertilizer dose as per the treatments. The recommended dose of fertilizer for the *rabi* sorghum was 80:40:40 kg N, P_2O_5 and K_2O ha^{-1} and for wheat crop 100:50:50 kg N, P_2O_5 and K_2O ha^{-1} respectively. Half dose of N and full dose of P_2O_5 and K_2O was applied at the time of sowing and remaining half dose of N was applied at 45 days after sowing for both crops. The source of nutrients was urea, single super phosphate and murate of potash and ferrous sulphate.

Soybean is grown as *rainfed* crop therefore it does not require any irrigation but in case of dry spell one or two life saving irrigation were given as protective irrigation. In *rabi* season three irrigations were given to *rabi* sorghum at vegetative growth, flowering and grain filling stage and five irrigation was given to wheat at CRI, tillering, late jointing stage, flowering and dough stage as per the necessity during the total period of investigation during both the years. Five plants from each net plot were selected randomly to represent the population in each net plot and labelled for recording growth observations. Observations on yield components were recorded after harvest of crop. The soybean, *rabi* sorghum and wheat yield was considered for converting in to soybean equivalent yield in kg ha^{-1} on the basis of prevailing market price in respective year of both the economic yield commodities under consideration. The soybean equivalent yield (SEY) was calculated by the following formulae for respective treatments for both the years of experiment (Ganajaxi et al 2013).

$$\text{SEY (Kg ha}^{-1}\text{)} = \frac{\begin{matrix}\text{*Yield of price} \\ \textit{Kharif} \text{ crop x (Rs. kg}^{-1}\text{)} \\ \text{(Kg ha}^{-1}\text{)}\end{matrix} + \begin{matrix}\text{Yield of price} \\ \textit{rabi} \text{ crop x (Rs. kg}^{-1}\text{)} \\ \text{(Kg ha}^{-1}\text{)}\end{matrix}}{\text{Price of soybean (Rs kg}^{-1}\text{)}}$$

*Yield= yield of both main and by product

Production efficiency of the system in terms of kg SEY day^{-1} ha^{-1} was worked out by dividing the soybean equivalent yield with the total duration of the crop sequence (Prasad et al 2013).

$$\begin{matrix}\text{Production efficiency} \\ \text{(Kg SEY day}^{-1}\text{ ha}^{-1}\text{)}\end{matrix} = \frac{\text{Soybean equivalent yield (kg ha}^{-1}\text{)}}{\text{Cropping period (days)}}$$

Land utilization efficiency (LUE) was estimated by dividing the total duration of different crops in a sequence with 365 days and expressed in percentage (Tomar and Tiwari 1990).

$$\text{Land utilization efficiency (\%)} = \frac{\text{Total duration of sequence}}{365} \times 100$$

RESULTS AND DISCUSSION

Yield of soybean: Conventional tillage recorded significantly higher soybean grain and straw yield in pooled analysis over the minimum tillage practices it may due to better seed bed *viz*., better physical environment in terms of lower bulk density, penetration resistance in turn there was an enhanced growth and productivity of soybean. Higher biological yield and harvest index also noted in conventional

tillage practices. Similar result observed by Monsefi et al (2014) Soybean based cropping systems treatment does not significantly influenced the grain, straw, and biological yield during both year. The significantly higher in grain and straw yield of soybean was observed with the application of 125 per cent levels of RDF over 75 per cent RDF application but 100 per cent RDF produced comparable yields to it. Whereas the biological yield harvest index was also higher in 125 per cent RDF levels applied to. These findings are in conformity with those of Thakur et al (2011) and Kang et al (2012).

Table 1. Mean seed, straw, biological yield and harvest index of soybean (kg ha^{-1}) as influenced by different treatments in pooled analysis (Pooled)

Treatments	Seed yield (kg ha^{-1})	Straw yield (kg ha^{-1})	Biological yield (kg ha^{-1})	Harvest index (%)
Tillage				
T_1: Minimum tillage	1391	2297	3688	37.68
T_2: Conventional tillage	1563	2393	4053	38.57
C.D. at 5%	103.02	133.91	236.28	--
Cropping system				
C_1:Soybean-*Rab*i sorghum	1465	2384	3850	38.04
C_2:Soybean-Wheat	1488	2402	3891	38.26
CD (p=0.05)	NS	NS	NS	--
Nutrient levels				
N_1: 75 % RDF	1277	2161	3439	37.14
N_2: 100 % RDF	1502	2418	3921	38.30
N_3: 125 % RDF	1651	2599	4251	38.82
CD (p=0.05)	152.50	244.15	380.65	--
Interaction				
T X C				
CD (p=0.05)	NS	NS	NS	--
T X N				
CD (p=0.05)	NS	NS	NS	--
C X N				
CD (p=0.05)	NS	NS	NS	--
T X C X N				
CD (p=0.05)	NS	NS	NS	--
General mean	1477	2379	4092	38.11

Yield of *rabi* sorghum: Practice of conventional tillage with application of 125 per cent to *rabi* sorghum produced higher grain yield of *rabi* sorghum followed by conventional tillage with 100 per cent RDF application it was superior over other treatments in pooled analysis. Similar trend noted in fodder, biological yield and harvest index during both years. This might be to owing conserved more rainwater and high water use efficiency resulting in better plant growth and yield attributes. Similar result reported by Tiwari (2013).

Yield of wheat: The effect of tillage practices with nutrient levels showed considerable impact on grain, straw, biological yield and harvest index during both the years. Practice of conventional tillage with application of 125 per cent RDF to wheat crop produced higher grain yield, straw yield, biological yield and harvest index. This might be due to the beneficial effect of conventional tillage during *kharif* followed by conventional tillage wheat in *rabi* resulted in better growth and yield attributes and reflected in higher grain and straw yield. Similar finding reported by Tuti et al (2011).

Soybean equivalent yield: The soybean equivalent yield of the cropping system was significantly higher with the practice of conventional tillage for soybean in *kharif* and *rabi* sorghum, wheat in *rabi* (3015 kg ha^{-1} in pooled results) than the minimum tillage treatments in pooled results. These findings are in close conformity with those reported by Ramesh et al (2009), Billore et al (2005). Soybean-wheat cropping systems recorded the significantly higher soybean equivalent yield over the soybean-*rabi* sorghum cropping systems in pooled study. In respect of nutrient levels, soybean equivalent yield was increased with the increase in fertiliser levels to soybean in *kharif* followed by *rabi* sorghum and wheat in *rabi*. It was significantly higher when crop was

Table 2. Yield of *rabi* sorghum as influenced by different treatments

Treatments	Seed yield (kg ha^{-1})		Fodder yield (kg ha^{-1})		Biological yield (kg ha^{-1})		Harvest index (%)	
	2014-15	2015-16	2014-15	2015-16	2014-15	2015-16	2014-15	2015-16
$T_1 N_1$	1802	1532	6739	6068	6739	6068	14.27	12.65
$T_1 N_2$	2079	1774	7542	6630	7542	6630	17.75	15.30
$T_1 N_3$	2273	2105	7950	7355	7950	7355	19.61	17.60
$T_2 N_1$	1923	1607	7125	6498	7125	6498	16.38	13.62
$T_2 N_2$	2339	2156	8114	7464	8114	7464	19.71	17.67
$T_2 N_3$	2421	2209	8371	7700	8371	7700	21.07	18.49
General mean	2139	1897	7640	6953	7640	6953	18.13	15.89

Table 3. Yield of wheat as influenced by different treatments

Treatments	Seed yield (kg ha^{-1})		Straw yield (kg ha^{-1})		Biological yield (kg ha^{-1})		Harvest index (%)	
	2014-15	2015-16	2014-15	2015-16	2014-15	2015-16	2014-15	2015-16
$T_1 N_1$	2324	2125	6000	5457	6000	5457	39.61	39.97
$T_1 N_2$	2728	2430	6800	6103	6800	6103	41.65	39.83
$T_1 N_3$	2882	2615	7135	6507	7135	6507	41.81	40.95
$T_2 N_1$	2501	2281	6275	5764	6275	5764	40.41	40.21
$T_2 N_2$	2930	2746	7207	6803	7207	6803	41.38	41.08
$T_2 N_3$	3101	2880	7572	7081	7572	7081	42.82	42.78
General mean	2744	2513	6831	6286	6831	6286	41.28	40.80

supplied with 125 per cent RDF over 75 per cent RDF and was at par with 100 per cent RDF in pooled results.

Table 4. Soybean equivalent yield (kg ha^{-1}) production efficiency (kg SEY ha^{-1}day^{-1}) and land use efficiency (%) as influenced by different treatments (Pooled)

Treatments	Soybean equivalent yield (kg ha^{-1})	Production efficiency (kg SEY ha^{-1} day^{-1})	Land use efficiency (%)
Tillage			
T_1	2727	12.67	59.04
T_2	3015	14.01	59.04
S.E. (m) ±	49.85	0.24	--
CD (p=0.05)	172.01	0.83	--
Cropping system			
C_1	2720	12.30	60.55
C_2	3022	14.38	57.53
CD (p=0.05)	172.01	0.83	--
Nutrient levels			
N_1	2496	11.59	59.04
N_2	2938	13.65	59.04
N_3	3179	14.78	59.04
CD (p=0.05)	233.59	1.16	--
Interaction			
T X C			
CD (p=0.05)	NS	NS	--
T X N			
CD (p=0.05)	NS	NS	--
C X N			
CD (p=0.05)	NS	NS	
T X C X N			
CD (p=0.05)	NS	NS	--
General mean	2869	13.34	59.04

For treatment details see Table 1

Production efficiency: Practice of conventional tillage recorded production efficiency of cropping system (14.01 kg SEY ha^{-1} day^{-1}) in pooled result, respectively, which was significantly higher than minimum tillage (T_1) in pooled study. Production efficiency was recorded by soybean-wheat was 14.38 kg SEY ha^{-1} day^{-1} in pooled result, respectively significantly higher than soybean-*rabi* sorghum cropping systems. Production efficiency was significantly higher (14.78 kg SEY ha^{-1} day^{-1} in pooled result) under the treatments receiving 125 per cent RDF as compared to the treatment of 75 per cent RDF, however, it was at par with 100 per cent RDF. These findings are in close conformity with those reported by Singh (2006) and Arbad et al (2011).

Land use efficiency: The land use efficiency of the system not influenced under the tillage practices, and levels of nutrient to soybean in *kharif* followed by *rabi* sorghum and wheat in *rabi*.. In case of cropping systems higher land use efficiency was recorded under soybean-*rabi* sorghum cropping systems. This might be due to required more periods for maturity, thus occupying land for more periods as compared to soybean-wheat cropping systems. Similar result reported by Ganajaxi et al (2013).

CONCLUSION

Soybean-wheat cropping system was found favourable in increasing system productivity under resource conservation technologies. Conventional tillage practices were found beneficial in increasing growth, yield attributes and yield of soybean, *rabi* sorghum and wheat in cropping sequence. Application of 125 per cent RDF increased the growth attributes, yield attributes and yield of soybean, *rabi* sorghum and wheat in cropping sequence compare to lower nutrient levels application. Practice of conventional tillage and 125 per cent RDF to soybean-wheat cropping system improved system productivity, soybean grain equivalent yield and production efficiency.

REFERENCES

Arbad BK and Ismail S 2011. Effect of integrated nutrient management on soybean (*Glycine max*)-safflower (*Carthamus tinctorius*) cropping system. *Indian Journal of Agronomy* **56**(4): 340-345.

Billore SD, Ramesh A, Joshi OP and Vyas AK 2005. Influence of tillage operations on sustainable production of soybean based cropping systems. *Soybean Research* **3**: 17-22.

Ganalaxi, Halihatti SI, Hiremath SM and Chittapur BM 2013. Produvtivity, profitability and energy-use efficiency of different cropping sequence in northern transition zone of Karnataka. *Indian Journal of Agronomy* **81**(10): 921-926.

Kang JS, Singh Avtar and Kaur M 2012. Studies on growth and yield of soybean under different planting methods and fertility levels. *Legume Research* **35**(3): 265-267.

Monsefi A, Sharma AR, Rang Zan N, Behera UK and DasTK 2014. Effect of tillage and residue management on productivity of soybean and physic-chemical properties of soil in soybean-wheat cropping system. *International Journal of Plant Production* **8**(3): 430:439.

Prasad D, Yadava S and Singh CS 2013. Diversification of rice (*Oryza sativa*)-based cropping systems for higher productivity and resource-use efficiency under irrigated ecosystem of Jharkhand. *Indian Journal of Agronomy* **58**(3): 264-270.

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Ramesh P, Panwar NR, Singh AB and Ramana S 2009. Production potential, nutrient uptake, soil fertility and economics of soybean (*Glycine max*) based cropping systems under organic, chemical and integrated nutrient management practices. *Indian Journal of Agronomy* **54**(3)*:* 278-283.

Singh P, Nepalia V and Tomar SS 2006. Effect of weed control and nutrient management on soybean (*Glycine max*) productivity. *Indian Journal of Agronomy* **51**(4): 314-317.

Thakur R, Sawarkar SD, Vaishya UK and Singh M 2011. Impact of continuous use of inorganic fertilizer and organic manure on soil properties and productivity under soybean-wheat intensive cropping of a vertisol. *Journal of the Indian Society of Soil Science* **59**(1): 74-81.

Tiwari A 2013. *Impact studies of different resource conservation practices on cropping systems in Kymore Plateau and Satpura Hills.* Ph.D. Dissertation, Jawaharlal Nehru Krishi Vishwa Vidyalaya, Jabalpur, Madhya Pradesh, India.

Tomar SS and Tiwari AS, 1990. Production potential and economics of different cropping sequences. *Indian Journal of Agronomy* **35**(1&2): 30-35.

Tuti MD and Das TK 2011.Carry-over effect of metribuzin applied to soybean (*Glycine max*) on weeds and wheat (*Triticum aestivum*) under zero and conventional tillage. *Indian Journal of Agronomy* **56**(2): 121-126.

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Influence of Mother Bulb Weight and Spacing on Quality Seed Yield of Onion

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Abstract: The present study was conducted to investigate the effect of mother bulb weight and spacing on onion seed production under Red and Laterite Zone of West Bengal, India. The mother bulbs were produced from botanical seed, were graded and stored under ambient condition up to November 2016. In *Rabi* 2016-2017, three levels of spacing [S1 (22.5 cm × 30 cm), S2 (30 cm × 30 cm) and S3 (45 cm × 30 cm)] and three levels of mother bulb weight [B1 (30-50g), B2 (51-65g) and B3 (66-80g)] were assessed. Maximum leaves per plant, umbel diameter, flowers per umbel and seeds per umbel was observed in wider spacing and also when larger bulbs were planted. The planting of bigger sized bulbs produced maximum number of scape per plant. Maximum seed yield (857.80 kg/ha) was obtained by following 30cm x 30cm spacing, which was similar to closely spaced plants of 22.5 cm × 30 cm. High seed yield (923.35 kg/ha) of good quality was also recorded by planting large sized bulbs (66-80g), which was superior than planting of medium and small sized bulbs. The combination of planting medium size bulbs (51-65g) in 30cm x 30cm spacing resulted in high seed yield. However, planting of large sized bulbs (66-80g) following any spacing ensures high seed yield with high seed germination.

Keywords: *Allium cepa*, Bulb size, Spacing, Growth, Seed yield

Onion (*Allium cepa* L.) is commercially propagated by true seeds. Onion seed has short shelf life as seed viability reduced very fast in ordinary storage condition. Farmers have to secure fresh seed for planting each year. However, a major limitation is the limited availability of quality seeds and poor seed replacement rate of onion in India (Gupta and Sharma 2011). Onion seed production might be increased by increasing the area with good variety, superior management practices and by using quality seed. But most of the farmers use own saved seeds for onion cultivation, which were often not produced scientifically following seed multiplication guidelines (Dhar et al 2018). Varietal admixture and heterogeneous material results reduced onion productivity of Indian farmers (Lawande et al 2009). In India, mostly short day cultivars were grown in winter season both for bulb and seed production. Onion is a non-traditional commercial crop of Red and Laterite Zone of West Bengal. In West Bengal, farmers are prefer to grow onion cv. Sukhsagar (an indigenous winter season cultivar)due to its higher production potential, good quality, better storability and adaptability in this region. However, some farmers of this region recently started commercial onion farming. Some of them were also venturing for seed production seeing its good return. However, poor selection of mother bulb and faulty crop management practices often results in crop failure or poor seed quality. Ginoya et al (2018) observed that small farmers have inadequate knowledge for selecting proper grade of the bulbs and plant spacing. The initiation of inflorescence is favoured by a large set or bulb size. Bulb size generally plays an important role in onion seed production (Khokhar 2014). The vegetative growth and seed production ability of the plants increased gradually with the increase in bulb size (Manna et al 2016). El-Damarany et al (2015) observed that bulb size and plant spacing are the key factors in producing onion seeds of high quality. Optimum plant spacing ensures proper growth and development of plant by reducing competition among the plants for nutrients, moisture, space and light, resulting in maximum yield and the best use of land (Kamboj et al 2017). Spacing plays a vital role for maximizing onion seed yield and quality (Sanjay Kumar et al 2015). Research on seed production of onion is meager in West Bengal. Manna et al (2016) standardized planting time and bulb size for onion seed production under New Alluvial Zone of West Bengal. However, study on onion seed production in red and laterite zone of West Bengal is lacking. Considering the importance of bulb size and spacing in onion seed production the present experiment was conducted to determine the effect of mother bulb weight and spacing under Red and Laterite Zone of West Bengal.

MATERIAL AND METHODS

The experiment was conducted at Institute of Agriculture, Sriniketan (West Bengal). The soil of the experiment field was loamy sand with soil pH of 5.8 and

organic carbon content 0.54%. The available soil nitrogen, phosphorus and potassium were 201.6 kg, 12.01 kg and 91.57 kg per hectare. The present experiment was conducted by following bulb to seed method. The whole experiment was completed in two years (*Rabi* season of 2015-16 and 2016-17). In first year, bulbs were produced, harvested and stored in a well ventilated room and in the second year, bulbs were transplanted for seed production. In September 2015, seed of onion cv. Sukhsagar were collected from the local progressive farmer. The seeds were sown on 16th October 2015 in nursery beds to raise seedlings for transplanting in the main field. Healthy seedlings were transplanted on 5th December 2015 in the main field when they were 50 days old. FYM @ 25 t/ha with NPK @ 125: 100: 100 kg/ha was applied to grow the bulb crop. Entire dose of FYM, phosphate and potash along with half the dose of N fertilizers was given as basal during final land preparation. The rest N was top dressed in two split doses at 30 and 50 days after transplanting. Further, the crop was grown with necessary cultural operations like regular irrigation, weeding. when required.Irrigation was stopped in 10 days before bulb harvesting. The bulbs were lifted when 75% plant showed neck fall at about 100 days after transplanting. The harvested bulbs were field cured for two days and then cured under naturally ventilated room by spreading in the floor for seven days. The dried leaves were trimmed from neck region leaving 2-3 cm attached with bulb. The damaged, twin and long necked bulbs were discarded. Then the bulbs were graded in three different sizes, small (30-50g), medium (51-65g) and large (65-80g). The graded bulbs were then stored under ambient condition up to November for seed production. During second year in *Rabi* 2016-17, seed production field was well prepared and twenty seven plots of 2.25 m x 1.8 m size were prepared. The same crop nutrition schedule was followed for seed crop as in bulb production *i.e.* FYM @ 25t/ha and NPK @ 125:100:100 kg/ha. The experiment comprising nine treatments was laid out in factorial randomized block design with three replications. The experiment had two factors *i.e.* three spacing (factor A) [S1 (22.5 cm × 30 cm), S2 (30 cm × 30 cm) and S3 (45 cm × 30 cm)] and three mother bulb weight (factor B) [B1 (30-50g), B2 (51-65g) and B3 (66-80g)]. Stored bulbs were sorted and only good quality bulbs which are visually free from any rotting were selected. Upper one third portions of the bulbs were cut to see their internal quality. The cut bulbs were treated with fungicide SAAF (Carbendazim12% + Mancozeb63% WP, UPL Limited, Mumbai) @ 2g/l before planting. Planting was done on 8th November, 2016. The observations were recorded on plant height, number of leaves, neck diameter, number of scape, scape length, scape diameter, umbel diameter and number of flowers per umbel from ten randomly selected plants in each replication. Data on number of seeds per umbel, seed weight per umbel, seed yield per plant and seed yield/plot were taken after umbel harvesting. Seed yield per hectare was computed from the seed yield obtained per plot.Three samples of 1000 seeds was taken, weighed and averaged for getting test weight of seed. The laboratory germination test was conducted as per the ISTA rules (Anonymous, 1996) by adopting Top of paper method. The seed vigour was calculated as Seed vigour = Germination (%) x Seedling length (cm).

RESULTS AND DISCUSSION

Growth traits: Maximum number of leaves per plant was observed in wider spacing of 45cm x 30cm, which was statistically at par with 30cm x 30cm spacing. Less number of leaves in narrower spacing may be ascribed to natural shading and possibly stiffer competition for light as well as other growth factors among onion plant. The findings are similar to Sanjay Kumar et al (2015). Maximum number of leaves was also when bigger bulbs (66-80g or 51-65g) were planted. Larger sized bulbs having more stored foods which support the production of more leaves as compare to small size bulbs. These results are in line with the findings of El-Damarany et al (2015) and Manna et al (2016). Interaction effect of spacing and bulb weight was non-significant for this trait. Plant height and neck diameter were not differed in various levels of spacing, bulb weight and their interactions.

Scape traits: Planting of different sized bulb significantly influenced the number of scape per plant. Scape number, however, was not affected by direct effect of spacing and interaction effect of spacing and bulb weight. Large size bulb (66-80g) produced maximum number of scape per plant. Khokhar (2014) observed that large bulbs produce more flower stalks. Morozowska and Hołubowicz (2009) discovered that the big bulbs gave larger numbers of seed stalks than the seed stalks grown from the medium and small ones. Spacing, bulb weight and their interactions were not influenced the scape length and diameter. Morozowska and Hołubowicz (2009) reported that bulb size had no effect on the seed stalk height or their diameter.

Umbel traits and seeds per plant: Maximum umbel diameter was in wider spacing of 45cm x 30cm and may be due to the less competition among the plant for fertilizer and moisture for growth than the lower spacing. Sanjay Kumar et al (2015) reported that wide plant spacing of 60cm x 30cm showed higher umbel diameter than closer spacing. Bulb weight also influenced the umbel diameter. The planting of large (66-80g) or medium sized bulbs (51-65g) produced greater umber diameter and may be due to more stored food

in large size bulbs. Morozowska and Hołubowicz (2009) showed a significant influence of bulb size on the inflorescence diameter. El-Damarany et al (2015) obtained maximum umbel diameter from the large mother bulb (6 >: 7.5cm), which was significantly higher than the medium and small sized bulb. Kocher (2014) observed the large sized bulbs produced the highest umbel diameter followed by the medium size. Interaction effect was non-significant for this trait. Maximum number of flowers per umbel (580.39) was in spacing of 45cm x 30cm. Widest spacing produced more number of flowers probably due to less competition for nutrients, light, space, and moisture. Different bulb sizes showed significantly effect on number of flowers per umbel. The maximum flowers per umbel (543.32) were larger bulbs (66-80g) followed by medium sized bulbs (530.41). Interaction between spacing and bulb sizes was not-significant. Maximum number of seeds per umbel (692.89) was in wider spacing (45cm x 30cm). Kamboj et al (2017) recorded maximum number of seeds per umbel under wide spacing of 60x45 cm and 45x45 cm. Less competition among the plants at widest spacing may encouraged the plants to produce more seeds per umbel. Planting of large (66-80g) and medium size bulbs (51-65g) produced maximum number of seed per umbel. Manna et al (2016) obtained maximum number of seeds per umbel from plants raised from large size bulbs. Interaction effect showed that number of seed per umbel was increased when bigger sized bulbs were planted in wider spacing. These results are in line with the findings of El-Damarany et al (2015). Widest spacing recorded highest number of seeds per and may be due to availability of photosynthates and less competition for nutrients, moisture and light source in widely spaced plants. However, bulb weight did not affect this trait. Interaction effect revealed that planting of small, medium or large sized bulbs in wider spacing (45cm x 30cm) registered maximum seed number. Therefore, it indicated that planting of bulbs in wider spacing is the key to obtain maximum number of seeds per plant.

Seed yield: Maximum seed yield per plant (12.61 g) was in wider plant spacing (45cm x 30cm). Similar results were obtained by Sanjay Kumar et al (2015). Higher seed yield per plant was also obtained by planting large size bulbs (65-80g). Seed yield per plant increased with increases of bulb size due to the more food stored in large bulb than the medium and small size bulb. Similar result was documented by Manna et al (2016). Morozowska and Hołubowicz (2009) observed that if

Table 1. Effect of spacing and bulb weight on growth and flower parameters of onion seed crop

Treatment	Plant height (cm)	Number of leaves	Neck diameter (mm)	Number of scape /plant	Scape length (cm)	Scape diameter (mm)	Umbel diameter (mm)	Number of flowers/umbel
Spacing								
S1	73.15[a]	30.46 [b]	14.91[a]	4.82[a]	82.91[a]	17.29[a]	57.80 [b]	494.76 [b]
S2	72.81[a]	33.00 [a]	15.23[a]	4.73 [a]	79.44[a]	16.48[a]	58.89 [b]	469.76 [b]
S3	72.24[a]	33.54 [a]	15.47[a]	4.96 [a]	81.50 [a]	17.09[a]	65.34 [a]	580.39 [a]
Bulb size								
B1	72.43[a]	29.19 [b]	15.07[a]	4.38 [b]	79.11[a]	16.93[a]	57.64 [b]	471.17 [b]
B2	73.59[a]	33.39 [a]	15.28[a]	4.46 [b]	82.05[a]	17.01[a]	61.10 [a]	530.41 [a]
B3	72.18[a]	34.43 [a]	15.25[a]	5.67 [a]	82.69[a]	16.93[a]	63.29 [a]	543.32 [a]
Spacing x Bulb size								
S1B1	74.67[a]	27.85[a]	14.44[a]	4.57[a]	82.92[a]	17.31[a]	57.60[a]	476.55[a]
S1B2	72.28[a]	31.07[a]	15.34[a]	4.64[a]	82.74[a]	17.48[a]	57.02[a]	504.43[a]
S1B3	72.51[a]	32.47[a]	14.94[a]	5.25[a]	83.06[a]	17.10[a]	58.78[a]	503.30[a]
S2B1	70.13[a]	28.93[a]	14.73[a]	4.11[a]	74.58[a]	16.28[a]	53.25[a]	370.16[a]
S2B2	76.29[a]	33.55[a]	15.42[a]	4.15[a]	81.78[a]	16.30[a]	60.47[a]	513.34[a]
S2B3	72.01[a]	36.51[a]	15.53[a]	5.93[a]	81.97[a]	16.87[a]	62.96[a]	525.77[a]
S3B1	72.47[a]	30.77[a]	16.04[a]	4.47[a]	79.84[a]	17.19[a]	62.07[a]	566.79[a]
S3B2	72.21[a]	35.54[a]	15.08[a]	4.58[a]	81.63[a]	17.25[a]	65.82[a]	573.47[a]
S3B3	72.04[a]	34.30[a]	15.29[a]	5.83[a]	83.04[a]	16.83[a]	68.14[a]	600.90[a]
Mean	72.73	32.33	15.20	4.84	81.28	16.96	60.68	514.97

Note: Bulb size [B1 (30-50g), B2 (51-65g) and B3 (66-80g)] and Spacing [S1=22.5×30cm, S2=30×30cm and S3=45×30cm];
Means with at least one letter common in a column are statistically *at par* using Fisher's Least Significant Difference

the onion bulbs used were large, the seed yield per plant was twice large as if the bulbs were small. Interaction effect showed that higher seed yield per plant was obtainedwhen 30-50g or 51-65g or 66-80g bulbs were planted in 45cm x 30cm spacing. Wider spacing gave unique opportunity to the individual plants to grow freely without facing competition from nearby plants. Plants eventually produced more seed yield. Ginoya et al (2018) obtained highest seed yield in the plants raised from the largest bulb size (75 g) and at the spacing of 60cm x 40cm. Similarly El-Damarany et al (2015) recorded highest seed yield/plant from the largest bulb size with the widest planting distance.The direct effect of spacing and bulb size and their interaction effects were significant. Maximum seed yield (857.80 kg) was in 30cm x 30cm spacing, but was at par with closest spacing (22.5 cm x 30cm). The minimum seed yield was in widest spacing (45cm x 30cm). Planting of bulbs in lesser spacing accommodate more plants per unit area, which assume to contribute cumulatively towards more yield per unit area. This was opposite to the trait seed yield per plant, where individual contribution increased by increasing spacing. The trend is in accordance to the findings of Kamboj et al (2017), who observed that the lowest seed yield was mainly due to lower plant population per unit area at wider plant spacing. The highest seed yield (923.35kg) was by planting large bulbs (66-80g), which was significantly superior than planting of medium and lessweight bulbs. Larger mother bulb having a larger food supply and water content than the smaller bulbs enables the development of vigorous plants and production of higher seed yields (Khokhar, 2014).El-Damarany et al (2015) and Manna et al (2016) concluded that planting of large size bulb produced significantly higher seed yield than planting medium and small size bulb. Morozowska and Hołubowicz (2009) concluded that for practical seed production, only large onion bulbs count. Maximum seed yield was recorded in combination of 30cm x 30cm spacing and medium size bulbs (51-65g), which was at par with 30cm x30cmspacing and large size bulbs, 22.5cm x 30cm spacing and large size bulbs and 45cm x30cm spacing and large size bulbs. The large bulb size gave maximum seed yield in all three spacing. Thus use of large size mother bulbs assure good seed yield in onion irrespective of spacing. Ginoya et al (2018) observed significantly high seed yield using largest bulb size (75 ± 5g) and medium spacing (45cm x 30cm). Similar observation was recorded by El-Damarany et al (2015).

Seed quality traits: The direct effect of spacing was observednon-significant for 1000 seed weight. Bulb weighthad significant influence on 1000 seed weight, though

Table 2. Effect of spacing and bulb weight on seed yield, its attributes and seed quality of onion

Treatment	Number of seeds /umbel	Number of seeds /plant	Seed weight /umbel (g)	Seed yield /plant (g)	Seed yield /ha (kg)	1000 seed weight (g)	Seed germination (%)	Seedling length (cm)	Seed vigour
Spacing									
S1	574.11 ^{b}	2530.77^{b}	2.02^{a}	8.93^{b}	855.34 ^{a}	3.56^{a}	82.44^{a}	5.68^{b}	470.37^{a}
S2	571.00 ^{b}	2500.71^{b}	2.07^{a}	9.07^{b}	873.80 ^{a}	3.62^{a}	86.00^{a}	5.67^{b}	487.80^{a}
S3	692.89 ^{a}	3441.50^{a}	2.41^{a}	12.61^{a}	717.83 ^{b}	3.67^{a}	84.44^{a}	6.73^{a}	568.55^{a}
Bulb size									
B1	585.00 ^{b}	2732.93^{a}	2.12^{a}	9.92^{b}	695.14 ^{c}	3.65 ^{a}	81.78^{b}	5.72^{a}	467.53^{a}
B2	621.33 ^{a}	2803.24^{a}	2.16^{a}	9.75^{b}	828.48 ^{b}	3.46 ^{b}	82.89^{b}	6.15^{a}	511.99^{a}
B3	631.67 ^{a}	2936.80^{a}	2.22^{a}	10.94^{a}	923.35 ^{a}	3.73 ^{a}	88.22^{a}	6.22^{a}	547.20^{a}
Spacing x Bulb size									
S1B1	576.67 ^{cd}	2611.53^{cd}	2.05^{a}	9.28^{c}	843.54 ^{bc}	3.64 ^{abc}	79.33^{a}	6.15^{a}	488.55^{a}
S1B2	574.67 ^{cd}	2469.10^{d}	1.88^{a}	8.09^{c}	792.76 ^{cd}	3.28 ^{d}	80.67^{a}	4.77^{a}	386.16^{a}
S1B3	571.00 ^{cd}	2511.67^{d}	2.14^{a}	9.43^{c}	929.71 ^{ab}	3.76 ^{ab}	87.33^{a}	6.13^{a}	536.40^{a}
S2B1	541.33 ^{e}	2282.53^{d}	1.93^{a}	8.06^{c}	665.93 ^{ef}	3.56 ^{bc}	82.67^{a}	5.07^{a}	419.89^{a}
S2B2	570.33 ^{c}	2244.53^{d}	2.01^{a}	7.90^{c}	1002.14 ^{a}	3.52 ^{c}	84.00^{a}	6.46^{a}	542.36^{a}
S2B3	601.33 ^{bc}	2975.07^{bc}	2.28^{a}	11.25^{b}	953.33 ^{ab}	3.79 ^{a}	91.33^{a}	5.49^{a}	501.15^{a}
S3B1	637.00 ^{b}	3304.73^{ab}	2.40^{a}	12.42^{ab}	575.97 ^{f}	3.76^{ab}	83.33^{a}	5.94^{a}	494.16^{a}
S3B2	719.00 ^{a}	3696.09^{a}	2.58^{a}	13.27^{a}	690.53 ^{de}	3.59^{abc}	84.00^{a}	7.21^{a}	607.44^{a}
S3B3	722.67 ^{a}	3323.67^{ab}	2.24^{a}	12.14^{ab}	887.00 ^{abc}	3.65 ^{abc}	86.00^{a}	7.03^{a}	604.05^{a}
Mean	612.67	2824.32	2.17	10.20	815.66	3.62	84.30	6.03	508.91

See Table 1 for details

the reason was unclear as larger and smaller sized bulbs had higher 1000 seed weight than medium sized bulbs. El-Damarany et al (2015) obtainedhigher 1000 seed weight using larger mother bulbs. They assume that the superiority of large bulbs may be related to its higher food reserves. Khokhar (2014) observed significant increase in 1000-seed weight with the increase in bulb size. Interaction between spacing and mother bulb weight showed that various treatment combination gave higher 1000 seed weight. However, no definite trend was noticed. The spacing did not affect percent seed germination. However, seeds obtained by planting 66-80g bulbs had maximum percent germination (88.22%) than medium and small sized bulbs. Similar trend was noted by El-Damarany et al (2015). They observed maximum germination percentage (87.45%) using large mother bulbs. No significant interaction was noted between spacing and bulb size for this trait.Plant spacing influenced the seedling length. Wider spacing (45 x 30cm) produced longest seedlings. Sanjay Kumar et al (2015) also recorded maximum seedling length in wider spacing. Direct effect of bulb weight and interaction between spacing and bulb weight was statistically non-significant for this trait. However, seed vigour was not influenced by direct and interaction effects of spacing and bulb weight.

CONCLUSION

The plant spacing and mother bulb weight largely influenced the seed yield and quality of onion. Planting medium size bulbs (51-65g) in 30×30cm spacing can be followed to obtain high seed yield. Alternately planting of larger sized bulbs (66-80g) at any spacing ensures high seed yield in onion. Planting of large sized bulbs also helped to get seeds with high germination.

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REFERENCES

Abdul-Baki and Anderson 1973. Vigor determination in soybean seed by multiple criteria. *Crop Science* **13**(6): 630-633.

Anonymous 1996. International rules for seed testing: rules (International Seed Testing Association). *Seed Science Technology* **24**: 29-156.

Dhar M, Mandal J and Mohanta S 2018. In: P. K. Chattopadhyay and D. S. Kushwaha (eds.) *Issues in sustainable development in India: present problems and future perspective*. Scope of onion (*Allium cepa* L.) seed production in West Bengal.New Delhi Publishers, New Delhi. p. 19-28.

El-Damarany AM, El-Shaikh KAA, Obiadalla-Ali HA and Abdel-Kader MM 2015. Effect of mother bulb size and planting space on seed production of onion (*Allium cepa*, L.) cultivar Giza 6 Mohassan. *Journal of Agricultural and Veterinary Sciences* **8**(2): 187-200.

Ginoya AV, PatelJB, Delvadiya IR and Jethva AS 2018.Effect of bulb size and plant spacing on seed yield and economics of onion (*Allium cepa* L.) seed production. *Plant Archives* **18** (2): 1479-1482.

Gupta RP and Sharma HP 2011. Onion and garlic seed requirement, constraints and future strategy. In national symposium on Alliums 2011: *Current scenario and emerging trends,* Pune, India, 56-63.

Kamboj NK, Batra VK, Brar NS, Rana MK and Tanuj 2017. Effect of various plant density at different levels of phosphorous and potash on growth and seed yield of onion (*Allium cepa* L.) cv. Hisar-2. *Indian Journal of Agricultural Research* **51**(5): 514-517.

Khokhar KM 2014. Flowering and seed development in onion - A rreview. *Open Access Library Journal* **1**: e1049.

Sanjay Kumar, Tomar BS, Jain SK, Singh N, Parsad R and Munshi AD 2015. Effect of planting time and density on plant growth, seed yield and quality attributes in onion (*Allium cepa*) cv. Pusa Riddhi. *Indian Journal of Agricultural Sciences* **85**(12): 1578-1585.

Lawande KE, Khar A, Mahajan V, Srinivas PS, Sankar V and Singh RP 2009. Onion and garlic research in India. *Journal of Horticultural Sciences* **4**(2): 91-119.

Manna D, Santra P, Maity TK and Basu AK 2016. Quality seed production of onion (*Allium Cepa* L.) cv. Sukhsagar as influenced by bulb size and date of planting. *Agricultural Research & Technology: Open Access Journal* **2**(3): 1-6.

Morozowska M and Hołubowicz R 2009. Effect of bulb size on selected morphological characteristics of seed stalks, seed yield and quality of onion (*Allium cepa* L.) seeds. *Folia Horticulturae Annuals* **21**(1): 27-38.

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Study on Off-season Performance of Some Vegetable Type Watermelon [*Citrullus lanatus* (Thunb.) Matsum and Nakai] Landraces

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Abstract: *Khero* or vegetable type watermelon is a minor cucurbitaceous vegetable cultivated during summer months in restricted areas under western laterite belt of West Bengal, India. This is the first-ever report of *khero* cultivation during offseason (post-monsoon) from the eastern part of India. Seven vegetable type watermelon landraces were experimented during the post-monsoon season in red and laterite zone of West Bengal. The observations revealed the significant diversity for the attributes like earliness in flowering, fruiting at lower nodes, average fruit weight, number of fruits per plant, desirable fruit dimension and total soluble solids. The genotype VC-3-6 was best for yield, earliness and total soluble solids, hence it was suggested for off-season cultivation. The maximum number of fruits per plant was produced by VC-12-2 followed by VC-3-6. Correlation study revealed the positive association between per plant fruit yield and fruit length, fruit circumference, average fruit weight and the number of fruits per plant. Thus, the landraces evaluated posed an ample potential and scope which will help to execute future breeding programmes as a source of desirable genes for higher yield, quality improvement and commercialising this crop during the off-season.

Keywords: *Khero*, *Citrullus lanatus,* Landraces, Genotypic variation

Vegetable type watermelon locally known as '*Khero*' [(*Citrullus lanatus* (Thunb.) Matsum and Nakai] belongs to the family Cucurbitaceae and the predominant sex form is monoecious. *Khero* is grown as minor annual crop during the summer season in western laterite belt of West Bengal. It is harvested at an immature stage for vegetable purpose. However, it also serves as a vital crop to earn significant returns by the farmers. Cultivation of this crop is chiefly based on indigenous landraces. At the end of the season farmers generally keep some good fruits on vine,considering their size and shape for seed production. However, they do not follow any pollination control for seed production. This practice created good variation within and between genotypes. However, no efforts were exerted to conduct a study on *khero*, its genetic resources and other aspects. Recently Mohanta and Mandal (2019b) documented the performance of vegetable type watermelon landraces from this region. However, the offseason production of this crop has not yet studied. Growing this crop during the post-monsoon season may be remunerative to the local farmers in terms of the market return. Keeping in view the above points the present study was undertaken to study the performance of vegetable type watermelon during offseason (post-monsoon) and also to identify the suitable genotype(s) for off-season growing of this vegetable.

MATERIAL AND METHODS

Seven land races of vegetable type watermelon (VC-3-6, VC-5-2, VC-8-1, VC-10-1(1), VC-10-3, VC-12-2, VC-12-3), which were earlier collected, purified and stabilized by Mohanta and Mandal, (2019b), was used as an experiment material. The experiment was planned in a randomised block design with three replications at the Institute of Agriculture, Sriniketan during the post-monsoon season of 2017. The planting method followed was channel and bed system with the spacing of 2m x 0.5m. FYM @ 20 t/ha and NPK @ 60:40:60 kg/ha was applied to grow the crop. Only 1/3rd of N with a full dose of P and K was applied as basal and the remaining N was applied in two equal splits at 30 and 50 days after sowing. Observations were recorded from five randomly tagged competitive plants per treatment and per replication. Parameters considered under experiment was vine length, number of days to first male and female flower opening, node to the first male and female flower appearance, days to first fruit harvest, number of fruits per plant, an average of individual fruit weight, fruit length and circumference, fruit yield per plant and total soluble solids (TSS). The TSS was determined by a digital hand-held pocket refractometer (PAL-1) manufactured by ATAGO CO., LTD. Japan. The readings were measured in ºBrix. The total variation exhibited by the genotypes for various characters was tested for significance

(F-test) using analysis of variance (ANOVA) tool. The test of significance of the difference between means of two genotypes for a character was done by 't' test and then the critical difference (C. D.) was computed.

RESULTS AND DISCUSSION

The seven genotypes of vegetable type watermelon significantly differed among themselves (Table 1). Days to first male flower opening, node to the first male and female flower appeared, days to first fruit harvest, fruit length, fruit circumference, average fruit weight, fruit yield per plant and TSS significantly differed at 1% level of significance, whereas days to first female flower opening and number of fruits per plant differed at 5% level of significance. The mean data of different traits have been presented in Table 2 and discussed below.

Vine length: No significant variation was present among genotypes. Average vine length was 2.7m.

Flowering traits and days to first fruit harvest: Since predominant sex form in khero is monoecious, female flowers appear later than male flowers. Days required for first male flower anthesis was lowest in VC-10-1(1) [34.1], which was statistically at par with genotypes VC-12-2 (34.4), VC-5-2 (34.6) and VC-3-6 (35.4). On an average first male flower opened in 36.6 days. The minimum number of days required for opening of the first female flower was in VC-3-6 (46), which was statistically at par with VC-5-2 (47.3), VC-10-1(1) [47.6], VC-10-3 (49.2) and VC-12-2 (50.9). The average number of days for the first female flower opening was 49.9. The earliest node which was approximately 7th from the base of the plant at which first male flower appeared was in VC-12-2 and was statistically at par with VC-8-1 (9th). The mean number of a node for the appearance of the first male flower was 11.8 (~12th) node from the base of the plant. The earliest node from the base of the plant at which first female flower appeared was surprisingly same in VC-8-1 (~24th) and VC-3-6 (~24th), they were statistically similar toVC-10-3 (~26th). On average, the node at which first female flower appeared was 27.3 (~27th) from the base of the plant. Even though early flowering is associated with earliness, the node at which first female flower appeared is given due consideration while judging earliness of a genotype. Since the number of days needed for the appearance of first female flower is vital as they determine the earliness or lateness of the crop, therefore it is often believed that traits such as days to first female flower anthesis and first female flowering node are associated with earliness. The possible explanation for the disparity in days to the appearance of the first male and female flower, node number at which first male and female flower appeared may be due to inter nodal length, number of internodes, vigour, genotype, environment and their interaction. The above results are in close conformity with Mohanta and Mandal (2019b) in their study they noted the presence of considerable variation for days to the first male (26.8–44.8) and female (39.8–61.3) flower opening. Further, they also saw differences in node number at with first male (5th–8th) and female (18th–27th) flowers appeared among twenty vegetable purpose watermelon genotypes. Similarly, Souza et al. (2005b) observed variability in triploid watermelon hybrids for earliness. The direct effect of earlinesscan be seen on the yield as it is directly related to early fruiting and harvest. Hence it is a vital attribute for grabbing an early market opportunity. The minimum number of days required for first fruit harvest was in VC-12-2 (61.0) followed by VC-12-3(62.4) and VC-3-6(62.4). The average number of days required for the first fruit harvest was 68.8 days. Cucurbits are warm-season vegetables. Hence, they are grown during the summer months. The variation among landraces for days to first fruit harvest seems obvious, owing to the exposure to an unprecedented situation during the off-season (post-monsoon) like high relative humidity, ill-timed rains, low temperature, some other factors includes growth hormone effect and vigour. Our results share similarities with findings of Rolania et al. (2004) they confirmed high estimates of heritability for days to first fruit harvest in watermelon.

Table 1. Analysis of variance of seven vegetable type watermelon genotypes for different characters

Source	D.F.	Mean sum of square											
		Vine length (m)	No. of days to first male flower opening	No. of days to first female flower opening	Node to first male flower appearance	Node to first female flower appearance	Number of days to first fruit harvest	Number of fruits per plant	Average fruit weight (g)	Fruit length (cm)	Fruit circumference (cm)	Fruit yield per plant (g)	Total soluble solids (°Brix)
Replication	2	0.02	0.35	7.49	7.61	0.99	2.37	0.03	4654.22	0.37	0.19	81376.65	0.00029
Treatment	6	0.3	19.39**	32.89*	44.64**	58.54**	291.97**	1.93*	272433.	70.43**	80.17**	9692326**	0.21**
Error	12	0.11	2.23	9.04	1.69	6.94	2.99	0.43	6423.79	0.71	3.31	109265.38	0.10

Note: * & ** means significant at 5% and 1% level respectively

Yield attributes, yield and TSS: Attribute like the number of fruits per plant is believed substantially important and coupled with yield in cucurbits (Choudhary et al 2012). The mean value for the number of fruits per plant was 5.6 or approximately 6. Genotype bearing the highest number of fruits per plant was VC-12-2 (~7) which was statistically at par with VC-3-6 (~6). Typically, immature fruits of vegetable purpose watermelon (*khero*) are preferred locally in the West Bengal state of India. Hence the fruits are picked early before the formation of seeds and attaining maturity. Early picking has a positive direct effect on yield, yet it is often observed that earlier the first fruit is harvested sooner, the next fruit is formed. Perhaps it is as a consequence of reduced competition among growing fruits for the nutritional elements. Additionally, sex ratio, fruit set percentage, genotype and its interaction with the environment are other facets which may affect fruit numbers in a genotype. It implies that the selection of a genotype can be made by judging total and number of marketable fruits per vine to enhance the overall yield of the crop. Our outcomes can be closely related to Mohanta and Mandal (2019b) who recently examined twenty genotypes of *khero* and documented good variation for the number of fruits per plant (6–9). Similar results were also observed Souza et al.(2005a) in watermelon. Average fruit weight was maximum in VC-3-6 (1019.3 g) while the minimum average fruit weight was in VC-5-2 (215.8 g) and mean value for an average fruit weight was 522.6 g. Fruit weight is a major yield factor, which is directly correlated with yield per plant and per unit area of land. Recently, Mohanta and Mandal (2019a) noted consistent variation for average fruit weight in watermelon hybrids and cultivars and the values varied between 1.3 kg and 4.5 kg. Subsequently, a similar investigation was executed in *khero* genotypes by Mohanta and Mandal (2019b) and found considerable variation for fruit weight (332.5–602.5 g). Moreover, one of the characters governing genetic divergence in watermelon lines was average fruit weight (11, 9%) as revealed by (Souza et al 2005a). Genotype with maximum fruit length was VC-3-6 (24.4 cm) whereas VC-8-1 (11.8 cm) was with minimum fruit length which was statistically at par with VC-5-2 (12.3 cm) and VC-10-1(1) [13 cm]. The mean value for average fruit length was 16.4 cm. Fruit circumference was maximumin VC-10-1(1) (33.2 cm) followed by VC-10-3 (30.9 cm) and VC-3-6 (30.3 cm), while the genotype bearing fruits with minimum fruit circumference was VC-5-2 (20.4 cm) followed by VC-8-1 (22.3 cm). Average fruit circumference was 27.0 cm. The above results can be correlated with those of Mohanta and Mandal (2019b) findings. They found appreciable variation for fruit length (18.1–29.4 cm) in twenty vegetable purpose watermelon genotypes. Yield per vine correlates positively with fruit length and circumference as highlighted by Sundaram et al (2011). Additionally, the combination also determines the size and shape of the fruit. The deviation in fruit length and circumference might be due to heredity, environmental effect and vigour of the crop. Fruit yield per plant varied significantly among genotypes of *khero*, maximum yielding genotype was VC-3-6 (5854.1 g) and the minimum was in VC-5-2 (960.2 g), which was statistically at par with genotype VC-8-1 (1517.4 g). Average fruit yield per plant was 2856.5 g. The deviation in fruit yield among genotypes could have been influenced by the expression of the component traits such as fruit set percentage, fruit length, number of fruits per vine, fruit weight, fruit circumference, genotype, environment, vigour, either independently or interacting with a couple of traits. Hence, the study on yield linked characters is vital for formulating and executing

Table 2. Yield and other parameters of vegetable type watermelon genotypes

Genotypes	Vine length (m)	Days to first male flower opening	Days to first female flower opening	Node to first male flower appearance	Node to first female flower appearance	Days to first fruit harvest	Number of fruits per plant	Average fruit weight (g)	Fruit length (cm)	Fruit circumference (cm)	Fruit yield per plant (g)	Total soluble solids (°Brix)
VC-3-6	3.1	35.4	46.0	9.7	23.5	62.7	6.3	1019.3	24.4	30.3	5854.1	3.2
VC-5-2	3.1	34.6	47.3	12.7	35.0	87.8	4.7	215.8	12.3	20.4	960.2	2.5
VC-8-1	2.4	40.1	55.1	9.0	23.5	76.7	5.4	299.2	11.8	22.3	1517.4	2.6
VC-10-1(1)	2.4	34.1	47.6	12.8	30.1	64.6	5.2	354.7	13.0	33.2	1735.9	2.7
VC-10-3	2.6	38.7	49.2	12.5	25.6	66.5	5.3	831.1	20.6	30.9	4194.6	2.4
VC-12-2	2.4	34.4	50.9	7.2	23.8	61.0	7.1	580.8	14.2	29.9	3857.6	2.5
VC-12-3	2.9	39.0	53.1	19.1	29.8	62.4	5.6	357.3	18.4	22.4	1876.0	2.8
Mean	2.7	36.6	49.9	11.8	27.3	68.8	5.6	522.6	16.4	27.0	2856.5	2.7
LSD (0.05)	NS	2.6	5.2	2.3	4.6	3.0	1.1	138.7	1.5	3.2	572.2	0.24
C.V. (%)	12.2	4.1	6.0	10.9	9.6	2.5	11.7	15.3	5.1	6.7	11.6	5.15

breeding programmes for crop improvement of khero. Our results are in close conformity with the findings of Mandal and Mohanta (2018), they discovered noticeable variation among seven genotypes of tinda and the per plant fruit yield varied between 298 g and 1188 g. Likewise, Mohanta and Mandal (2016) registered significant genotypic variation for fruit yield per plant (3–12.3 kg) among thirteen watermelon genotypes. Furthering this idea, Mohanta and Mandal (2019b) assessed twenty vegetable purpose watermelon landraces and noted a huge difference in fruit yield (1.5–5.2 kg). Moderate to high genotypic coefficient of variation existed for fruit yield per plant among fifteen genotypes of watermelon, as reported by Rolania et al. (2004). The total soluble solids (TSS °Brix) content of the fruit, mainly sucrose and fructose, is crucial for quality determination. Likewise, it could also help in figuring the right stage of maturity in fruits. Genotype VC-3-6 (3.2 °Brix) was recorded with highest TSS, whereas the lowest TSS was in VC-10-3 (2.4 °Brix) which was statistically comparable with VC-5-2 (2.5 °Brix), VC-12-2 (2.5 °Brix) and VC-8-1 (2.6 °Brix). The observed variation in TSS could be because of genetic variation among landraces. The findings, as mentioned earlier are in agreement with Mohanta and Mandal (2019a), they documented variation in TSS content among watermelon hybrids and cultivars, which varied between 7.7 °Brix and 11.6 °Brix. Likewise, Souza et al. (2005b) noted similar results in triploid watermelon hybrids.

Correlation coefficient: It is evident from the correlation study (Table 3) that fruit yield per plant was significant and positively correlated with fruit length (r =0.809**), fruit circumference (r = 0.575*), average fruit weight (r = 0.951**) and the number of fruits per plant (r = 0.537*). However, it showed a significant negative correlation with the node to the first female flower appearance (r = -0.615*) and days to first fruit harvest (r = -0.604*). Similarly, Mohanta and Mandal (2019) noted a positive association between fruit yield and number of fruits per plant in vegetable purpose watermelon genotypes. Their results were in agreement with the earlier reports of Sundaram et al (2011) who found a positive correlation between fruit yield per plant and fruit weight in watermelon and Choudhary et al (2012), who reported a positive correlation between fruit yield per plant with fruit weight, number of fruits per plant and node at which first female flower appeared in watermelon. Average fruit weight was significantly and negatively correlated with the node to first female flower appearance (r=-0.582*) and days to first fruit harvest (r=-0.536*). However, it presented a highly significant and positive correlation with fruit length (r = 0.855**); significant and positive correlation with fruit circumference (r = 0.567*). Average fruit weight has a very high positive direct effect on yield. Simultaneously, a strong correlation exists between fruit weight and fruit length (Narciso 2009). A significant positive correlation was found between days to first male flower anthesis and number of days to first female flower anthesis (r = 0.586*). First female flowering node recorded a significant negative correlation with average fruit weight (r = -0.582*) and fruit yield per plant (r = -0.615*). Days to first fruit harvest was significantly and negatively correlated with yield (r = -0.604*), average fruit weight (r = -0.536*) and number of fruits per plant (r = -0.589*). The surprising correlation observed between fruit yield per plant and vine length was positive but non-significant unlike Sundaram et al (2011), whose findings described that yield per vine was positive and significantly correlated with fruit diameter and vine length in watermelon.

Table 3. Character association among different parameters in vegetable type watermelon genotypes

Characters	MFA	FFA	NMFA	NFFA	FFH	FL	FC	AFW	VL	FPP	FY
MFA	1.000										
FFA	0.586*	1.000									
NMFA	0.244	0.097	1.000								
NFFA	-0.227	-0.099	0.523	1.000							
FFH	0.004	-0.055	-0.029	0.462	1.000						
FL	0.130	-0.271	0.113	-0.339	-0.533*	1.000					
FC	-0.366	-0.351	-0.304	-0.336	-0.656*	0.358	1.000				
AFW	-0.032	-0.293	-0.273	-0.582*	-0.536*	0.855**	0.567*	1.000			
VL	-0.200	-0.372	0.316	0.222	0.219	0.342	-0.266	0.115	1.000		
FPP	-0.186	0.064	-0.361	-0.404	-0.589*	0.208	0.297	0.322	-0.273	1.000	
FY	-0.119	-0.279	-0.380	-0.615*	-0.604*	0.809**	0.575*	0.951**	0.077	0.537*	1.000

Note: MFA= Days to first male flower anthesis, FFA= Days to first female flower anthesis, NMFA= Node to first male flower appearance, NFFA= Node to first female flower appearance, FFH= Days to first fruit harvest, FL= Fruit length, FC= Fruit circumference, AFW= Average fruit weight, VL= Vine length, FPP= Fruits per plant, FY= Fruit yield per plant; * and ** means statistically significant at p=0.05 and p=0.01, respectively

Insignificant differences in vine length among genotypes might be due to the environmental effect during the off-season. Node to the first pistillate flower is practically a good measure of earliness and yield. Hence, the selection of genotypes with a lower node number for first female flower and fewer days to maturity is an earliness measure. To increased yield, emphasis can be given upon direct selection of the genotypes with traits like average fruit weight and the number of fruits per plant. The number of fruits per plant shows a negative indirect effect on yield. A possible explanation for this might be the genotypes with big sized fruits yield few fruits per plant and small-fruited genotypes produce more fruits per plant. Hence, it is difficult to increase the individual fruit weight and the number of fruits per plant at the same time through selection.

CONCLUSION

The significant variation was persistent among the genotypes studied for all the traits except for vine length. Genotype VC-3-6 produced attractive, medium-sized dark green fruits with non-fibrous white flesh. It was earliest to flower (46 DAS) and early to harvest (63 DAS) with a maximum average individual fruit weight of about 1 kg. The genotype VC-3-6 can be suggested for off-season (post-monsoon) cultivation under Red and Laterite Zone of West Bengal. The genotypes with maximum number of fruits per plant (VC-12-2 and VC-3) can be employed in the future breeding programmes to improve per plant fruit numbers and other attributed traits.

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REFERENCES

Choudhary BR, Pandey S and Singh PK 2012. Morphological Diversity Analysis Among Watermelon (*Citrullus lanatus* (Thunb.) Mansf.) Genotypes. *Progressive Horticulture* **44**(2): 321-26.

Mandal J and Mohanta S 2018. Field assessment of Tinda [*Praecitrullus fistulosus* (Stocks) Pangalo) genotypes under lateritic soils of eastern India. *Vegetable Science* **45**(1): 287-90.

Mohanta S and Mandal J 2016. Performance of watermelon (*Citrullus lanatus*) in red and laterite zone of West Bengal. *Journal of Crop and Weed* **12**(3): 175-77.

Mohanta S and Mandal J 2019a. Evaluation of some watermelon hybrids and cultivars under lateritic belt of West Bengal. *Journal of Crop and Weed* **15**(1): 78-82.

Mohanta S and Mandal J 2019b. Assessment of vegetable purpose watermelon [(*Citrullus lanatus* (Thunb.) Matsum and Nakai) genotypes collected from laterite belt of eastern India. *Journal of Pharmacognosy and Phytochemistry* **8**(3): 2508-512.

Narciso JO 2009. Phenotypic variability and correlation analysis of selected traits in tomato (*Lycopersicon esculentum* Mill.), cucumber (*Cucumis sativus* L.), sweet pepper (*Capsicum annuum* L.), melon (*Cucumis melo* L.) and watermelon [*Citrullus lanatus* (Thunb.) Matsum. & Nakai). *Philippine Journal of Crop Science* **34**(3): 102-07.

Rolania S, Fageria MS, Dhaka RS and Jat RG 2004. Genetic variability for growth and yield attributes in watermelon [*Citrullus lanatus* (Thunb.) Mansf). *Agricultural Science Digest* **24**(3): 218-20.

Souza FdeF, Queiroz MA de and Dias R de CS 2005a. Genetic divergence in watermelon lines. *Horticultura Brasileira* **23**(2): 179-83.

Souza FdeF, Queiroz MA de and Dias RdeCS 2005b. Heterotic effects in triploid watermelon hybrids. *Crop Breeding and Applied Biotechnology* **5**(3): 280-86.

Sundaram M, Kanthaswamy V and Kumar GA 2011. Studies on variability, heritability, genetic advance and character association in watermelon [*Citrullus lanatus* (Thunb.) Matsum and Nakai). *Progressive Horticulture* **43**(1): 20-24.

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Time Series Modeling and Forecasting on Pulses Production Behavior of India

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Abstract: The present investigation was an attempt to study the trend behavior of pulses production, productivity, and net availability in India. For stochastic trend estimation, time series parametric models *i.e.* Linear, Quadratic, Exponential, Logarithmic, Power, ARIMA, and ARIMAX models were worked out and compared for estimating appropriate econometric model to capture the trending behavior of pulses data series considered in this study. Based on the performance of goodness of fit criterion *i.e.* R^2, RMSE, MAPE, MAE, AIC, and SBC were considered to find the best-fitted model. Cross-correlation function (CCF) was employed to check the relationship with explanatory variables for building ARIMAX model. The assumption of 'Normality' of error term was estimated by using K-S- test and S-W- test, whereas Run-test was used to examine the 'Independency of randomness' of the error term. From the forecasted figure, pulses production will reach 24.34 MT in 2025-26, whereas productivity will gain 877.36 kg ha^{-1} in the same year. Per capita net availability of pulses will reach 24.89 kg $year^{-1}$ in 2025-26. This research helps in formulating the national agriculture policymaker.

Keywords: Productivity, Net availability, ARIMA, ARIMAX, Forecasting

India being the world's largest producer (25% of global production), a consumer (27% of world consumption) and importer (14%) of a wide variety of pulses is dominated by subtropical and tropical crops. Pulses contribute around 8.32% of total food grains production in the country in 2018-19. Simple growth rate of per capita net availability of pulses in India has 0.02% over the 69 years. It is estimated that pulses carry 20-25 percent of protein by weight and have twice the protein available in wheat and thrice that is present in rice, which is the major food grain in the country. As pulse production is affected severely by erratic rainfall and other extraneous factors (Reddy 2009), it is a need to check the forecast behavior of pulse production in advance for effective planning (Vishwajith et al 2014). Auto Regressive Integrated Moving Average (ARIMA) is the most general class of models for forecasting a time series. A number of studies have been considered up by several authors in different forms to analyze the production behavior of crops using Auto Regressive Integrated Moving Average (ARIMA) model. Yaziz et al (2011) studied ARIMA and GARCH models for analysis and forecasting crude oil prices and found that the GARCH model performed well than ARIMA model. Vishwajit et al (2019) studied statistical modeling and forecasting mung production and found that ARIMA (4,1,4) was the best-fitted model for production as compare to ARIMAX and GARCH model.

This research study made an attempt to examine the future behavior of production, Productivity, and per capita net availability of Pulses by using ARIMA and ARIMAX models and find out the best-fitted models based on different goodness of fit. Different parametric trend models i.e. linear, quadratic, exponential, logarithmic are also applied based on past information. With the application of Box-Jenkins methodology (1976), it has taken as a valuable process to utilize the forecast behavior of pulses data series. The study has also been attempted to compare the above methods with the help of actual data series.

MATERIAL AND METHODS

Data with respect production, productivity, and per capita net availability of pulses were obtained for the periods of 1951-52 to 2018-19 from the Directorate of Economics and Statistics, Department of Agriculture and Cooperation, Government of India. To develop the best models and subsequently to analyzed the forecast behavior, data for the whole period excepting the last four years are used to model development and last four years are used for model validation. Before analysis, as the study is dealing with time series, present data have been verified with measure central tendency and dispersion as well as to check the existence of outlier and randomness. Descriptive statistics is the term given to the analysis of data that helps to describe, show, or summarize data in a meaningful way. The selected descriptive measure i.e. means, standard error, standard

deviation, skewness, kurtosis, maximum, minimum, simple growth rate (SGAR%), and compound growth rate (CGAR%).

For detecting the existence outlier, Grubb's test is used in time series data and it is based on the assumption of normality. The outlier is expunged from the dataset and the test is iterated until no outliers are detected. However, multiple iterations change the probabilities of detection, and the test should not be used for sample sizes of six or fewer since it frequently tags most of the points as outliers. If an outlier is detected, one can choose to either exclude the value from the analysis or go for transformation of data or keep the outlier. The data were replaced by the median if only one outlier was detected, which is often referred to as robust (i.e. small variability) in the presence of a small number of outliers.

Some of the parametric and non-parametric trend models are tried to examine the trending behavior in the respective dataset under consideration. The models along with their equations are given below (Ray and Bhattacharyya 2016):

Linear model: $X_t = a + b_t + e_t$

Quadratic model: $X_t = a + b_t + ct^2 + e_t$

Power model: $X_t = at^b$

Exponential model: $X_t = a[Exp\ (b_t)] + e_t$

Logarithmic model: $X_t = a + b\ ln(t) + e_t$

In order to apply these models, $e_t \sim_{iid} N(0, \sigma^2)$. The testing of significance of the models and individual regression coefficient was tested by F test and t-test respectively.

ARIMA model: ARIMA stands for Autoregressive Integrated Moving Average Model, also known as Box-Jenkins (BJ) methodology (1976). The ARIMA Model Includes the combination of AR model, MA model, and ARMA model.

Autoregressive (AR) model): Let, the values of a process at equally spaced time epochs *t, t-1, t-2,….*by Z_t, Z_{t-1}, Z_{t-2},….., then $Z_t$can be described by the following expression:

$Z_t = C + \varphi_1 z_{t-1} + \varphi_2 z_{t-2} + \ldots\ldots\ldots + \varphi_p z_{t-p} + \varepsilon_t$

If autoregressive model of order *p* is denoted as

$\varphi(B) = 1 - \varphi_1 B - \varphi_2 B^2 - \ldots - \varphi_p B^p$,

Where *B* is the backshift operator such that $BZ_t = Z_{t-1}$, the autoregressive model can be written as $\varphi(B)\, Z_t = \varepsilon_t$.

Where, $\varepsilon_t \sim$ WN $(0, \sigma^2)$, *WN* indicating White Noise.

Moving average model (MA): z_t can also be modeled as a linear combination of white noise stochastic error terms. We call this type of model a moving average (MA) model. if z_t is considered as a weighted average of the uncorrelated $_t$'s, MA(*q*) moving average component of order *q*, which relates each z_t value to the *q* residuals of the *q* previous z estimates may be expressed as

$Z_t = e_t - q_1 e_{t-1} - q_2 e_{t-2} - \ldots - q_q e_{t-q}$

If we define a moving average operator of order *q* by

$\theta(B) = 1 - \theta_1 B - \theta_2 B^2 - \ldots - \theta_q B^q$

Where *B* is the backshift operator such that $BZ_t = Z_{t-1}$, the moving average model can be written as $Zt = \theta(B)\, \varepsilon_t$

ARMA model: The AR and MA models for stationary series to account for both past values and past shocks may be combined. Such a model is called an *ARMA (p, q)* model with *p* order AR terms and *q* order MA terms. Thus, an *ARMA (p, q)* model is written as

$Z_t = C + \varphi_1 z_{t-1} + \varphi_2 z_{t-2} + \ldots\ldots\ldots + \varphi_p z_{t-p} + \varepsilon_t - q_1 e_{t-1} - q_2 e_{t-2} - \ldots - q_q e_{t-q}$

Or $\varphi(B) Z_t = \theta(B)\, \varepsilon_t$

In practice, it is an obvious case that adequate representation of actual occurrence of stationary time-series can be obtained with autoregressive, moving average, and or mixed models, in which *p* and *q* are not greater than 2 and often less than 2.

ARIMA models: Mostreal-time series show a trend, an average increase or decrease over time which means that they are non-stationary *i.e.*, they are integrated. Series also show cyclic behavior. Trends and cycles can be removed from a series through differencing. By differencing several times and/or at different lags, most series can be converted to a stationary series, and then ARMA model for $\{Z_t\}$is applied. Thus, the combined model for the original univariate time series, which involves autoregression, moving average, and integration, is termed as ARIMA *(p, d, q)* if $\Delta^d Z_t = (1 - B)^d\, \varepsilon_t$

The model is written as

$\varphi(B)\,(1 - B)^d Z_t = \theta(B)\, \varepsilon_t$

Where $\varepsilon_t \sim$ WN $(0, \sigma^2)$, the difference *d* is non-negative integer.

If *d*=0, then ARIMA (*p, d, q*) = ARMA (*p, q*)

ARIMA model is carried out in three stages *i.e.* identification, estimation, and diagnostic checking. To identify the model of ARIMA (*p,d,q*) is based on the concepts of time-domain and frequency-domain analysis i.e. autocorrelation function (ACF), partial autocorrelation function (PACF), and spectral density function. The ACF (*k*) at lag *k* of the $\{Z_t\}$ series is the linear correlation coefficient between $\{Z_t\}$ and $\{Z_{t-k}\}$, calculated for *k* =0, 1, 2...

$$\rho_k = \frac{Cov(z_t, z_{t-k})}{\sqrt{Var(z_t)\,Var(z_{t-k})}}$$

The PACF is defined as the linear correlation between $\{Z_t\}$ and $\{Z_{t-k}\}$, controlling for possible effects of linear relationships among values at intermediate lags. Once the order of differencing has been diagnosed and the differenced univariate time series can be analyzed by the method of both time-domain and frequency-domain approach.

The appropriate *p, d,* and *q* values of the model and their

statistical significance can be judged by t-distribution to estimate the parameter of autoregressive and moving average terms in the model. The autocorrelations of the residuals are to be estimated for the diagnostic checking of the model. These are judged by Ljung-Box statistic under null hypothesis consideration that autocorrelation coefficient is equal to zero and the function is given by

$$LB = n(n+2)\sum_{k=1}^{m}\left(\frac{\hat{\rho}_k^{\,2}}{n-k}\right) \sim \chi^2_m$$

The stationarity requirement ensures that one can obtain useful estimates of the mean, variance, and ACF from a sample. If a process has a mean that is changing in each time period, one could not obtain useful estimates since only one observation available per time period. This necessitates testing any observed series of data for stationarity. Dickey and Fuller (1979) established the Augmented Dickey Fuller test was used to check the stationarity of time series in the present study.

Time series model with exogenous variable (ARIMAX) model: Nonlinear least square method employed to estimate the parameters of ARIMAX model. Following Bierens (1987), above equation can be written as follows;

$$y_t = \mu/\left(1+\sum_{s=1}^{r}\gamma_s\right)+\left[\left(\sum_{s=1}^{p}\alpha_s L^s+\sum_{s=1}^{p}\gamma_s L^s\right)/\left(1+\sum_{s=1}^{r}\gamma_s L^s\right)\right]$$

$$y_t+\left[\left(1+\sum_{s=1}^{q}\beta_s L^s\right)/\left(1+\sum_{s=1}^{r}\gamma_s L^s\right)\right]x_t+e_t$$

$$\theta_0 = (\mu,\alpha_1,\ldots..\ \alpha_p,\beta_1,\ldots.\ \beta_q,\gamma_1,\ldots..,\gamma_r)$$

$$z_t = (y_t, x_t), \phi(\theta_0) = \mu/(1+\sum_{s=1}^{r}\gamma_s)$$

The above equation can be written as an ARX model:

$$y_t = \varphi(\theta)+\sum_{s=1}^{\infty}\eta_s(\theta)z_{t-s}+e_t$$

Assuming that only $z_1 \ldots\ldots z_n$ are observed, nonlinear least square estimator of θ_0. e_t is an error term, and *p, q,* and *r* are natural numbers specified in advance.

The first step in building an ARIMAX model consists of identifying a suitable ARIMA model for the exogenous variable. The ARIMAX model concept requires testing for stationarity of exogenous variables before modeling.

The stationarity transformations in mean and variance were applied to the explanatory variable to ensure stationarity in mean and variance, if the series of the explanatory variable is not stationary. The cross-correlation function was used to determine the differencing order explanatory variable lags include in the model.

Cross-correlation function: The cross-correlation function (*ccf*) of two series is the product moment correlation, as a function of lag between the series and it is very helpful to identifying lags of the explanatory variable that might be useful to predictor variable. Thus cross-correlation function (*ccf*) is a basic exploratory tool, that could be employed in the identification process for time series with exogenous variable of ARIMAX model.

Theoretically, the h^{th} cross-correlation between two covariance stationary series $\{y_t\}$ and $\{x_t\}$ defined as (Adekanmbi et al 2017)

$$\rho_{yx,h} = \frac{E(y_t x_{t+h})-\mu_y\mu_x}{\sqrt{V(x_t)(Vy_t)}} = \frac{\gamma_{yx}(h)}{\sigma_y\,\sigma_x}$$

And

$$\rho_{xy,h} = \frac{E(x_t y_{t+h})-\mu_x\mu_y}{\sqrt{V(x_t)(Vy_t)}} = \frac{\gamma_{xy}(h)}{\sigma_y\,\sigma_x}$$

Where (x_t, y_t) represent a pair of stochastic processes that are jointly wide sense stationary. μ_x and σ_x are the mean and variance of the process $\{x_t\}$ and are constant over time due to stationarity. μ_y and σ_y are the mean and variance of the process $\{y_t\}$ and are also constant over time due to stationarity. $\rho_{x,y,h}$ and $\rho_{y,x,h}$ varies from -1 to +1.

Among the competitive ARIMA and ARIMAX models, the best fitted models are selected based on the maximum R^2, minimum value of Akaike's Information Criterion (AIC), Bayesian Information Criterion (BIC), Mean Error (ME), Root Mean Square Error (RMSE), Mean Absolute Error (MAE), and Mean Absolute Percentage Error (MAPE) (Ray and Bhattacharyya, 2019). Above the models, which has fulfilled most of the criteria is selected as best fitted model. Kolmogorov-Smirnov test and Shapiro-Wilk test was applied to check the normality and Run-test was used for checking the randomness of the residuals for best fitted models (Das *et.al.* 2019*)*. Statistical analysis was done by using SAS, SPSS and Excel software.

RESULTS AND DISCUSSION

Being the world's largest producer of pulses, *per se* performance of production, productivity, and per capita net availability was shown in Table 1. The production under India varies from 8.35 million tonne to 25.40 million tonnes, registering simple growth rate 2.58 percent per year during the study period. Average production under pulses being 13.14 million tonnes with leptokurtic and positive skewness in nature says that maximum changes in production has taken

place during early half of the period and remained almost same in latter half. The yield varied from 377.00 kg/ha to 853.00 kg/ha during the study period with registering growth rate 1.20 percent per annum. Positive kurtosis along with positive skewed nature under productivity indicates that maximum shift has occurred at early stage under study period and almost remained same in latter half. Per capita net availability of pulses varied from 10.60 kg/year to 27.30 kg/year registering a vary minimum growth rate 0.02 percent per year during the study period. Average net availability of pulses being 16.78 kg/year with positive skewness and negative kurtosis indicated that a decreasing order during early half of the study period and it's remained steady for long time. There is a significant outlier under production dataset was noticed in 2017-18, $Z_{cal} = 3.653 > Z_{tab} = 3.252$; hence it has been treated as typological error and replaced by median of the series. There was no extreme observation (*i.e.* outlier) present in case of productivity and net availability data series.

Before analysing by time series ARIMA and ARIMAX model, five parametric regression model were also fitted on the data series and the values of the precision coefficients were given in Table 2. Quadratic and Exponential model performed well for production and productivity data series on the basis of maximum R^2, minimum value of RMSE, AIC and SBC. For per capita net availability data series, Quadratic

Table 1. Per se performance of pulses production, yield and net availability

	Production (MT)	Yield (Kg ha^{-1})	Net availability (Kg year^{-1})
Mean	13.143	556.000	16.767
Standard error	0.404	12.201	0.530
Standard deviation	3.355	101.345	4.399
Kurtosis	3.335	0.748	-0.387
Skewness	1.647	0.916	0.798
Minimum	8.350	377.000	10.600
Maximum	25.400	853.000	27.300
Grubb's test (Outlier) Critical value- 3.252	Yes	No	No
CAGR%	1.492	0.878	0.020
SGAR%	2.578	1.200	0.020

Note: MT- Million tonne

Table 2. Parametric trend of production, productivity and net availability

Production (Million tonne)							
					Parameter estimation		
	R^2	RMSE	AIC	SBC	Constant	b1	b2
Linear	0.583	2.149	111.624	118.326	8.673	0.128	
Logarithmic	0.358	2.669	141.487	148.189	5.906	2.208	
Quadratic	0.744	1.687	80.106	89.043	11.787	-0.135	0.004
Power	0.419	2.614	138.650	145.356	7.505	0.163	
Exponential	0.623	2.056	105.418	112.121	9.337	0.009	
Productivity (Kg ha^{-1})							
					Parameter estimation		
	R^2	RMAE	AIC	SBC	Constant	b1	b2
Linear	0.693	55.719	560.803	567.506	408.788		
Logarithmic	0.423	79.451	604.459	611.161	318.424		
Quadratic	0.814	43.347	528.154	537.091	490.549	-2.703	0.099
Power	0.441	74.239	600.406	607.108	360.339		
Exponential	0.697	52.813	553.427	560.129	424.534		
Net availability (Kg year^{-1})							
					Parameter estimation		
	R^2	RMAE	AIC	SBC	Constant	b1	b2
Linear	0.414	3.342	172.517	179.219	21.707	-0.141	
Logarithmic	0.539	2.967	156.054	162.757	28.400	-3.552	
Quadratic	0.773	2.081	109.149	118.086	27.814	-0.657	0.007
Power	0.512	3.098	162.037	168.739	30.960	-0.197	
Exponential	0.402	3.230	167.808	174.510	21.415	-0.008	

and Logarithmic model performed well basis of goodness of fit. Quadratic model was superior to other best fitted regression models based on goodness of fit criteria models. All the time series data might be following a quadratic growth pattern.

After checking the parametric trend model and outlier of each data series, analysed the forecast behavior for the years to come. ARIMA and ARIMAX techniques were used under study as discussed in the material and methods section. At first stationarity of all data series were tested by Augmented Dickey Fuller (ADF) test (Prabakaran and Sivapragasm 2014). ADF test for unit root confirmed that all the data series of production, productivity and net availability were non-stationarity at the level point and became stationary at first difference as the calculated values were lesser than critical values at 5 percent levels of significance (Table 3). It was also supported by the trend of time series plot at first difference *i.e.d*=1 and correlogram of ACF and PACF plot given for all data series in Figure 1. From correlogram of ACF and PACF, it was observed that there was only one significant spike for ACF and PACF at lag 1 under the production and net availability data series. In case of productivity data set, two significant spicks for ACF at lag 1 and lag 12 and for PACF at lag 1 and lag 2 were present (Fig. 1).

After checking the stationarity, various ARIMA and ARIMAX models were tried for each data series and only best

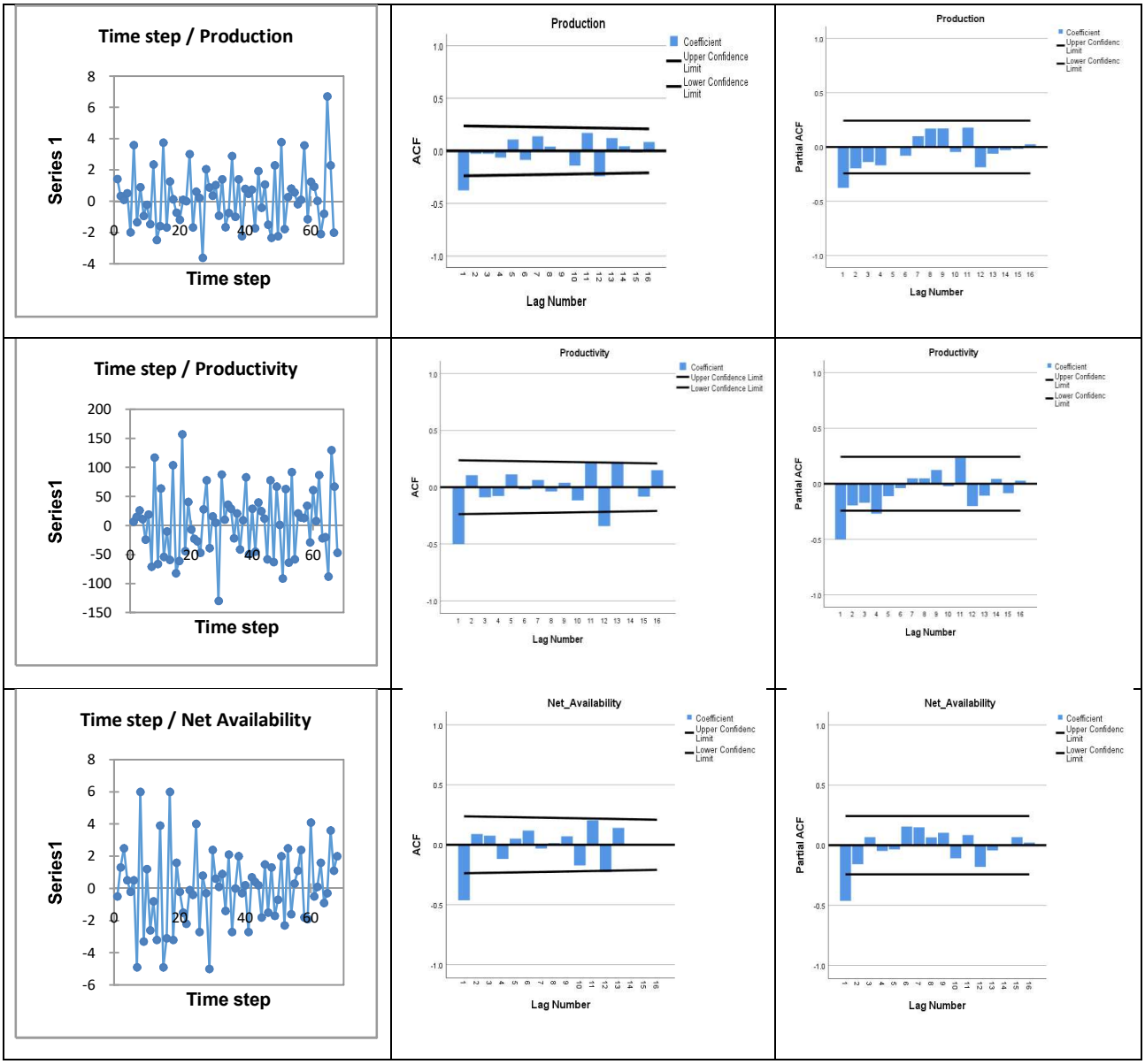

Fig. 1. Graphical representation of data set and correlogram of ACF and PACF after differencing

fitted models among the competitive model for each series were selected (Table 5). ARIMA (*p,d,q*) model such as (1,1,1), (1,1,2), (1,1,3) and (1,1,4) were compared and one can find out that ARIMA (1,1,4) fitted well for pulses production data series based on minimum values of RMSE, MAPE, AIC SBC and high R^2 value. For productivity data series best ARIMA (*p,d,q*) model *i.e.* (2,1,4), (3,1,4), (4,1,2) and (4,1,4) were compared and one can find that ARIMA (4,1,2) was the best fitted ARIMA model based on goodness of fit criterion, specially minimum values of RMSE, AIC and SBC. ARIMA model for net availability, (1,1,2), (2,1,1), (3,1,2) and (2,1,3) were found for best competitive model for each other and one can say that ARIMA (1,1,2) was best fitted ARIMA model following most goodness of fit criterion. The Ljung-Box Q test of residuals for every competitive ARIMA model for all data series were worked out and there are no autocorrelation present in residuals for all ARIMA models as calculated value Q_{cal} < critical value of χ^2 (Table 5).

Before constructing ARIMAX model, cross-correlation function (CCF) was worked out to check the relationship of pulses production, productivity and net availability along with the population (Table 4 and Fig. 2). It was observed that there was no significant relationship present between net availability and production as well as net availability and productivity as the lags from 7 to -7. But the series between net availability and population have shown strong negative

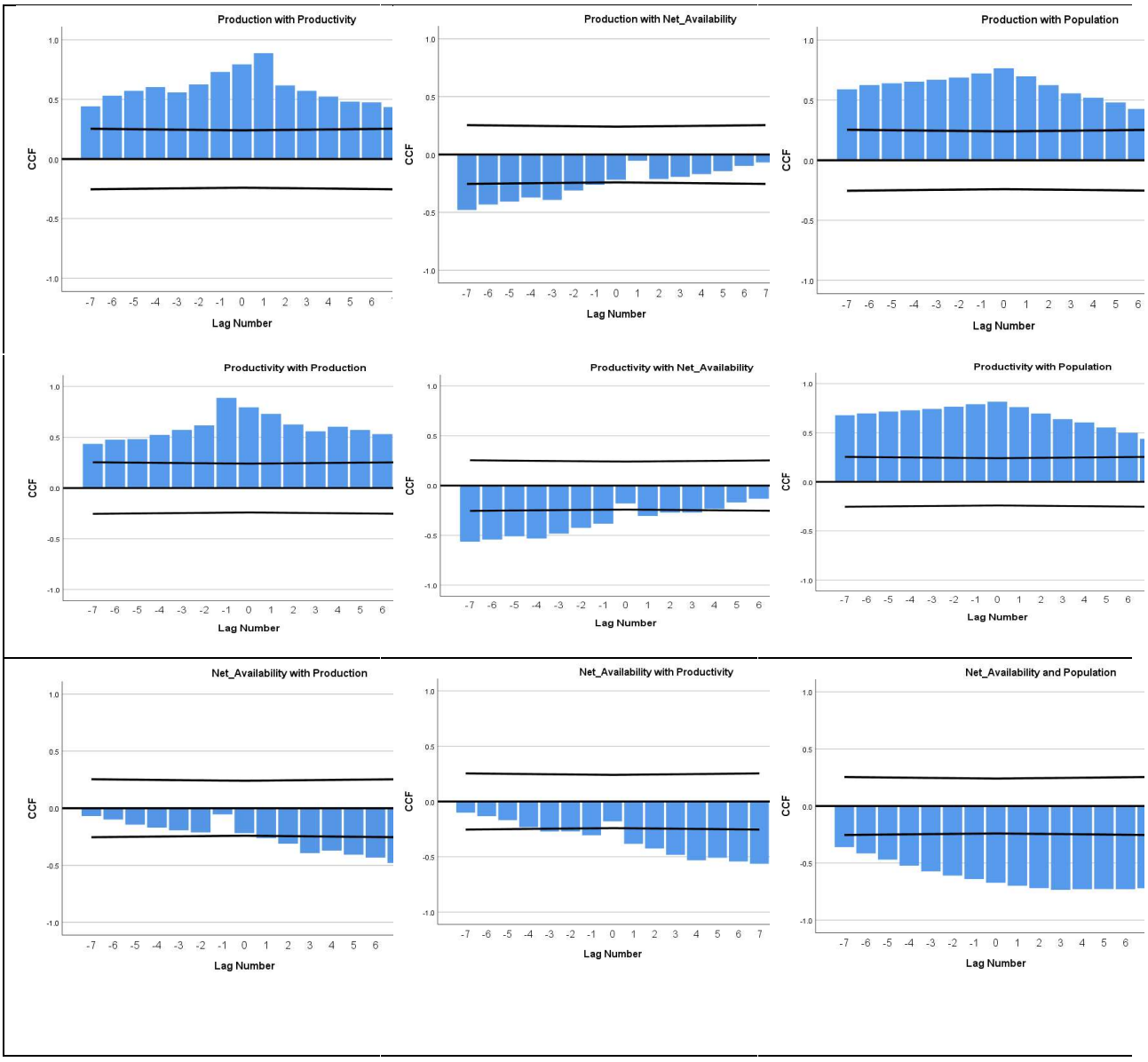

Fig. 2. Testing the significance of Cross Correlation Function (CCF) with production, productivity, Net availability, population data sets

cross-correlations at lag *h*= 5, *r* = -0.728 and at lag *h*= 6, *r* = -0.729, so that both data series fit to ARIMAX model for net availability. There were a strong positive cross-correlation between production and productivity at lag *h*=1, *r*= 0.888 and at lag *h*= 0, *r*= 0.795 and between production with population, productivity with production, and productivity with population. ARIMAX model for productivity therefore worked out with production and population data series as explanatory variables (Table 4 & Fig. 2). Different competitive ARIMAX models were tried to find the best fitted model for all data series and ARIMAX (1,1,1) model for production, ARIMAX (0,1,1) model for productivity and ARIMAX (3,1,2) selected as best fitted model based on maximum value of R^2, minimum values of RMSE, MAPE, MAE, AIC and SBC (Table 5). The Ljung-Box Q test of residuals for every ARIMAX model for all data series were worked out and it was observed that there are no autocorrelation present in residuals for all ARIMAX models as calculated value Q_{cal}< critical value of χ^2 (Table 5).

In the present study, all ARIMA and ARIMAX models were compared to each other for all data series of pulses and among all possible model ARIMAX (1,1,1) model for production, ARIMAX (0,1,1) model for productivity, ARIMA (1,1,2) model for net availability were selected as best fitted model on the basis of goodness of fit criterion (Table-5). All autocorrelation and partial autocorrelations lie between 95% control limit, which confirmed the 'good fit' of the selected models (Fig. 3).

For checking normality of residuals. Kolmogorov-Smirnov test and Shapiro-Wilk test were performed, which confirmed that the selected models' residuals follows normal distribution as the probability value was greater than the 5 percent level of significance (*i.e.*>0.05) (Table 6). For checking the randomness of residuals, Run test was applied and it was observed that the probability value was greater

Table 3. ADF test for stationarity check

	Production		Productivity		Net availability	
	Level	Diff 1	Level	Diff 1	Level	Diff 1
Tau (Observed value)	0.518	-4.754	-0.893	-6.124	0.732	-5.261
Tau (Critical value)	-3.412	-3.408	-3.412	-3.423	-3.412	-3.423
p-value (one-tailed)	0.997	0.001	0.930	< 0.0001	0.998	0.002
alpha	0.05	0.05	0.05	0.05	0.05	0.05

Table 4. Cross correlation between production, productivity, net availability and population

Lag	Production with productivity	Production with Net availability	Production with population	Productivity with production	Productivity with Net availability	Productivity with population	Net availability with production	Net availability with productivity	Net availability with population
	Cross correlation	Cross correlation	Cross correlation	Cross correlation	Cross correlation	Cross correlation	Cross correlation	Cross correlation	Cross correlation
-7	0.442	-0.479	0.590	0.435	-0.563	0.678	-0.068	-0.101	-0.360
-6	0.532	-0.432	0.626	0.476	-0.542	0.696	-0.099	-0.132	-0.415
-5	0.573	-0.407	0.640	0.482	-0.509	0.716	-0.143	-0.169	-0.470
-4	0.604	-0.371	0.654	0.524	-0.532	0.728	-0.170	-0.233	-0.523
-3	0.559	-0.393	0.671	0.573	-0.483	0.743	-0.193	-0.271	-0.573
-2	0.626	-0.311	0.689	0.618	-0.425	0.765	-0.212	-0.271	-0.610
-1	0.731	-0.261	0.723	0.888	-0.383	0.791	-0.054	-0.305	-0.640
0	0.795	-0.218	0.765	0.795	-0.180	0.816	-0.218	-0.180	-0.672
1	0.888	-0.054	0.699	0.731	-0.305	0.761	-0.261	-0.383	-0.699
2	0.618	-0.212	0.625	0.626	-0.271	0.695	-0.311	-0.425	-0.720
3	0.573	-0.193	0.557	0.559	-0.271	0.639	-0.393	-0.483	-0.735
4	0.524	-0.170	0.521	0.604	-0.233	0.605	-0.371	-0.532	-0.729
5	0.482	-0.143	0.481	0.573	-0.169	0.554	-0.407	-0.509	-0.728
6	0.476	-0.099	0.427	0.532	-0.132	0.497	-0.432	-0.542	-0.729
7	0.435	-0.068	0.373	0.442	-0.101	0.438	-0.479	-0.563	-0.721

than the 5 percent level of significance (*i.e.*>0.05) indicating residuals for all selected models were distributed independently (Table 6).

Finally, forecasting was done for pulses production, productivity and per capita net availability of India from 2016 to 2025 by using best fitted models, where first four years used for validation of the model can be regarded as in sample forecast and last six years data were used for prediction purpose known as out sample forecast (Ray et al 2016, Dhekale et al 2017) (Table 7). The forecasted figure for

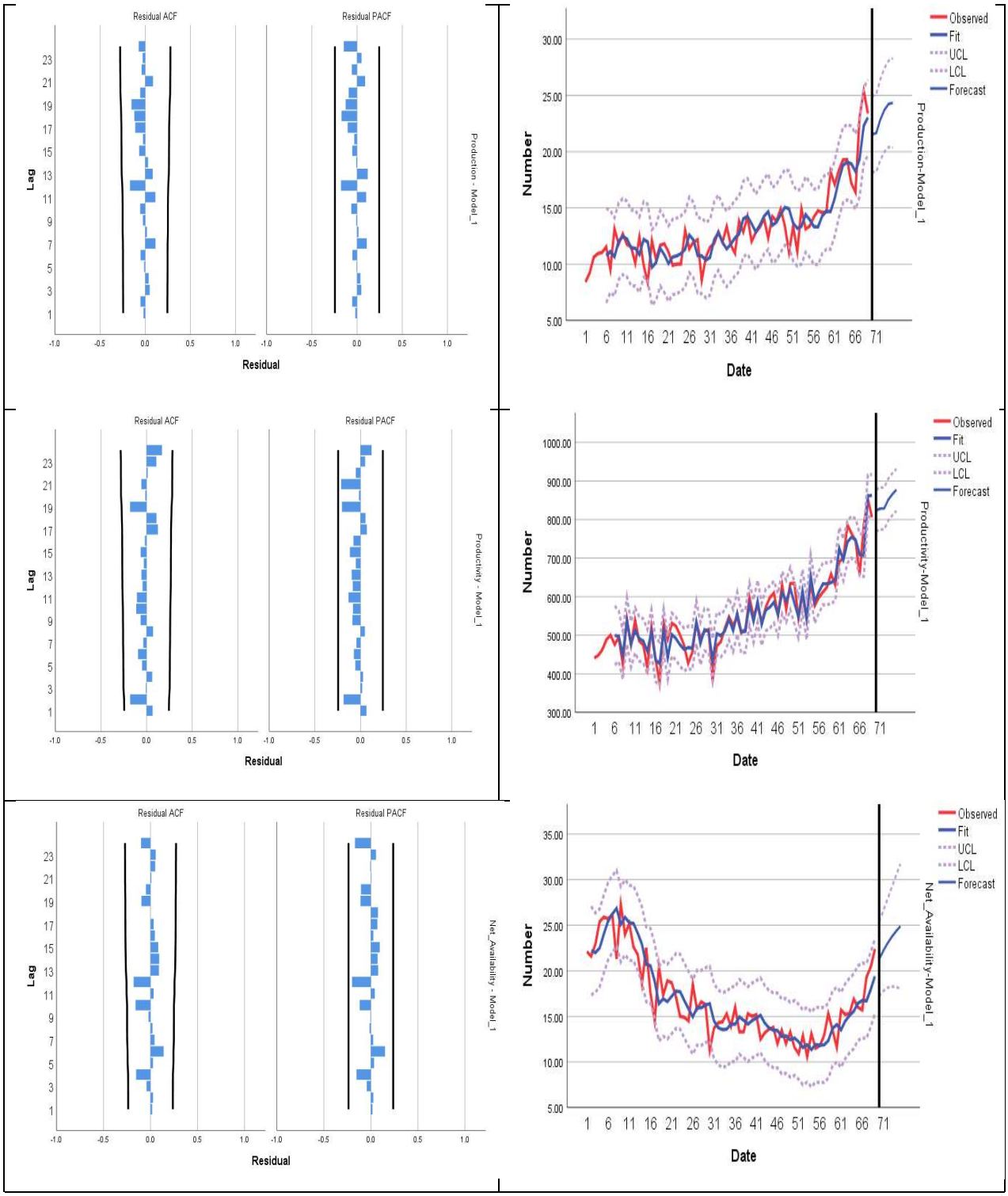

Fig. 3. Residuals of ACF, PACF and forecasted graph of Best fitted ARIMA and ARIMAX model

Table 5. ARIMA and ARIMAX model for production, productivity and per capita net availability

Production	Goodness of fit						Ljung-Box Q (18)			
	R^2	RMSE	MAPE	MAE	AIC	SBC	Statistic	DF	Critical value	Sig
ARIMA (1,1,1)	0.751	1.688	9.696	1.238	76.123	85.059	14.810	16	26.30	0.539
ARIMA (1,1,2)	0.755	1.685	9.592	1.224	76.848	88.018	19.159	15	25.00	0.207
ARIMA (1.1.3)	0.765	1.663	9.890	1.225	75.911	89.316	13.679	14	23.69	0.474
ARIMA (1,1,4)	0.770	1.659	9.531	1.202	76.529	88.168	10.652	13	22.36	0.640
ARIMAX (1,1,1)	0.793	1.677	8.949	1.138	59.822	68.759	8.835	16	26.30	0.920
Productivity	Goodness of fit						Ljung-Box Q (18)			
	R^2	RMSE	MAPE	MAE	AIC	SBC	Statistic	DF	Critical value	Sig
ARIMA (2,1,4)	0.786	49.053	6.509	34.638	544.716	562.589	12.075	12	21.03	0.440
ARIMA (3,1,4)	0.792	48.723	6.761	35.793	544.646	564.753	10.810	11	19.68	0.459
ARIMA (4,1,2)	0.794	48.047	6.768	35.859	541.858	554.731	11.456	12	21.03	0.490
ARIMA (4,1,4)	0.798	48.473	6.812	36.056	544.776	567.117	9.427	10	18.31	0.492
ARIMAX (0,1,1)	0.937	27.574	3.443	18.888	446.816	453.518	9.646	17	27.59	0.918
Net availability	Goodness of fit						Ljung-Box Q (18)			
	R^2	RMSE	MAPE	MAE	AIC	SBC	Statistic	DF	Critical value	Sig
ARIMA (1,1,2)	0.788	2.064	9.547	1.553	104.782	115.953	10.989	15	25.00	0.753
ARIMA (2,1,1)	0.782	2.092	9.716	1.578	106.678	117.849	8.932	15	25.00	0.881
ARIMA (3,1,2)	0.797	2.055	9.438	1.551	106.013	121.652	7.119	13	22.36	0.896
ARIMA (2,1,3)	0.788	2.099	9.586	1.559	108.919	124.558	8.883	13	22.36	0.782
ARIMAX (3,1,2)	0.799	2.072	9.629	1.568	104.672	119.311	9.271	13	22.36	0.752

Table 6. Normality and randomness test of residuals of best fitted models

	Tests of normality				Runs Test		
	Kolmogorov-Smirnov[a]		Shapiro-Wilk				
	Statistic	Sig.	Statistic	Sig.	Z-Statistic	No. of Runs	Sig.
Production ARIMAX (1,1,1)	0.084	0.200	0.985	0.633	0.01	33	0.901
Productivity ARIMAX (0,1,1)	0.081	0.200	0.977	0.270	-0.504	31	0.614
Net availability ARIMA (1,1,2)	0.067	0.2	0.98	0.343	-0.244	34	0.807

Table 7. Model validation and forecasting for production, productivity and net availability of pulses with best fitted models

Year	Production (MT) ARIMAX (1,1,1)				Productivity (kg ha^{-1}) ARIMAX (0,1,1)				Net availability (kg $year^{-1}$) ARIMA (1,1,2)			
	Actual	Predicted	LCL	UCL	Actual	Predicted	LCL	UCL	Actual	Predicted	LCL	UCL
2016	16.40	18.23	14.88	21.59	656.00	708.78	654.38	763.18	15.70	16.75	12.64	20.85
2017	23.10	19.35	16.00	23.71	786.00	706.72	652.32	761.11	19.30	16.70	12.59	20.81
2018	25.40	22.31	18.96	25.67	853.00	861.35	806.96	915.73	20.40	17.95	13.84	22.05
2019	23.40	23.03	19.68	26.39	806.00	862.50	805.12	916.88	22.40	19.40	15.30	23.51
2020		21.55	18.19	24.90		823.38	769.01	877.75		21.29	17.18	25.39
2021		21.65	18.20	25.11		828.45	774.08	882.83		22.22	17.80	26.64
2022		22.86	19.27	26.45		829.01	774.64	883.39		23.03	18.15	27.91
2023		23.72	20.00	27.44		851.66	797.28	906.03		23.74	18.27	29.2
2024		24.25	20.41	28.10		865.95	811.58	920.33		24.35	18.23	30.48
2025		24.34	20.37	28.31		877.36	822.98	931.73		24.89	18.05	31.73

Note: MT- million tonne. LCL= Lower Control Limit, UCL= Upper Control Limit

production, productivity and net availability were captured in Figure 3 and that actual and predicted values were closely related and predicted values were lies within the 95% confidence intervals. From the forecasted values, can conclude that for few coming years production, productivity and net availability of pulses will follow in increasing trend. For pulses production, it has been estimated as 24.34 million tonnes in 2025, whereas for pulses productivity 877.36 kg/ha has been estimated in 2025. In case of net availability of pulses, it has been estimated as 24.89 kg/year in 2025 with steady increasing order.

CONCLUSION

Time series analysis for forecasting may be regarded as a useful practice to develop an appropriate econometric model for estimating future behavior on the basis of previously observed behavior. ARIMAX (1,1,1) model for pulses production, ARIMAX (0,1,1) model for productivity and ARIMA (1,1,2) model for net availability were found as most appropriate among other competitive models and hence, forecasting behavior has been studied for pulses production, productivity and net availability of India. This present study can be play vital role to with future food security scenario and planning for policy makers in India. Steady increasing pattern of pulses availability may take a serious concern which may be improved by better management practice, technological improvement, high government policies *i.e.* agricultural funding, price support programmes etc. and enhancing relationship between farmers and researcher maybe an important factor in sustaining and improvement the behavior of crop production trend for long term.

REFERENCES

Bierens HJ 1987. ARIMAX model specification testing with an application to unemployment in the Netherland. *Journal Econometrics* **35:** 161-190.

Bolanle ADM and Oluwadare A 2017. ARIMA and ARIMAX Stochastic models for fertility in Nigeria. *International Journal of Mathematics and Computer Application Research* **7**(5): 1-20.

Received 04 July, 2020; Accepted 15 October, 2020

Box GEP and Jenkins GM 1976. *Time Series Analysis: Forecasting and Control*. Holden-Day, San Francisco, p 575.

Das SS, Ray S, Sen A, Siva GS and Das S 2019. Statistical study on modelling and forecasting of jute production in West Bengal, India. *International Journal of Current Microbiology and Applied Science* **8**(7): 1719-1730.

Dhekale BS, Sahu PK, Viswajith KP and Mishra P 2017. Analysis of growth, instability, modelling and forecasting of cotton production scenario in India. *Indian Journal of Economic and Development* **13**(2a): 211-216.

Dickey DA and Fuller WA 1979. Distribution of estimators for Autoregressive Time Series with a unit root. *Journal of American Statistical Association* **74**: 427-431.

FAO (Food and Agriculture Organization) 2018. FAOSTAT. United Nation.

Gooijer JGD and Hyndman RJ 2006. Twenty five years of time series forecasting. *International Journal of Forecasting* **22:** 443-473.

GoI (Government of India) 2011. Office of the Registrar General and Census Commissioner India, Ministry of Home Affairs, Government of India, New Delhi.

Hamjah MA 2014. Climatic Effects on Major Pulse Crops Production in Bangladesh: An Application of Box-Jenkins ARIMAX Model. *Journal of Economics and Sustainable Development* **5**: 14-20.

Prabakaran K and Sivapragasam C 2014. Forecasting areas and production of rice in India using ARIMA model. *International Journal of Farm Science* **4**(1): 99-106.

Ray S and Bhattacharyya B 2019. Statistical modeling and forecasting of ARIMA and ARIMAX models for food grains production and net availability of India. *Journal of Experimental Biology and Agricultural Science* **8**(3): 296-309.

Ray S, Bhattacharyya B and Pal S 2016. Statistical Modeling and forecasting of food grains in effects on public distribution system: An application of ARIMA model. *Indian Journal of Economic and Development* **12**(4): 739-744.

Ray S and Bhattacharyya B 2016. A Statistical Investigation on Food Consumption Pattern in India. *Journal of Crop and Weed* **12**(3): 47-54.

Reddy A A 2009. Pulses production technology: Status and way forward. *Economic and Political Weekly* **44**: 73-80.

Vishwajith KP, Sahu PK, Mishra P, Devi M, Dubey A, Shingh RB, Dhekale BS, Fatih C and Suman 2019. Modelling and forecasting of mung production in India. *Current Journal of Applied Science and Technology* **34**(1): 1-19.

Vishwajith KP, Dhekale BS, Sahu PK, Mishra P and Noman Md. 2014. Time series modelling and forecasting of pulses production in India. *Journal of Crop Weed* **10**: 147-154.

Yaziz SR, Ahmad MH, Nian LC and Muhammad N 2011. A comparative study on Box-Jenkins and GARCH models in forecasting crude oil prices. *Journal of Applied Sciences* **11**: 1129-1135.

Indian Journal of Ecology (2020) 47(4): 1150-1157

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Carryover and Dissipation of Imidazolinone Herbicides Application and their Effect on Succeeding Following Crops: A Review

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Abstract: The persistence of herbicides in the soil depends on numerous factors such as organic matter, soil pH, herbicides doses, soil temperature, and soil moisture. These factors are responsible for rapid degradation of herbicides in soil. These residues are damaging non-tolerant crops cultivated in succession. Imidazolinone has a long persistence in the soil, which can cause phytotoxicity damage in none-tolerant crops, contaminate surface, and groundwater sources. The restricted knowledge, the lack of warning, and periods of limitations in the instructions for use of herbicides sold for sensitive crops grown in succession lead to the occurrence of a major damage to most cultivation fields. Imidazolinone residues in the soil which can cause unacceptable injury, in vegetable or others crops, can also decrease plants growth and productivity; leading to more heavy loss that may lead the farmer to leave his land. This review aims to elucidate information pertaining to imidazolinone herbicides residues, to explain the carryover effect in most vegetable crops, to understand the conspecific nature resistance mechanism, and to point out some sustainable techniques for the shift down imidazolinone herbicides residues in the soil.

Keywords: Imidazolinone, Carry over, Residues, Herbicide, Environment

The world population is increasing dramatically and this leads to increase the demand on food worldwide especially crop calories; therefore, methods have been sought aiming to increase crops productivity. One of these methods is the increasing use of herbicides family which plays an essential role in higher crop production by killing or restraining a variety of weeds which are the main biological constraint to the production (Mahesh et al 2016), and it is considered as one of the most important factors affecting crop yields. Therefore, persistence of herbicides in soil field could be useful due to shifting the effectiveness of control of weeds (Mohammad 2019). However, at the same time herbicides persistence for a long time in the soil may lead to an adverse impact, because the chemical and biochemical process may potentially affect the next crop (carry over) cultivated on the same field. In addition, contaminating both surface and groundwater through leaching and runoff processes can occur (Sondhia et al 2015). However, the use of herbicides has become irreplaceable for controlling different weeds in cultivated lands, due to the increasing labours cost in almost all parts of the globe. Because of intensive research in herbicide production field, many new types of herbicides are available to cater the farmers need. Worldwide consumption of herbicides is 44%, insecticides 22%, fungicides 27%, and others 7% (Sondhia 2014). The process of action of herbicides is often classified regarding their chemical process affected, diffusion inside the tissues of plants, site of action, target enzyme. Therefore, herbicides within the same family and the mode of action will give similar output results on target plants. Here we offer the commonly used herbicides, and their mode of action are shown in (Table 1).

Herbicides are part of pesticides that play an important role to achieve high productivity percentage due to the control weed plants to acceptable levels while not affecting the yield (Bzour et al 2018). During the last two decades, the introduction of herbicide resistant crops has moved to new types of non-transgenic resistant crops, as the imidazolinone resistant crops. This came concurrently with using the imidazolinone herbicide which has been used extensively in the past 20 years under the assumption that side effects were low. In addition, it is considered as the most persistent types of polar herbicides, have a broad spectrum of weed control activity and are used in Clearfeld® production systems (CPS) (Bzour et al 2018). Imidazolinone herbicides was introduced in the 1970's in the United States by the American Cyanamid Company. It is characterized by their low doses (100-200 g ha^{-1}) in the soil when compared with other pesticides classes, and low toxicity effects on mammals. Imidazolinone herbicides are assumed to be environmentally safe (Ramezani et al 2009), high level of soil persistence, and a wide spectrum of weed control (Alister and Kogan 2005). However, they are still an environmental concern due to their

Table 1. Commonly used herbicides with their mode of action

Mode of action	Example
Amino acid synthesis inhibitors	Imazethapyr, Glyphosate
Lipid synthesis inhibitors	Cyclohexanediones
Seedling growth inhibitors	Pendimethalin, Alachlor
Photosynthesis inhibitors	Atrazine, Metribuzin
Cell membrane disruptors	Paraquat
Growth regulators	2,4-D, 2,4,5-T, Dicamba
Pigment synthesis inhibitor	Bromoxynil

*Adapted with permission from (Ranjan et al 2020)

anionic character, being very mobile in the soil and easily leached into high depth (Souza 2020). Ibrahim et al. (2017) pointed that, imidazolinone herbicides was toxic to human, animals and its residual activity in soil up to 18 weeks after application in the field. Application of the imidazolinone herbicides is currently becoming more popular in most planting areas worldwide. The Imidazolinone family include a group of herbicides, comprising of imazapic, imazapyr, imazamox, imazethapyr, imazamethabenz, and imazaquin (Grey et al 2012). Imidazolinone residual herbicides are those that control weeds in the fields in different seasons because of persistence of bioactive residues in the soil. Herbicide residue that remains in soil field when the next crop is planted is termed herbicide carryover. It works as a selective herbicide that inhibits the acetolactate synthase (ALS) gene and branched chain of three amino acids: valine, isoleucine, and leucine (Shivrain et al 2009). In addition, Imidazolinone herbicide ceases protein production, thereby slowing down the plant's cell division rate and disturb the movement of essential materials to the growth points. Eventually, it causes a decrease in whole plant growth and inflicting the plant to slowly die (Bzour et al 2018). Therefore, information to establish guidelines to decrease the negative impacts of the imidazolinone herbicides residues on non-target organisms, and the environment is required. In this light, the aim of this review is discussing aspects of the imidazolinone herbicide behavior in soil and water; in addition, to determining the soil residual effects on rotation crops and vegetable, as well as presenting possible strategies to reduce the residual herbicides in soil.

Imidazolinone persistence and carryover effect for crops following cultivation in the field: Imidazolinone herbicide is relatively persistent in soil, with a half-life about three months; however, it depends on the type (Kemmerich et al 2015). As example, for imazapyr herbicide range is 34-65 days, while imazapic has a half-life of 3 months (Michael and Neary 1993); imazethapyr herbicide has plant injury was still present at about 705 days after application (Moraes et al 2011). The practice crop rotation is growing diverse crops with the systemic way on the same specific land. on the contrary, the monoculture of one or limited crop is planted in all seasons of the year which encourages the infested weeds to grow with high density (Power and Follett 1987). Reports revealed that the yield production is shift up during the crop rotation, and sometimes the percentages increase about 10-15% or higher that. It is commonly used in the production fields, and it gives a great benefit to the field (Christiane et al 2016). However, the use of imidazolinone herbicides with long residual effect on the previous crops can damage growth and development of sensitive vegetables crops in succession. The movement of imidazolinone herbicide is defined as the transport and flow of the herbicide in the pores of the soil (Christoffoleti et al 2008), which may occur by volatilization, absorption, leaching, and run-off (regards to its spiral movement on soil surface) (Fig. 1). In the same vein, imidazolinone herbicide residues in the soil may be adsorbed or leached at different levels. A lot of factors control the leaching process as the physicochemical properties of the soil, encompassing solubility, organic matter, and the pH of the soil (Süzer and Büyük 2010). The rainfall index is an important factor for determining this type of herbicide leaching (Bzour et al 2017).

Assalin et al (2014) revealed that the pH value of this type of herbicides more than 6 leads the imidazolinone herbicides to be weakly adsorbed into the soil particles in the field. In addition, is the type of the soil texture. Imidazolinone sorption shifts up alongside clay soil content due to increase bindings of the herbicide to soil particles. (Bzour et al 2017). The residues of herbicides may refer to a small trace amount of the herbicides that may remain on the surfaces or leached to the soil and water. Residual herbicides are those for which season-long weed control are expected due to their persistence in soil. Some herbicides applied to the cultivated crop can carry over and injure vegetable crops grown the following year due to high residues in the soil, so by increasing the concentration of the herbicides, it will lead to more residues in the soils and water as well as more carryover on rotation plants. Imidazolinone herbicide is a class of herbicide relatively persistent in soil (Baohong & Shaoyi 2001). Pinto et al (2009) revealed that, in Southern Brazil, ryegrass crop is usually planted as succession plants, in winter, following rice, and there are many problems related carryover effects and residues imidazolinone herbicides in soil on ryegrass. The behavior of herbicides in the environment is affected mainly by degradation, sorption, and movement processes (Yavari et al 2020). Greenland (2003) shows that, the percentage of injury from herbicide residues, persistence, and degradation is controlled by many factors, including the soil properties, rainfall, microbial activity,

following vegetable crop, the type herbicide used, tillage depth, the dosage used, temperature and the moisture (Norsworthy and Young 2020). Degradation process is a major process that influences the fate of herbicides in soil and water environments (Fig. 2). Flint and Witt (1997) pointed that, microbial degradation mechanism is considered as one of the main processes for imidazolinone dissipating. For example, the degradation of imidazolinone was about 4.5 times slower in sterile soils, when compared 100% of the herbicides were degraded in non-sterile soils (natural conditions) (Wang et al 2005).

However, the massive usage of these herbicides in the agriculture may lead to the huge effect on the environment. Nonetheless, increasing used herbicides contaminate our water and soil and create a new type of what called resistant weed. Traces of imazapyr were also found in groundwater eight years after its application to control weed plants on Swedish railway embankment (Börjesson et al 2004). This could lead to be transported outside the root absorption region, by leaching or runoff, and can contaminate the surface or subsurface water sources. These residues could be also interred and reach our food chain (Tariq et al 2007) and can bio accumulate, reach, and affect the biodiversity. In the same context, Jourdan et al (1998) revealed that, after three months, imazethapyr was detected in the soil (from 5 to 10 cm). A lot of previous studies were evaluated the carryover effect of imidazolinone herbicides applied in preceding crop (Table 2).

Weedy rice resistance: Rice (*Oryza sativa L.*) is the most important and major food grain in the world. There are many constraints for successful production of crops (Prakash et al 2019). The enormous overuse of a single herbicide multiple time as imidazolinone in a growing season is leading to a 'naturally' acquired resistance to this herbicide. As for the (ALS) gene, point mutations making the enzyme, and consequently the plant, resistant to ALS-inhibiting herbicides especially weedy rice (Bourdineaud 2020). Weedy rice, the dominant weed of rice paddies, occurs in rice-growing areas all over the world and causes severe yield losses. In the recent research on the emergence weedy rice which morphologically looks like commercial cultivated rice in worldwide. It is characterized by a set of attributes such as severe seed shattering, a red pericarp, and especially in height leading weedy rice almost unrecognizable (Mispan and Baki 2008). In the same vein, one of these traits are tillering capacity, and some types have fewer tillering, but the majority have high tillering, so it bears more panicles, rapid vegetative growth, taller than rice cultivar, its leaves take long time to drop, has high ability in fertilizer absorption, high shattering seeds and variable seeds dormancy as per in (Fig. 3).

Weedy rice species need selective chemical control which is sometimes not easily achieved. In South Asia as there are complications and the serious effect of continuous use of imidazolinone herbicides for controlling the weedy rice in the fields and the gene flow to weedy rice is a rapid exchange. Therefore, this leads to accelerate the weedy rice resistant in the field (Bzour et al 2018). Weedy rice treated with herbicides is capable of resisting its effects after a certain level of exposure, and will go on to produce new seeds that will grow into a species with different (more resistant) features (Gressel & Valverde 2009). Globally, the weedy rice have shown high phenotypic diversity in weedy population, both within and among geographical regions (Sudianto et al 2016) and is highly more difficult to control compared to other types of weeds in rice fields (Baki and

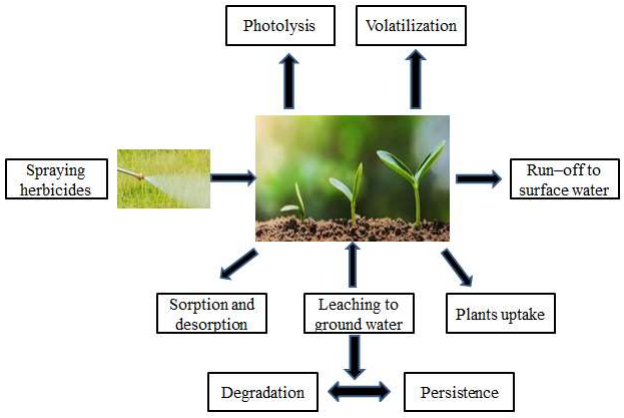

Fig. 1. Diagram represents the most herbicides behavior in soil during field application

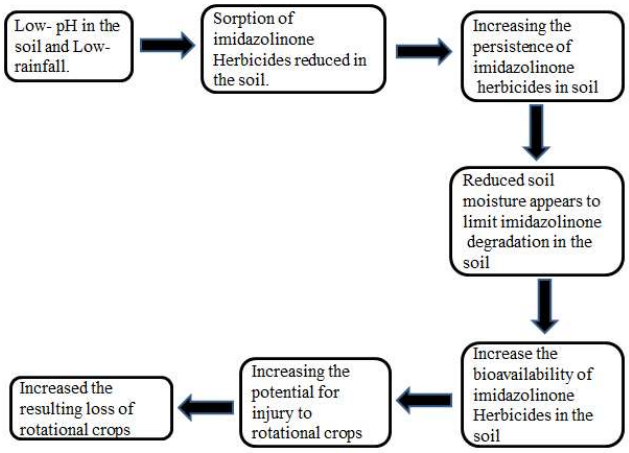

Fig. 2. Diagram represents the effect of multiple factors on imidazolinone herbicides application up to reach the rotational crops

Table 2. Carryover effect of imidazolinone herbicides in diverse vegetable crops worldwide

Type of vegetable and crop cultivated	Type of imidazolinone applied	The dose applied (g ha^{-1} a.i)	The time after herbicide applied	The effects	Country	References
Onion, cabbage, and tomato	Imazethapyr	(280)	About 1 year	Yield production of tomato	EUA (North Dakota)	Greenlad (2003)
Radish and tomato	Imazapic and Imazethapyr	(100-200)	A bout 3years	Reduction of height, and root dry matter	Brazil	Sousa et al (2012)
cabbage, tomato, and potato	Imazethapyr	(100-200)	1-2years	Reduction in the yield	Canada	O' Sullivan et al (1998)
Melon and tomato	Imazapyr and imazapic; imazapyr and imazethapyr	(39.9 + 119.7)	About 3years	Reduction in the yield	Chile	Alister & Kogan (2005)
Alfalfa and pea	Imazapyr and imazapic; imazapyr and imazethapyr	(39.9 + 119.7)	About 5months	Reduction of yield and fresh weight	Santiago, Chile	Alister & Kogan (2005)
Corn	Imazethapyr, Imazaquin and Imazethapyr Imazapic and imazapyr	(140-280)	About 2years	Reduction of yield/ Imazethapyr	Ohio	Loux & Reese (1993)
Cucumber	Imazapic and imazapyr	(0, 52.5 1 17.5, and 105 1 35)	About 2years	Cucumber was more sensitive	Brazil	Ulbrich et al (2005).
Non-tolerant rice	Imazapic and imazethapyr	(25+75)	371-705day	55% reduction in yield	Brazil	Marchesan et al (2010)
Sugar-beet	Imazethapyr	(70)	3months	Make injury	USA	Bresnahan et al (2000)
Ryegrass	imazethapyr + imazapic and imazapyr + imazapic	(140)	9months	The sensitivity of crop	Brazil	Santos et al (2014)
Beet	Imazamox + imazapyr	(33+15)	9months	Yield decreased by 26%	Turkey	Süzer & Büyük (2010).
Cotton	Imazapic	(70)	1 year	reduce plant height and node number	North Florida	Wiatrak et al (2009)
Ryegrass	Imazethapyr + imazapic	1 L ha-1 of formulated mixture	128d	Dry weight mass reduction	Brazil	Bundt et al (2015)
Oilseed	Imazethapyr	0.002 mg. kg-1	30d	High potential for damage to oilseed rape plant,	Iran	Mohammad (2019)
Barley	Imazapyr	160	165d	Reduced barley yield by 45%	Argentina	Julio et al (2017)
Cotton	Imazapic	70-140	1 year	Visibly injured cotton 19 to 58%	North Carolina	York et al (2000)
Spanish	Imazethapyr+ imazaquin	70+140	4months	injury and yield reduction to spinach	Arkansas	Johnson & Talbert (1993)
Sorghum	Imazethapyr + imazapic	75+25	150d	Reductions in dry matter	Brazil	Souza (2016)
Watermelon and cotton plants	Imazapyr + imazapic	105+35	120d	Reduction in the mass accumulation of watermelon plants and cotton	Brazil	Souza (2020)
Non-Imidazolinone Resistant rice	imazethapyr, imazamox and imazapyr	Commercial dose	2 years	Visual injury	Columbia	Heiser & Kendig (2007)
cotton	imazaquin	70	1 year	severe injury	Arkansas	Johnson et al (1995)
Corn	imazaquin and imazethapyr r	280+140	5 Months	Corn root growth was more sensitive	United State	Loux et al (1989)
Non- tolerant rice	Imazethapyr and imazapic	75+25	705d	plant injury	Brazil	Marchesan et al (2010)
sorghum	Imazapic	140+210	1 year	height reductions	Texas	Matocha et al (2003)
Corn	Imazethapyr	140	28d	biomass reduction	Columbia	Cornelius & Bradley (2017
Corn, sorghum, Cotton, and watermelon	Imazapic + Imazethapyr	0.013 lb/A 0.063lb/A	The same year	Dry matter weight was a viable	Texas	Grichar et al (1999)

Mispan 2010). Therefore, rice farmers should take several precautions before planting the crops to reduce the degree of weedy rice infestation in the fields and decrease yield loss. Consequently, willing to escape from the bottleneck, we should focus on the main reasons and different ways of weedy rice movement as per in the tabulated (Fig. 4).

Globally, continuous use of imidazolinone herbicides has led to evolution of herbicide-resistant weeds (Olofsdotter et al 2000). The evolution of herbicide-tolerant crops has provided new alternatives strategy for management of herbicide-resistant weeds in the field. However, the negative part is the widespread adoption of these crops that may lead to volunteer control problems in the next year. Equally important, crops and weeds are subject to different selection pressures. The use of the same herbicide repeatedly to control the weed in the fields can lead to selection pressure which considered as introduction and increase the risk of selecting ALS- resistant weeds in the field (Fig. 5).

Guidelines for decreasing imidazolinone residues and carryover in vegetable crops: It is very difficult to abandon herbicides in the field, but everyone must be careful in dealing with. Excessive use of agricultural herbicides leads to more and more residues in the soil and this increases the carryover problem in the fields. Therefore, farmers should take all the precautions and guidelines to guarantee a successful vegetable crop. The level and percentage of carryover-related vegetable crops injury is influenced by different factors in the field, including the type of herbicide used, vegetable crop species cultivated, soil physiochemical characterizes and properties of the soil, tillage depth, and environmental conditions (Singh et al 2019). For this reason, strategies based on both chemical improvement and integrated crop management are advocated in order to accomplish significant reductions in herbicide residues and negative effect to the environment (Langeroodi et al 2018). Therefore, due to these risks related herbicides residues, much attention is being focused on the alternative methods of weed control. Crop rotation is an important method used by many farmers who struggle to build a powerful management system. Integrated Weed Management (IWM) in the field (behaviour, biological, mechanical, physical, and chemical ways) (Angrej et al 2015) (Fig. 6) is considered one of the most important mechanisms that can be used by the farmers to get rid of different weeds in the field, which cause high competition with cultivation crops, and decrease crop yields (Bzour et al 2018). In the same context, educational courses

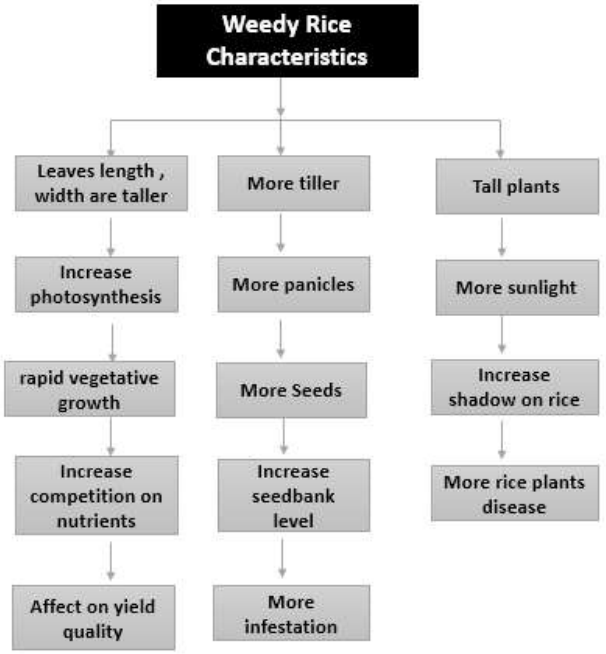

Fig. 3. Weedy rice traits and its consequences that affect rice cultivation crop

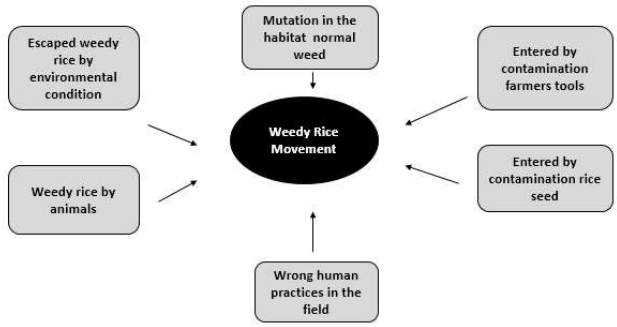

Fig. 4. The main ways to shift up weedy rice movement and infestation in the field

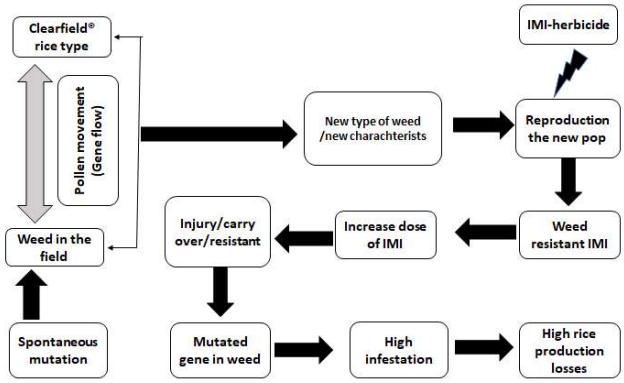

Fig. 5. Development of imidazolinone resistance in weedy rice population in the fields. a Gray Arrow represents gene flow due computability between rice and weed; Black Arrows represent weed in rice resistant pathway mechanism; and IMI (Imidazolinone herbicide)

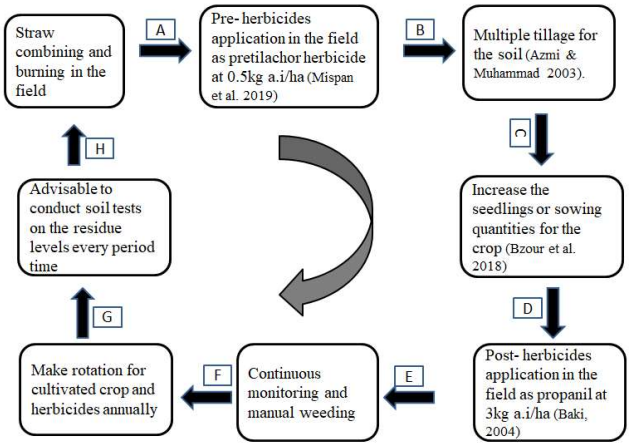

Fig. 6. Diagram represents the weed management practices to shift down the effect of imidazolinone herbicide carryover on the succeeding/rotation crops in the field (Black Arrows represent the direction from A-H; the large grey one represents the direction of the practices)

and continuous support for farmers need to be intensified regarding the control and management of weed in the fields (Mispan et al 2019). This can be achieved through campaigns, lectures, field days and trainings about using commercial doses of this type herbicides that could be leaving negative effect in the soil. Another weed management practice is achieved by suitable cover crops. It is an essential component of most conservation tillage systems and they grow before winter and produce sufficient biomass before the cultivation of the main crops, residues remain on the soil surface as organic dead materials that can control weeds by reducing light entrance, and increasing the soil temperature range (Langeroodi et al 2018).

CONCLUSION

The danger posed by imidazolinone herbicide carryover and crop injury occur under different scenarios are discussed. The succeeding/rotation crops as example vegetable crops are varied in sensitive to imidazolinone family residues in the soil. Certain safe period of time is needed to grow vegetables after this type of herbicides to shift down damages as increasing the doses of herbicides increase their adverse effects on susceptible plants. The further research needs to be conducted to determine the minimum time interval for planting/ pre-cultivation is suggested for sensitive rotation vegetable crops after imidazolinone application to reduce herbicides damages. It is advisable to conduct soil tests on the residue levels of these types of herbicides before transplanting vegetable crops in the field because this type of herbicides depends on the pH in the soil. A global effort will be needed to collect a appropriate high quality about this type of herbicide, better understanding the role of soil pH on the persistence of imidazolinone, and its active mobility in the soil, especially over multiple years at sites where the herbicide will be widely used.

REFERENCES

Alister C and Kogan M 2005. Efficacy of imidazolinone herbicides applied to imidazolinone-resistant maize and their carryover effect on rotational crops. *Crop Protection* **24**(4): 375-379.

Assalin MR, Queiroz SC, Ferracini VL, Oliveira T, Vilhena E and Mattos MT 2014. A method for determination of imazapic and imazethapyr residues in soil using an ultrasonic assisted extraction and LC-MS/MS. *Bulletin of Environmental Contamination and Toxicology* **93**: 360-364.

Angrej Singh, Singh, Rajender Kumar and Uppal 2015. Effect of irrigation methods and irrigation regimes under different planting methods on crop productivity in sugarcane. *Indian Journal of Ecology* **42**(1): 90-95.

Azmi M and Baki BB 2003. Weed species diversity and management practices in the Sekinchan Farm Block, Selangor's South West Project: A highly productive rice area in Malaysia. Proc. *19th Asian-Pacific Weed Science Society Conference*, Manila, the Philippines, pp. 174-184.

Baohong S and Shaoyi Y 2001. Study on safety of imidazolinone herbicides to succeeding crops. *Chinese Journal of Pesticide Science* **2**: 004.

Börjesso 2004. The fate of imazapyr in a Swedish railway embankment. *Pest Management Science* **60**(6): 544-549.

Bourdineaud JP 2020. Toxicity of the herbicides used on herbicide-tolerant crops, and societal consequences of their use in France. *Drug and Chemical Toxicology* 1–24. doi:10.1080/01480545.2020.1770781.

Bresnahan GA, Koskinen WC, Dexter AG and Lueschen WE 2000. Influence of soil pH-sorption interactions on imazethapyr carry-over. *Journal of Agriculture and Food Chemistry* **48**: 1929-1934.

Bundt AD, Avila LA, Agostinetto D, Nohatto MA, and Vargas HC 2015. Carryover of imazethapyr + imazapic on ryegrass and non-tolerant rice as affected by thickness of soil profile. *Planta Daninha* **33**(2):357-364.

Bzour MI, Zuki FM, Mispan MS, Kheiredeen M, Jodeh S and Monzir S 2017. A simple method for determination and characterization of imidazolinone herbicide (imazapyr/imazapic) residues in Clearfield® rice soil. *Applied Ecology and Environmental Research* **15**(4): 891-903.

Bzour MI, Zuki FM and Mispan MS 2018. Introduction of imidazolinone herbicide and clearfield® rice between weedy rice control efficiency and environmental concerns (residues/resistance): A review. *Environmental Reviews* **26**(2): 181-198.

Bzour MI, Zuki FM and Mispan MS 2018. Determination the leaching potential and residues activity of imidazolinone herbicide in clearfield rice soil using high performance liquid chromatography/UV. *Bulletin of Environmental Contamination and Toxicology* **103**: 348-353.

Christiane AD, Roque CD, Kassio FM and Marcelo RR 2016. Herbicides carryover in systems cultivated with vegetable crops. *Revista Brasileira de Herbicidas* **15** (1): 67-78.

Christoffoleti PJ, López-Ovejero RF, Damin V, Carvalho SP, Nicolai M 2008. *Comportamento Dos Herbicides Aplicados Ao Solo Na Cultura Da Cana-de-açúcar.* Ph.D. Dissertation, Universidade de São Paulo, Piracicaba.

Cornelius DC and Bradley WK 2017. Carryover of common corn and soybean herbicides to various cover crop species. *Weed Technology* **31**: 21-31.

Flint JL and Witt WW 1997. Microbial degradation of imazaquin and imazethapyr. *Weed Science* **45**(4):586-591.

Grey TL, Cuts III, GS and Johnson J 2012. Imidazolinone-resistant soft red winter wheat weed control and crop response to ALS-inhibiting herbicides. *Weed Technology* **26**: 405-409.

Greenland RG 2003. Injury to vegetable crops from herbicides applied in previous years1. *Weed Technology* **17**(1):73-78.

Gressel J and Valverde BE 2009. A strategy to provide long-term control of weedy rice while mitigating herbicide resistance transgene flow, and its potential use for other crops with related weeds. *Pest Management Science* **65**(7): 723-731.

Grichar JW, Sestak CD and Nester RP 1999. Imidazolinone herbicide effects on rotational crops following peanut (*Arachis hypogaea* L.) in South Texas, *Texas Journal of Agriculcher and Natural Reserces* **12**: 1-10.

Heiser WJ and Kendig A 2007. *Dissipation and Carryover of imidazolinone herbicides in imidazolinone-resistant rice* (*Oryza sativa*). Master thesis, University of Missouri Library Systems.

Ibrahim MB, Juraimi AS, Hakim M, Aslani F, Karim S and Alam MA 2017. Residual effect of imidazolinone herbicide used in clearfield (r) rice on non-clearfield rice. *Bangladesh Journal of Botany* **46**(1): 335-341.

Johnson DH and Talbert RE 1993. Imazethapyr and imazaquin control puncture vine (*Tribulus terrestris*) carry over to spinach (*Spinacia oleracea*). *Weed Technology* **7**: 79-83.

Johnson DH, Talbert RE and Horton RD 1995. Carryover potential of imazaquin to cotton, grain sorghum, wheat, rice, and corn. *Weed Science* **43**: 454-460.

Kemmerich M, Bernardi G, Adaime MB, Zanella R and Prestes OD 2015. A simple and efficient method for imidazolinone herbicides determination in soil by ultra-high performance liquid chromatography–tandem mass spectrometry. *Journal of Chromatography* A **1412**: 82-89.

Langeroodi AS, Radicetti E and Campiglia E 2018. How cover crop residue management and herbicide rate affect weed management and yield of tomato (*Solanum lycopersicon* L.) crop. *Renewable Agriculture and Food Systems* **34**(6): 1-9.

Loux MM, Liebl AR and Slife WF 1989. Availability and persistence of imazaquin, imazethapyr, and clomazone in soil. *Weed Science* **37**: 259-267.

Loux MM and Reese KD 1993. Effect of soil type and ph on persistence and carryover of imidazolinone herbicides. *Weed Technology* **7**: 452-458.

Julio AS, Jorgelina CM, Mario RV, Ramón G, Carolina I and Juan PR 2017. Impact of imazamox and imazapyr carryover on wheat, barley, and oat. *Weed Technology* **31**(6): 838-846.

Mahesh CS, Kukal SS and Naveen G 2016. Performance of direct-seeded rice in relation to water and weed management scenarios in a sandy loam soil. *Indian Journal of Ecology* **43** (1): 70-74.

Marchesan E, Dos Santos FM, Grohs M, De Avila LA, Machado S L, Senseman SA and Sartori GM 2010. Carryover of imazethapyr and imazapic to nontolerant rice. *Weed Technology* **24**(01): 22-28.

Matocha MA, Grichar WJ, Senseman SA, Gerngross CA, Brecke BJ and Vencill WK 2003. The Persistence of imazapic in peanut (*Arachis hypogaea*) crop rotations1. *Weed Technology* **17**(2): 325-329.

Mispan MS, Bzour MI, Zuki FM, Mahmod IF, Md-Akhir AH and Zulrushdi QA 2019. Managing weedy rice (Oryza sativa L.) in Malaysia: challenges and ways forward. *Journal of Research in Weed Science* **2:** 149-167.

Mohammad M 2019. Sensitivity of oilseed rape (*Brassica napus* L.) to soil residues of imazethapyr herbicide. *International Journal of Agriculture, Environment and Food Sciences* **3**(1): 46-49.

Moraes BS, Clasen B, Loro VL, Pretto A, Toni C, de Avila LA, Marchesan E, de Oliveira Machado SL, Zanella R and Reimche GB 2011. Toxicological responses of *Cyprinus carpio* after exposure to a commercial herbicide containing imazethapyr and imazapic. *Ecotoxicol Environ Safety* **74:** 328-335.

Michae JL and Neary DG 1993. Herbicide dissipation studies in southern forest ecosystems. *Environmental Toxicology and Chemistry* **12:** 405-410.

Mispan MS and Baki BB 2008. They stand among equals: descriptive analysis on the new biotypes of weedy rice (*Oryza sativa* L.) in Malaysia. In: *5th International Weed Science Congress.* International Weed Science Society, Vancouver, Canada.

Norsworthy JK and Young ML 2020. Benzobicyclon carryover to crops in the Mississippi Delta. *Crop, Forage & Turfgrass Management* **6**(1): 1-7.

Pinto JO, Noldin JA, Rosenthal MD, Pinho CF, Rossi FV, Machado A, Piveta L, and Galon L 2009. Residual activity of (Imazethapyr + Imazapic) on Ryegrass (*Lolium multiflorum*), following Clearfield® rice. *Planta Daninha* **27**: 609-619.

Prakash P, Hemalatha M and Joseph M 2019. Influence of zinc nutrition and green leaf manuring on dry matter yield, nutrient uptake and economics of rice cultivation. Indian *Journal of Ecology* **46**(1): 65-69.

Power J and Follett R 1987. *Monoculture*. Scientific American (USA).

Ramezani M, Simpson N, Oliver D, Kookana R, Gill G and Preston C 2009. Improved extraction and clean-up of imidazolinone herbicides from soil solutions using different sorbents. *Journal of Chromatography A* **1216**: 5092-5100.

Ranjan NP, Ram JC, Anurag T, Nilesh J, Kumar BP, Suresh Y and Rahul K 2020. Breeding for herbicide tolerance in crops: a review. *Research Journal of Biotechnology* **15**(4): 154-162.

Santos LO, Pinto JJ, Piveta LB, Noldin JA and Concenço L 2014. Carryover effect of imidazolinone herbicides for crops following rice. *American Journal of Plant Sciences* **5:** 1049-1058.

Singh V, Masabni J, Baumann P, Isakeit T, Matocha M, Provin T, Bagavathiannan M 2019. Activated charcoal reduces pasture herbicide injury in vegetable crops. *Crop Protection* **117**: 1-6.

Shivrain VK, Burgos NR, Sales MA, Mauromoustakos A, Gealy DR, Smith KL, Black HL and Jia M 2009. Factors affecting the outcrossing rate between Clearfield™ rice and red rice (Oryza sativa). *Weed Science* **57:** 394-403.

Sousa CP, Bacarin MA and Pinto JO 2012. Crescimento de espécies bioindicadoras doresidual do herbicida (imazethapyr+imazapic), semeadas em rotação com arroz Clearfield®. *Planta Daninha* **30**(1): 105-111.

Souza DA, Leal FJ, Langaro CA, Carvalho SG and Pinho FC 2020. Leaching and carryover for safrinha corn of the herbicides imazapyr + imazapic in soil under different water conditions. *Revista Caatinga* **33** (2): 1983-2125.

Souza MF, Neto MD, Marinho MI, Saraiva DT, Faria AT, Silva AA and Silva DV 2016. persistence of imidazolinones in soils under a clearfield system of rice cultivation. *Planta Daninha* **34**(3): 589-596.

Sondhia S 2014. Herbicides residues in soil, water, plants and non-targeted organisms and human health implications: an Indian perspective. *Indian Journal of Weed Science* **46**(1): 66-85.

Sondhia S, Khankhane P J, Singh PK and Sharma AR 2015. Determination of imazethapyr residues in soil and grains after its application to soybeans. *Journal of Pesticide Science* **40**(3):106-110.

Sudianto E, Neik TX, Tam SM, Chuah TS, Idris AA, Olsen KM and Song BK 2016. Morphology of malaysian weedy rice (oryza sativa): Diversity, origin and implications for weed management. *Weed Science* **64**(3): 501-512.

Ulbrich AV, Souza JP and Shaner D 2005. Persistence and carryover effect of imazapic and imazapyr in brazilian cropping systems 1. *Weed Technology***19**: 986-991.

Wang X 2005 Biodegradaton of imazapyr in typical soils in Zhejiang Province, *China. Journal of Environmental. Science* **17**(4): 593-597.

Wiatrak PJ, Wright DL and Marois JJ 2009. Influence of imazapic herbicide simulated carryover on cotton growth, yields, and lint quality. *Crop Management* **8**(1): 1-7.

Yavari S, Sapari NB, Malakahmad A, Razali AM, Gervais ST and Yavari S 2020. *Bulletin of Environmental Contamination and Toxicology* **104**: 121-127.

York AC, David LJ, Roger BB and Culpepper A 2000. Cotton response to imazapic and imazethapyr applied to a preceding peanut crop. *The Journal of Cotton Science* **4**: 210-216.

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Integrated Resource Management for Sustainable Agricultural Land Use Plan in Hisar District Using Geo-Informatics- A Case Study

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Abstract: The present study is based on the uses of qualitative and quantitative data for sustainable management of natural resources (soil, underground water quality, depth of water table etc.) with the aims to analyze the authentication of present land use in the context of sustainability of agriculture. The productivity level of rice, cotton, wheat, mustard and gram crops is showing a declining, trend, despite manifolds increase in fertilizer use and plant protection chemicals in the study area. Sustainable agricultural practices fulfill the demand of coming generation and increasing population in respect to the sustainability of natural resources. The study suggested that 700.83, 18.57, 123.92 square kilometer of the study area is recommended for agri-horticulture crops, agro forestry and for double crop with clone eucalyptus plantation on field boundary,119.98 square kilometer area is recommended for horticulture plantation with drip irrigation and 2340.57 square kilometer area is recommended for existing cropping system with good agriculture management practices with soil and water conservation measures.

Keywords: Sustainable agriculture, Satellite data, Remote sensing, GIS, Landuse recommendation

The agriculture system which encompasses the interactions of physical, biological, technical and socio-economic factors, some of which are under human control, for the purpose of producing food, the agro- ecological entity. The agro-ecosystem, therefore, is considered to be in equilibrium with environmental and management factors, which produce a sustained yields. Today with emphasis on quick production, the optimum balance between the use of land/soil resources and agro-production conditions are disturbed. Thus, the productivity level of different crops, has either reached at plateau level or showing declining, trend, despite manifolds increase in fertilizer use and plant protection chemicals. Farmers here continue to grow rice-wheat and cotton - wheat as dominant crops due to government incentives and market price ignoring the suitability of soil, water and climatic conditions. The inappropriate land use and introduction of canal irrigation have resulted in soil degradation, soil erosion, salinity & alkalinity and waterlogging, besides nutrient losses as well as depletion of ground water at an alarming rate. The problems of salinity, sodicity and waterlogging have been attributed to irrigation without providing drainage.

It may seem like an economic boost for a few decades, but the environmental damage is permanent because agricultural land use pattern will consume the soil and water resources. Present agricultural practices are based on the monoculture and there is lack of crop diversification. The present study evaluated the utilization of the land resources with reference to natural resource characteristics and land use pattern and also examined the sustainability performance of current land use types with reference to land resources.

MATERIAL AND METHODS

Indian Remote Sensing satellite Series (LISS-III) satellite data for the years 2017-18 was used for interpretation of the existing landuse / land cover, cropping pattern and crop rotation. The projection system and datum for geo-referencing of the satellite images were taken as World Geodetic System 84 and Universal Transverse Mercator projection respectively (UTM). Data related to soil series and maps were collected from HARSAC with their physical and chemical properties. Data related to underground water depth and quality is collected from Central Ground Water Board, Ministry of Water Resources, Government of India. Toposheets of Survey of India were used for defining locations of villages, transport network, cultural features, canal network and demarcation of major & minor towns/ cities. Climatic data, published literature, maps and reports were collected, consulted and used pertinent. Arc GIS Desktop 9.3 (Integration and overlay analysis) ERDAS Imagine 9.3, (geo-referencing) and Geometica 10.3 (digital classification) software were used.

The study is mainly concerned to develop and suggest sustainable agricultural land use plan for the study area based on existing resources such as soils, cropping pattern,

ground water table depth, ground & surface water quality and present land use. Satellite images were used after image rectification and suitable image enhancements technique will be applied to facilitate the delineation and interpretation of different thematic information. Visual interpretation method was used to prepare pre-field interpreted map. The satellite data is interpreted based on image interpretation elements like tone, texture, size, shape, pattern, aspect, association etc. Suitable field sampling will be used to assess the interpreted elements and relate with satellite data. The field data collections are aided by GPS in order to locate the ground verification points on the image and for further incorporation of detail. Integrating ground water resources map was prepared using interpolation techniques in GIS environment. Water table deepness maps for pre monsoon and post monsoon with water quality and draping of depth to water table map in GIS environment.

The GIS and remote sensing software was used for analysing the spatial distribution of the various aspects taken up for study. GIS techniques were used in order to create layers of present land use/ land cover.All these layers were overplayed in Arc GIS desktop 9.3 software and a common or single layer is generated using all above layers through union command. This single layer has all information like soils, water quality, water table depth; present land use/ land cover for each and every polygon. Based on these layers characteristics such as soil type and texture, physiographic unit, underground water quality, underground water depth, type of present land use and land cover; a final recommendation is given to each and every polygon. These layers were put in GIS format to create the database. On the basis of database pre land use recommendation were suggested.

The sustainable agricultural land use plan has been prepared by integrating different thematic maps with socio-economic conditions. These thematic maps were analyzed in term of resources potential and limitations individually and jointly. For recommending sustainable agricultural land use action plan various decision rules have been formulated. Based on decided rules and integration of all thematic maps, land resources action plan has been explained. Major suggested recommendations for management of agricultural land are agro-horticulture, agro forestry, agro forestry with dry land crops management, double crop, crop diversification with suitable soil conservation measures and agri horticulture with suitable soil conservation measures. The management of wastelands includes forest plantation for scrubland, silvi pasture for degraded pastures and leveling and dune stabilization for sand dunal areas.

As per decision rules, a short discussion was complete on utility and sustainability of current land use pattern particularly in context of agricultural construction and quality of ecosystem. Later on, the suitability of these existing practices were examined and various alternative land use activities like agro horticulture, agro forestry, agro forestry with improved dry land crops management, double crop, silvi pasture, leveling & dune stabilization have been considered. For recommending these package & practices, the basic research activity of CCS, HAU, Hisar (Rabi & Kharif Faslon Ki Samagra Sifarasen, HAU, Hisar) and ICAR with latest technologies of agriculture research and development were considered in the district.

Study area: The location of the district is 28°53'45" to 29°49'15" North latitude and 7475°13'15" to 76°18'15" East longitude having 3983 square kilometers area. It has surrounded by Fatehabad and Jind districts of Haryana in north east and north respectively. The climate of the area is famous for its waterlessness and boundaries of hotness with insufficient rainfall and varies arid to semi arid type. It is sub-tropical, monsoonic and continental. The average annual rainfall in the district is 307.7 mm which usually increases towards south west to north east direction. Near about 65% of the yearly rainfall arrived in rainy season (July to September). Physiographically, the study area consists of alluvial plain, flood plain, aeolian plain and fluvio aeolian plain in which dune complexes exist. The main soils in the area varies from loamy to clay loamy in low lying plain, sandy loam to loamy in nearly level plain and sand to loamy sand in aeolian plain. Situated in the northwest, Hisar is one of the leading agriculture district of the state whereas 132.89 square kilometres area of the district is under wastelands that is 3.34 percentage to the total geographical area of the district. It is also the most intensively cultivated with 193% (statistical abstract of Haryana, 2017) cropping intensity. It covers 3983 square kilometres area with a population of 1,743,931 persons (Census of India, 2011).

RESULTS AND DISCUSSION

Different thematic maps like land use / land cover, soils family, soil sub group , soil texture, soil available water holding capacity map, water quality and depth, cropping pattern and rotation coupled with socio-economic and agro-climatic data were integrated to suggest suitable combinations of practices for various agricultural land use parcels. In formulation of action plan remaining land use/land cover and wastelands have been taken as basis for assessing the present land use and to suggest alternative sustainable agricultural land use suitability.

Soil resources: Eleven soil series have been observed in the district that are Kharia, Bichpari, Ratia, Bas, Fatehpuri,

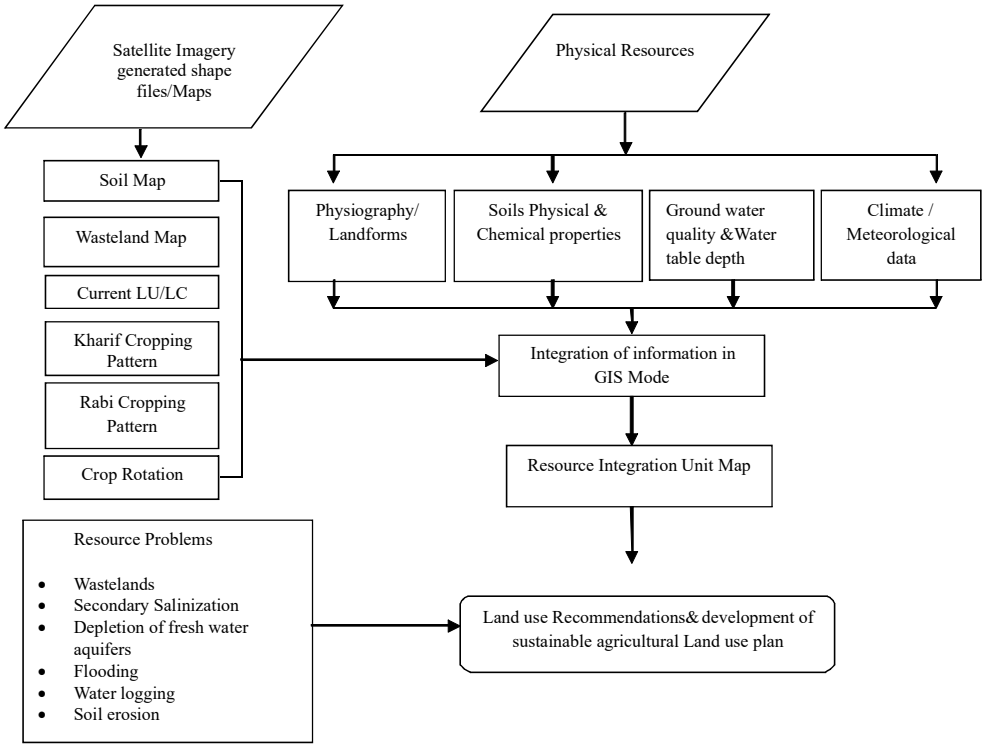

Fig. 1. Methodology Flow Chart

Kanala, Dabra, Gangwa, Jundli Khurd, Dhingsra and Niyana. Above all soil series are classified according to Soil Taxonomy. It was observed that four types soil texture family classes (Coarse loamy, Fine loamy, Fine and Sandy) are existing in the district. Fine loamy class covers 2076.56 square kilometers area that is 49.79 % of the district. Mainly this class is found in eastern part of the study area in Narnaund, Uklana, Hansi-I, Hansi-II and Hisar-I blocks. Second largest class is coarse loamy that covers 1570.67 square kilometers area which is 37.66 % of the district. This class is dispersed in western part of the study area in Adampur, Hisar-II and Agroha blocks. Third largest class is sandy that covers 259.08 square kilometres area which is 6.21 % of the study area and founded in scattered patches in whole district. Other class is fine which covers only 2.80 square kilometers.

Ground water quality status: The overall ground water prospects of the district vary from poor to excellent. The units of alluvial origin have very good to excellent underground water scenarios but on the other hand, ground water prospects in aeolian plain and sand dunal areas are moderate and poor respectively. Alluvial plain with sand have good ground water potential. The ground water quality of study area is good to saline. These include fresh water (38.11 %), sub marginal (40.00%) marginal (18.44%) and saline (3.45%). It was observed that adjacent to water body like canal, ponds and river; the sub surface water quality is good.

Ground water table depth status: The depth of underground water table in the study area is lying between 1.5 to >15 meters below ground level (BGL) in various parts. The 96 percent of total area falls under the depth zone of 1.5 to >15 meters below ground level during pre monsoon. Highest depth of water table observed in surrounding Balsamand village. Near about fifty eight to sixty percent of the study area in pre monsoon season falls under 5-10 meter depth (2510.83 square kilometres) followed by 10-15 meter depth (958.49 square kilometres). The depth which is considered critical and falls under waterlogged category (Pre monsoon) is between 0-1.5 meter and covers an area of 8.76 square kilometers.

Land use / land cover: Land use and land cover map has been generated by visual interpretation of satellite images of October 2017 and March 2018. The land use of the study area has been broadly categorized into built up land, agriculture, wastelands and water bodies. The landuse statistics reveals that major land use in this area is agriculture, which covers 3877.12 square kilometres including double crop, rabi only, kharif only and current fallow class. The double cropped area under agriculture land use constitutes 80.89 percent of total area. The study indicated a moderate intensity of cropping of 191.92 percent. The wasteland categories viz. degraded pastures, scrublands and sands comprises of only 3.65

percent of the study area. Built-up land use categories occupy 8 percent of total area and rest of area is covered by water bodies. It is concluded that area under input intensive crops of green revolution has increased at the cost of traditional crops and desi cotton, gram, pulses and millets cropped area have declined significantly. Due to these input intensive agriculture, the area is suffering from decreasing water table, excessive use of fertilizers and pesticides from primary to serious ecological difficulties.

Cropping pattern: *Rabi* and *Kharif* are the main two cropping seasons in the study area. *Kharif* crop season starts in May-June and continues upto September- October. Remote Sensing data of *Kharif* season (September -2017) estimated that the Cotton, Sugarcane, Rice, Bajra/Jowar/Guar and other crops occupied 1660.20, 0.53, 773.83 and 280.33 square kilometres area correspondingly. In *rabi* season (March 2018) wheat crop sown in 2131.25 square kilometers area, followed by mustard (686.32 square kilometers) and pulses (146.67 square kilometers). The study has exposed that there is serious need for diversification of cropping pattern. The area is also facing another problem of complete absence of natural forest, therefore; there is urgent need of forest plantation on wastelands community land, government land and along with transport network and irrigation channels to restore ecological balance of the study area.

Development of agricultural land use plan: Agricultural land resources management has emerged as one of most important issue to improve agricultural productivity and sustainability through protection and rational consumption of our natural resources base like water, soil, vegetation, livestock and genetic diversity. Sustainable agricultural land use plan was developed for the study area and different agricultural land use recommendations were suggested. Agri- horticulture is suggested in 806.92 square kilometres that was 20.23% of the total recommended area. Agri horticulture class included different sub classes that are Agri horticulture after land leveling, Agri horticulture with mixing of tube well and canal water, Agri horticulture with crop diversification required, Agri Horticulture with eucalyptus plantation on field boundary and Agri horticulture with salt tolerant species.

Recommendation related to horticulture plantation (including Horticultural plantation/ Silvi pasture, Horticulture plantation for panchayat income or on contract, Horticulture plantation with drip irrigation, Horticulture plantation with drip irrigation adopting rainwater harvesting/ surface water / water tank purifier) occupied 186.22 square kilometers area that was 4.67% of the total recommended area. Agro forestry class recommended in 227.57 square kilometres that was 5.71% of total recommended area. Agro forestry activity involve Agro Forestry / Fodder dairy cattle, Agro forestry after land leveling, Agro forestry with dry farming, Agro forestry/ forest plantation, Agro forestry with salt tolerant tree species and Agro forestry with bio drainage. Like that, Double crop recommended class occupies total area of 127.33 square kilometers which was 3.19 percent of total recommended area. This class include Double crop after land leveling or double crop with sprinkler irrigation, Double crop with clone eucalyptus plantation on field boundary, Double crop with drain out sub classes. Area wise suggested agricultural land use recommendations are displayed in Table 1 and spatial distribution of different

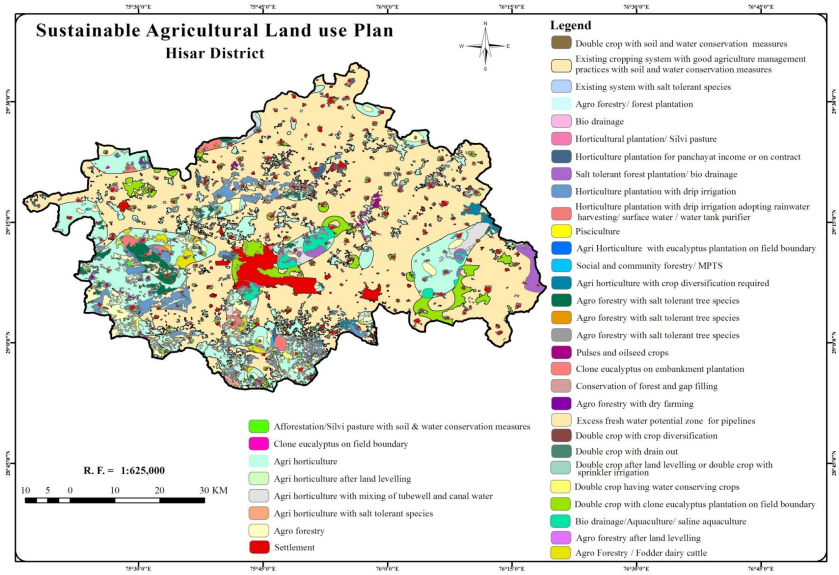

Fig. 2. Spatial distribution of different suggested environmentally sound agricultural land use

Table 1. Area under different suggested agricultural land use recommendation

Suggested agricultural land use recommendation	Area in square kilometres	Total geographical area (%)
Afforestation/Silvi pasture with soil & water conservation measures	37.84	0.95
Clone eucalyptus on field boundary	0.91	0.02
Agri horticulture	700.83	17.58
Agri horticulture after land levelling	1.38	0.03
Agri horticulture with mixing of tubewell and canal water	50.28	1.26
Agri horticulture with salt tolerant species	24.48	0.61
Agro forestry	183.57	4.60
Agro Forestry / Fodder dairy cattle	30.16	0.76
Agro forestry after land levelling	0.18	0.00
Agro forestry with dry farming	5.99	0.15
Excess fresh water potential zone for pipelines	0.47	0.01
Bio drainage/Aquaculture/ saline aquaculture	44.45	1.11
Clone eucalyptus on embankment plantation	16.31	0.41
Conservation of forest and gap filling	2.19	0.05
Double crop after land levelling or double crop with sprinkler irrigation	3.39	0.08
Double crop having water conserving crops	17.13	0.43
Double crop with clone eucalyptus plantation on field boundary	123.92	3.11
Double crop with crop diversification	10.56	0.26
Double crop with drain out	0.02	0.00
Double crop with soil and water conservation measures	7.86	0.20
Existing cropping system with good agriculture management practices with soil and water conservation measures	2340.57	58.70
Existing system with salt tolerant species	0.14	0.00
Agro forestry/ forest plantation	1.23	0.03
Bio drainage	0.33	0.01
Horticultural plantation/ Silvi pasture	11.04	0.28
Horticulture plantation for panchayat income or on contract	30.68	0.77
Salt tolerant forest plantation/ bio drainage	40.49	1.02
Horticulture plantation with drip irrigation	119.98	3.01
Horticulture plantation with drip irrigation adopting rainwater harvesting/ surface water / water tank purifier	24.52	0.61
Pisciculture	2.27	0.06
Agri Horticulture with eucalyptus plantation on field boundary	1.13	0.03
Social and community forestry/ MPTS	22.26	0.56
Agri horticulture with crop diversification required	28.82	0.72
Agro forestry with salt tolerant tree species	77.68	1.95
Saline aquaculture on embankment plantation	1.37	0.03
Agro forestry with bio drainage	6.44	0.16
Pulses and oilseed crops	16.76	0.42
Grand Total	3987.65	100.00

suggested environmentally sound agricultural land use recommendations is displayed in Figure 2.

CONCLUSIONS

Presently there is urgent need of integrated land & water resources development and crop diversification plans for sustainable agriculture development. This crop diversification plan has considered the climate, existing soils, irrigation facilities, mechanization and socio-economic factors.The potential benefits of natural resources development plan in the form of increased production of food grains, oil seeds, pulses, fruits and vegetables. The increased fodder production correspondingly increases livestock products. The natural resources development plans will also help to generate employment opportunity and improve economic and nutrition standard of the people. This resources development plan will improve over all environmental conditions of area in form of saving the land from degradation, improve the soil fertility increasing the area under irrigation and reducing the impact of drought.

REFERENCES

Arya VS, Arya S, Khatri SS, Singh H, Kumar S, Kumar D, Sharma PP, Sharma H and Hooda RS 2011. *Wastelands Atlas of India*. National Remote Sensing Centre (NRSC), Hyderabad, Govt. of India.

Arya VS, Arya S, Kumar S, Singh S and Hooda RS 2015. Monitoring wasteland of Hisar District, Haryana through space technology. *Current Trends in Technology and Science Journal* **4**(1): 446-449.

Arya VS, Hooda RS, Kumar A, Ompal, Kumar S and Singh H 2014. Management of waterlogging and soil salinity in central Haryana. *Technical Report: HARSAC/TR/02/2014*, Haryana Space Applications Centre (HARSAC), Hisar.

Chaudhary BS, Kumar M, Roy AK and Ruhal DS 2006. Application of remote sensing and geographical information system in ground water investigation in Sohna block, Gurgaon district, Haryana, India. *International Archives of Photogrammetry and Remote Sensing* **31**(6): 16-23.

Kumar S, Arya VS, Subrahamanyam C, Prasad J and Pande LM 1998. A remote sensing approach in appraisal of soil for sustainable land use planning: A case study in Semi Arid region, Haryana. *Journal of Society of Soil Survey & Land Use Planning, Nagpur*, India, 101-106.

Mahdi S 2017. Application of remote sensing indices for mapping salt- affected areas by using field data methods. *International Journal of Advanced and Applied Sciences* **4**(10): 181-187.

Meena and Nandal S 2018. *Sustainability of Agriculture in Haryana Some Issues.* Department of Geography, MDU, Rohtak, Haryana.

Meenakshi, Sharma PK, Kaur A and Shalley V 2005. Satellite based study of land transformation of Ludhiana district, Punjab. *Journal of ISRS* **33**(1): 181-186.

NIFA 2009. *Sustainable Agriculture: United States Department of Agriculture.* National Institute of Food and Agriculture, Washington DC, U.S.A.

Ray SS, Sood A, Das G, Panigrahy S, Sharma PK and Parihar J S 2005. Use of GIS and remote sensing for crop diversification: A case study of Punjab state. *Journal of ISRS* **33**(1): 181-186.

Rockade VM, Kundal P and Joshi AK 2004. Water resources development action plan for Sasti watershed, Chandrapur district, Maharashtra using remote sensing and GIS. *Journal of ISPRS* **32**(4): 363-372.

Sahu KC, Pradhan BN, Mishra and Sundram S 2002. Land use / land cover mapping of Viskhapatnam district, Andhra Pradesh, India using Remote Sensing and GIS. Resources and Environment Monitoring, Hyderabad, India. *IAPRS & SIS* **34**(7): 581-583.

Saroha GP, Chaudhary BS and Prasad J 2003. GIS in Natural Resources Management in Gurgaon district, Haryana. Abstracts: *National Conference GIS India*, Birla Auditorium, Jaipur 8-10.

Thomas A, Sharma PK and Sood A 1999. Hydro-geomorphological mapping in accessing of ground water by using remote sensing data-A case study in Lehragaga block, Sangrur district, Punjab. *Journal of ISRS* **27**(1): 31-42.

Venkatesan R and Manavalan 2000. Satellite data based analysis of land use/ land cover round Kalapakkam Nuclear site. *NNRMS Bulletin* 12-14.

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Enhancing Productivity and Profitability of *Rabi* Pulses through Farmer Participatory Action Research

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Abstract: Frontline demonstrations in cluster approach were conducted to enhance productivity and profitability of chickpea and lentil using improved crop management technologies by Krishi Vigyan Kendra, S.A.S Nagar, Mohali in two blocks during the rabi season of 2017- 18 and 2018-19 covering an area of 20.0 hectares respectively. Latest crop production and protection technologies including improved high yielding varieties, seed treatment with fungicide and bio-fertilizers, soil test based nutrient management, use of herbicide for weed control and recommended dose of plant protection chemicals based on economic threshold level of pests were demonstrated to farmers to show them productivity potential and profitability. Extension yield gaps varied by 430 and 185 kg ha^{-1} in chickpea and lentil, respectively and by adopting improved production technology, productivity can be raised by 28.2 and 19.5 % in chickpea, and lentil, respectively. Technology indexes in chickpea (11.36%) and lentil (18.92%) revealed that demonstrated technology under is quite feasible in prevailing farming situations in Punjab, but it strongly emphasizes educating farmers intensively to adopt available technology. Improved technology package has also enhanced profitability and additional returns enhancing incremental benefit–cost ratio (40 and 32%) in chickpea and lentil, respectively. FLD-TTP has great potential to scale up pulse productivity and farmer's livelihoods in Punjab and collateral farming situations in the developing world to enhance agricultural production.

Keywords: Chickpea, Lentil, Frontline demonstrations, Productivity, Profitability

India is the largest producer of chickpea (*Cicer arietinum* L.) with 67.5 % of share in global production which is a drought tolerant leguminous crop and used as a source of dietary protein (Singh et al 2016). Lentil is another protein-rich winter season pulse crop which can be grown under conserved moisture conditions after monsoon rains. It can be intercropped successfully in wheat, barley, mustard and linseed. The cultivation of lentil after rice improves physical properties of soil and increases the yield of succeeding cereal crop due to biological nitrogen fixation and other rotational effects. Historically, pulses formed an important part of the farming system in Punjab, but the area, production and productivity of pulses in Punjab (especially chickpea and lentil) has declined significantly over the years. The success of the Green Revolution was based on input intensive cultivation of rice and wheat in Punjab; as a result, the area under *rabi* season pulses was either greatly reduced or shifted to marginal land in this region (Grower and Singh 2012). These crops are now caught in vicious cycle, as farmers do not follow recommended production practices; grow them on marginal lands even without protective irrigation at critical stages leading to low and uncertain productivity, which further compel farmers to grow pulses under sub-optimal conditions. As a result, there exists a wide yield gap between the yield realized in experimental station and farmer's field in both these crops. The production potential of these pulses can be improved through introduction nutrient responsive high yielding varieties and assured supply of quality seed, efficient nutrient management techniques, weed management and integrated pest and disease management. Agricultural researchers recommend the use of improved varieties with its full package as inevitable solution for yield enhancement of *rabi* pulses. On the other hand, farmers are sticking to their inherent local cultivars and traditional agronomic practices (Kumar et al 2013). Extension workers are doing all efforts to bridge the yield gap between research stations and farmers field by enhancing understanding of farmers towards adoption of improved agricultural techniques. “Cluster Frontline Demonstrations on Pulses” project under National Food Security Mission (NFSM) of Department of Agriculture, Cooperation and Farmers Welfare (DAC&FW) was started during *rabi* 2015 to give a boost to the domestic production of pulses. The current study is generally intended to crack the paradox in the extension system on chickpea and lentil production practices.

MATERIAL AND METHODS

Field studies on lentil and chickpea were conducted by KVK S.A.S. Nagar (Mohali) during *rabi* seasons 2017-18 and

2018-19 in two blocks viz. Kharar and Majri, S.A.S. Nagar (Mohali), Punjab where chickpea and lentil crops were in existing cropping system (Table 1). The climate of the experimental site is sub-tropical characterized by hot summer with mean maximum temperature of 42± 50 C during June and cool winter with mean minimum temperature of 4 ± 20 C during December. The average annual rainfall in the study area varies from 650- 1300 mm of which ~75-80% is received during rainy season extending from July to September and rest during the winter season. The relative humidity in the district varies from 36.3-93.7% demarcating a peak during July-August, the days when monsoon in the area is on full swing. Soil from demonstration sites were analysed for initial physio-chemical properties and found to be sandy loam in texture (0-15 cm), average pH 7.83, electrical conductivity 0.256 dS/m, soil organic carbon 4.35 g kg^{-1}, available P 17.3 kg ha^{-1} and available K 166.5 kg ha^{-1}.

The problem of low productivity of *rabi* pulses was analyzed through using Participatory Rural Appraisal (PRA) techniques like focus group discussion and group discussion. Among the bio-physical constraints, the lack of good quality seed of new improved varieties were ranked first. In this context, new improved varieties *viz*. PBG 7 (chickpea) and LL-931 (lentil) were selected for FLD to minimize the problem of low yield of these pulses. The demonstrations were conducted based on full package of practices. During these two years (20 hectares under chickpea and 20 hectares under lentil were demonstrated with improved management practices using improved varieties. There were 48 and 56 farmers were closely associated with chickpea and lentil demonstrations, respectively. In those demonstrations, the control plot was also kept where farmers raised the crop on their own (Table 2). Opinion of the farmers about technologies used under demonstration was collected for further improvement in research and extension activities. Harvesting and threshing were done manually and yield data was collected from both demonstration plots and farmers practice plots. Yield advantages from the treatments were assessed over local check as well as state and national average. Data was analyzed for per cent increase, technology gap, extension gap and technology index (Samui et al 2003) by using following formula to assess the impact of scientific technology among the farmers and its horizontal spread. Extension gap is the difference between demonstrated plot yield and farmers practice plot yield. Technology gap is the difference between potential yield and demonstrated plot yield. The technology index shows the feasibility of evolved technology at the farmers' fields.

$$\text{Per cent increase in yield} = \frac{\text{Demonstration yield} - \text{Farmer's practice yield}}{\text{Farmer's practice yield}} \times 100$$

$$\text{Technology Gap} = \text{Potential yield} - \text{Demonstration yield}$$

$$\text{Extension Gap} = \text{Demonstration yield} - \text{Farmer's yield}$$

$$\text{Technology index} = \frac{\text{Potential yield} - \text{Demonstration yield}}{\text{Potential yield}} \times 100$$

Economic analysis: The impact of all interventions was assessed on the parameters of net returns/ ha, increase in net returns and B: C ratio. Gross returns were estimated based on the prevailing market prices and the yield obtained by the farmers during both the years. For obtaining input cost, the sum of expenditure on land preparation, planting method, fertilizer, insecticide, fungicide, herbicide, irrigation, labour and harvesting cost, etc. were calculated from each plot. Net return was computed by subtracting the total operational costs from the gross return calculated at the selling price of chickpea and lentil respectively at the time of investigation. Simple statistics like mean and percentage were applied to draw meaningful conclusions. Benefit: Cost was calculated as ratio of net return over cost of cultivation.

RESULTS AND DISCUSSION

The average yield of demonstration unit of chickpea was 19.5 q ha^{-1}. However, in farmers practice was 15.2 q ha^{-1}. An increase of (28.2%) Singh (2002) and Kirar et al (2006) reported similar trend. In lentil, an average increase of 19.47% was in demonstration plots yield over yield and was due to scientific package. Biofertilizers played an important role to improve the yield as it increases the biological nitrogen fixation (BNF) in legumes. Dual inoculations of Rhizobium and plant growth promoting rhizobacteria (PGPR) resulted in enhancing production and productivity. Sowing of chickpea

Table 1. Average area and productivity (National, state and district level) of chickpea and lentil during 2017-18

Crops	India		Punjab		S.A.S Nagar (Mohali)	
	Area (m ha^{-1})	Productivity (q ha^{-1})	Area (t ha^{-1})	Productivity (q ha^{-1})	Area (t ha^{-1})	Productivity (q ha^{-1})
Chickpea	10.56	10.63	1.7	11.81	0.1	10.23
Lentil	1.55	10.34	0.8	5.65	0.4	5.75

***Source**:* Directorate of Economics & Statistics, DAC&FW * 4th Advance Estimates in Agricultural Statistics at a Glance 2018 and Statistical Abstract of Punjab, 2018

on broad bed furrows (BBF) also helped to save and conserve the water as well as left the space to grow other crops like maize, sugarcane etc. Seed treatment was one of the important agronomic practices followed in demonstration plots but not used in farmer's practice plots that suffered loss in yield due to infestation of several diseases particularly of wilt. The demonstration plots also had seed treatment with carbendazim @ 2.5 g kg^{-1} of seed and choloropyriphos @ 6 ml kg^{-1} to control fusarium wilt disease. Moreover, in conventional sowing the use of higher seed rate coupled with poor land preparation resulted into poor yield.

Technology index: Lower the value of technology index, higher is the feasibility of the improved technology. The technology index in chickpea variety PBG 7 was 11.36 % and in lentil variety LL 931 it was 18.92% during 2017-18 and 2018-19, respectively (Table 3). The results of the present study are in recurrence with the findings of Bar and Das (2015).

Technology gap: The technology gap was recorded 250 kg ha^{-1} (chickpea) and 265 kg ha^{-1} (lentil des) during 2017-18 and 2018-19, respectively. These findings are in agreement with that of Sandhu and Dhaliwal (2016). This indicates that a strong gap exists between the generated technologies at the research institution and disseminated at the farmer's field (Vaghasia et al 2005, Kumari et al 2007). Fluctuations in technology gap were observed may be due to several biotic and abiotic factors. These results are in close conformity with the findings of Mitra and Samajdar (2010) .

Extension gap: Extension gap is the product of subtraction of farmers' practice yield from demonstration yield. During 2017-18 extension gap was 430 kg ha^{-1} (chickpea demonstrations) and during 2018-19 was 185 kg ha^{-1} (lentil demonstrations) (Table 3). There is a need to decrease this extension gap through implementation of latest techniques. It could be reduced through considerable co-ordination between researchers, extension workers and farmers. These findings are in line with those of Hiremath and Hilli (2012). Data obtained in this study emphasizes the need to educate

Table 2. Package of practices followed for demonstrations and local check (Farmers' practice) in chickpea and lentil

Practices	Demonstration plots (chickpea)	Demonstration plots (lentil)	Local check (Farmer's practice plot)
Variety	Improved high yielding varieties (PBG 7)	Improved high yielding varieties (LL 931)	Local varieties of both crops
Seed rate	37.5 kg/ha	30 kg/ha	45 kg/ha (chickpea) 40 kg/ha (lentil)
Seed Treatment	Fungicide (Captan/Bavistin @3g per kg of seed + Biofertiliser culture (Mesorhizobium (LGR 33) and Rhizobacterium (RB-1)	Fungicide (Captan/Bavistin @ 3g per kg of seed + Biofertiliser culture (*Rhizobium* (LLR-12) and Rhizobacterium (RB-2)	Not applied
Sowing time	Under rainfed conditions (October 10-25). Under irrigated conditions (25th October-10th November)	Under rainfed conditions (October 10-25). Under irrigated conditions (25th October-10th November)	Under rainfed conditions (1st October- 10th November). Under irrigated conditions (15th October-25th November)
Sowing method	Pora method (line sowing) with row-to-row distance of 30 cm	Pora method (line sowing) with row-to-row distance of 22.7 cm	Broadcasting
Weed control	Pre emergence Stomp 30 EC @1 liter followed by Hand weeding (30 DAS)	Pre emergence Stomp 30 EC @1 liter followed by Hand weeding (30 DAS)	One hoeing
Fertilizer dose	Urea @ 32.5 kg/ha and SSP @ 125 kg/ha (On soil test basis)	Urea @ 27.5 kg/ha and SSP @ 125 kg/ha (On soil test basis)	Non-application of urea and S.S.P
Plant protection measures	Chloropyriphos 20 EC @ 10 ml/kg for termite control, 20 ml Indoxcarb 14.5 SC per acre for gram caterpillar control and Indofil M 45 for blight and grey mould (on economic threshold basis)	Use of rust resistant variety LL 931	Farmers neither use pesticides nor disease resistant varieties

Table 3. Effect of frontline demonstrations on yield, technology gap, extension gap and technology Index of *rabi* pulses

Year	Crop	Average demonstration yield (q ha^{-1})	Number of demonstration	Local check yield (q ha^{-1})	Increase in yield (%)	Potential yield of improved variety (q ha^{-1})	Technology gap (q ha^{-1})	Extension gap (q ha^{-1})	Technology index
2017-18	Chickpea	19.50	48	15.20	28.2	22.0	2.50	4.30	11.36
2018-19	Lentil	11.35	56	9.5	19.47	14.0	2.65	1.85	18.92

Table 4. Effect of improved agronomic practices on economic profitability of *Rabi* pulses

Crop	Control plots (Farmers practice plot)				Demonstration plots (Full package of improved techniques)				
	Gross cost (Rs ha^{-1})	Gross return (Rs ha^{-1})	Net return (Rs ha^{-1})	B:C ratio	Gross cost (Rs ha^{-1})	Gross return (Rs ha^{-1})	Net return (Rs ha^{-1})	B:C ratio	Net returns increase (%) over control
Chickpea	21950	66880	44930	2.05	22700	85800	63100	2.78	40.4
Lentil	16400	41800	25400	1.54	17250	50791	33541	1.95	32.0

the farmers through various means for adoption of improved production technologies to fill the extension gap. Similar result also reported by Singh et al (2014). The differences on the observed technology gaps may be attributed to dissimilarity in the soil fertility status, agriculture practices and local climatic conditions. These productivity gaps can be reduced by enhancing farmer's knowledge through more effective extension methods.

Economic returns: During 2017-18, higher average gross return of chickpea was reported in demonstration plots (Rs 85,800 ha^{-1}) as compared to farmers practice plots (Rs 66,6880 ha^{-1}). During 2018-19 improved technology produced higher gross return (Rs 50,791 ha^{-1}) in lentil as compared to Farmers practice plots (Rs 41800 ha^{-1}). However, increase in net return of demonstration plots was 40% and 32% over check plot, in case of chickpea and lentil, respectively. Higher net returns among demonstration was due to higher grain yield obtained as compared to Farmers practice plots. Ajrawat et al (2013) and Sandhu and Dhaliwal (2016) also reported similar results. The benefit: Cost ratio during 2017-18 was 2.78:1 in demonstration plots as compared to FP plot (2.05:1). Lentil demonstrations during 2018-19 also followed similar trends. However, chickpea cultivation was more profitable than lentil due to higher yield obtained. The results confirm the findings by Singh et al (2016) on chickpea and Naik et al (2016) on sunflower.

CONCLUSION

The yield of chickpea and lentil can be enhanced by 32 to 40 % with the use of improved technologies. Higher benefit cost ratio has confirmed the economic viability of the demonstrations. These demonstrations create a confidence and friendly relationship between farmers and scientists. The participated farmers in FLDs acted as source of information and improved seeds for larger spreading of the improved agronomic practices for chickpea and lentil for other adjoining areas of farmers.

REFERENCES

Ajrawat B, Parmar AM and Jamwal M 2013. Impact of frontline demonstration of oilseed crops in improved technology transfer. *Journal of Oilseed Brassica* **4**(2): 96-97.

Bar N and Das S 2015. Enhancement of production and productivity of arhar crop through front line demonstration. *International Journal of Innovative Research and Development* **4** (5):1-3.

Grower DK and Singh JM 2012. Possibilities and constraints for increasing the production of pulses in Punjab and impact of National Food Security Mission on pulses, AERC Study no. 26, Agro-Economic Research Centre, Department of Economics and Sociology, Punjab Agricultural University, Ludhiana, p 1–154.

Hiremath SM and Hilli JS 2012. Yield gap analysis in chilli production technology. *Asian Journal of Horticulture* **7**(2): 347-350.

Kirar BS, Narshine R, Gupta AK and Mukherji SC 2006. Demonstration: An effective tool for increasing the productivity of Urd. *Indian Research Journal of Extension Education* **6**(3): 47-48.

Kumar S, Barpete S, Kumar, Gupta J P. and Sarker A 2013 Global Lentil Production: Constraints and Strategies, *SATSA Mukhapatra* **17**: 1-13.

Kumari V, Kumar A and Bhateria S 2007. Demonstration - an effective tool for increasing the productivity of rapeseed- mustard in Kangra district of Himachal Pradesh. *Himachal Journal of Agricultural Research* **33**(2): 257-261.

Naik A, Patil DH, Teggelli RG and Ahamed Z 2016. Performance of front line demonstrations on sunflower (*Helianthus annuus* L.) in Kalaburagi Region of 368 Northern Karnataka. *Indian Journal of Ecology* **43**(1): 368-369.

Mitra B and Samajdar T 2010. Yield gap analysis of rape seed-mustard through frontline demonstration. *Agricultural Extension Review* **22**(1): 16-17.

Samui SK, Mitra S, Roy DK Mandal AK and Saha D 2000. Evaluation of front line demonstration on groundnut. *Journal of Indian Society of Coastal Agricultural Res*earch **18**(2): 180-183.

Sandhu BS and Dhaliwal NS 2016. Evaluation of front line demonstration programme on summer moong in south western Punjab. *Journal of Food Legume* **29**: 245-248.

Singh MP, Singh R, Ansari MA, Singh A, Saquib M, Ansari MH, Yadav B, Katiyar NK and Singh K 2015. Growth, yield and quality of Chickpea (*Cicer arietinum* L.) as influenced by sulphur and boron application and rhizobium inoculation. *Indian Journal of Ecology* **42**(1): 183-187.

Singh AP, Vaid A and Mahajan V 2014 Impact of KVK training programmes and frontline demonstrations on adoption of Pusa Basmati 1121 in Kathua district of Jammu and Kashmir *Journal of Krishi Vigyan* **2**(2): 44-48.

Singh AK, Gautam US, Chahal VP, Singh NP, Singh A, Dubey S K and Yemul SN 2016. *Demonstrational performance of pulses in India: Experiences of KVKs under NFSM* (2015-16) 122p.

Singh PK 2002. Impact of participation in planning on adoption of new technology through FLD *Manage Extension Research Review* 45-48.

Vaghasia PM, Savalia RL and Kelaiya GR 2005. Evaluation of frontline demonstrations on groundnut in Saurashtra region of Gujarat. *Journal of Oilseeds Research* **22**(1): 238-239.

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Prevalence and Partial Molecular Characterization of Citrus Psorosis Virus in Morocco

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Abstract: Citrus is one of the most economically important fruit tree crops in Morocco. *Citrus psorosis virus* (CPsV), the type species of the genus *Ophiovirus*, is the causal agent of psorosis, an economically important graft-transmissible disease of citrus. In order to assess the occurrence and distribution of CPsV in Morocco, surveys were conducted between 2017 and 2019, in the main citrus production areas of the country. Commercial groves, nurseries and one varietal collection were inspected for psorosis symptoms and a total of 435 samples were collected for analyses. The CPsV was widely distributed in the country with an infection rate of 44.8%, especially in the commercial orchards located in the Gharb region where 58.7% of the tested trees were infected. After RT-PCR, six CPsV isolates obtained from six Moroccan citrus growing areas were selected and submitted for molecular characterization by partial sequencing the coat protein gene. Multiple alignment of the obtained sequences showed high nucleotide identity (99.34-99.83%) among the Moroccan CPsV isolates, which clustered in the phylogenetic tree together with isolates from Argentina, USA and Egypt. CPsV spread in Morocco may be due to bud propagation, by small nurseries, from infected old trees, which were planted before the implementation of the certification program in the country.

Keywords: Citrus, Citrus psorosis virus, Surveys, RT-PCR, Molecular characterization, Morocco

Citrus is an economically important fruit crop in Morocco; citrus industry occupies about 128,000 Ha with an annual production of 2 million tons (Anonymous 2019). Moroccan citrus industry is still facing several constraints that extent of citrus decline, including viral and viral-like diseases which can cause varying degrees of damage and affect the quality and quantity of the produce on the one hand and the vigour and the longevity of the trees on the other. Psorosis, a graft transmissible disease of citrus, is a widespread disease causing serious damage in citrus plantings in many growing regions including North and South America and the Mediterranean basin. Two types of psorosis syndromes have been described in the field. Psorosis A (PsA), the most common type, characterized by the presence of bark scaling only in the trunck and limbs, whereas the most aggressive form, called psorosis B (PsB), causes bark scaling even in thin twigs, and old leaves may show chlorotic blotches with gummy pustules in the leaf underside (Velásquez et al 2015). Psorosis is primarily spread by propagation of infected buds. Up-to-date, no natural vector has been identified to transmit psorosis, but the possible involvement of a fungus (*Olpidium* spp.) in the disease transmission has been suggested (Palle et al 2005). *Citrus psorosis virus* (CPsV), the type species of the genus Ophiovirus (Milne et al 2000), is the presumed causal agent of citrus psorosis (Martín et al 2004). The virus has filamentous particles, highly kinked of about 3 nm in diameter. CPsV has a segmented genome, formed by three single-strands, negative sense RNAs (vRNAs) and a ~48 kDa coat protein (CP) (Martín et al 2005). In the present work, serological assays based on ELISA were carried out to study the prevalence and geographical distribution of CPsV, by conducting comprehensive field surveys in the main citrus production areas in Morocco. Furthermore, diversity and variation among six Moroccan CPsV isolates and those reported worldwide were evaluated by sequencing the amplified partial CP gene.

MATERIAL AND METHODS

A large scale survey for CPsV was conducted between 2017 and 2019 in the main citrus growing areas in Morocco: Gharb, Haouz, Loukkos, Moulouya, Souss and Tadla (Fig. 1). Field inspections for psorosis symptoms were carried out, and a total of 435 samples of different cultivars were randomly collected from 30 commercial groves, two nurseries and one varietal collection. Eight leaves were sampled around the canopy of each tree and were labelled

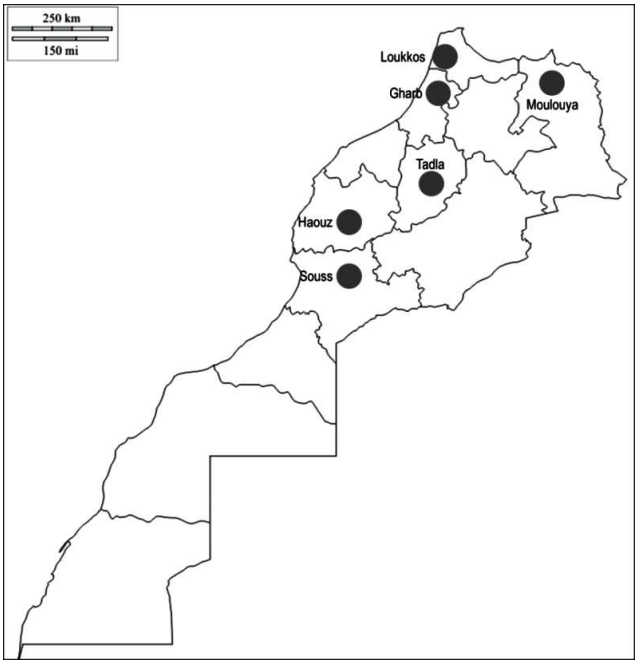

Fig. 1. Location of samples from the main citrus production areas in Morocco

and placed in plastic bags. Samples were transported to the laboratory on ice and kept at 4°C until analyses. All samples were tested by DAS-ELISA using commercially available kit (Agritest, Italy), following the manufacturer's instructions. In the presence of PBS-buffer, extracts were obtained from leaves (1g/10mL), using mortars and pestles. Optical Density (OD) of ELISA reactions was measured spectrophotometrically at 405 nm using the ELx800 ELISA reader (BioTek Instruments, USA). Virus positive and negative controls were included. Two wells were used per sample. The test was considered positive when the mean absorbance value was over 2.5 times that of healthy control. Among the CPsV-infected trees, six CPsV isolates collected from different regions were randomly selected on the basis of serological tests (Table 1). Total nucleic acids (TNA) from 100 mg fresh tissue were prepared using TRIzol reagent (Invitrogen, USA) following the manufacturer's instructions and RNA was resuspended in 50 µl of RNase-free water. RNA purity and concentration were quantified using the NanoDrop™ 2000c spectrophotometer (Thermo Fisher Scientific, USA).

One-step RT-PCR was carried out using the QIAGEN OneStep RT-PCR (QIAGEN, Germany). The RT-PCR was conducted in a 25 µl mixture consisting of 1 µg of TNA, 5 µl of 5X QIAGEN OneStep RT-PCR buffer, 0.4 mM of dNTPs, 0.6 µM of each primer CPV1/CPV2 (Barthe et al 1998), 1 µl of Qiagen OneStep RT-PCR Enzyme Mix, and RNase-free water. The thermocycling conditions included: 1 cycle of 30 min at 50°C for cDNA synthesis, 1 cycle of 15 min at 95°C for HotStartTaq DNA polymerase activation; 40 cycles of 30 s at 94°C, 45 s at 50°C and 1 min at 72°C, followed by an extension step of 10 min at 72°C. Ten microliters of the PCR products were analysed by electrophoresis in a 2% agarose gel stained with ethidium bromide and visualized under an UV trans illuminator and using the 100 bp Plus DNA Ladder (Fermentas) for size estimation. RT-PCR analysis included negative, positive and no-template controls.

To study the molecular variation and genetic diversity of CPsV in different infected regions, six isolates collected from the six regions. Amplified PCR products were purified with the Wizard SV gel and PCR clean-up system kit (Promega, USA), and sequenced in both directions. Multiple alignment of nucleotide sequences of CPsV was done using the Bio-Edit software version 7.0.9 (Hall 1999) and identity with known CPsV sequences was determined with the BLAST program (Altschul et al 1990). The sequences used to understand the phylogenetic relationships between the detected Moroccan CPsV and those distributed in other countries all over the world were obtained from NCBI database (Table 1). Phylogenetic analysis was performed using the molecular evolutionary genetic analysis software MEGA version 5.05 for the estimation of the nucleotide homology (Tamura et al 2011).

Table 1. Geographical origins, isolates and GenBank accession numbers of the nucleotide sequences of CPsV used in the phylogenetic analyses

Country	Isolate	Accession No.
Argentina	-	AF060855
Egypt	Egyptian	KM206785
Italy	CRSA-UBAps 101	AM40931
	NA5	AY194903
	NA8	AY194905
	NA10	AY19490
	NA35	AY194910
	P53	LN610695
Lebanon	P71	LN610697
Mexico	INIFAP-Nuevo Leon	EF618547
Spain	173-22 A1_b	AM235984
	C3_a	AM235975
	NA37 I5_c	AM235949
	P30	LN610693
	Terra Ceia T3_a	AM235971
Syria	C7	HG964696
Tunisia	P17	LN610692
USA	4e	AF036338

RESULTS AND DISCUSSION

During the survey, typical symptoms of psorosis bark scaling were observed on different cultivars in all the surveyed regions, in particular on 'Valencia Late' and 'Washington Navel' oranges, and 'Common Clementine' (Fig. 2) and samples were collected randomly from both symptomatic and symptomless trees. A total of 435 samples were collected, between 2017 and 2019, from commercial citrus orchards, nurseries were individually tested by DAS-ELISA for the presence of CPsV (Table 2). Out of 390 samples tested form commercial orchards, 183 trees were CPsV-infected, representing an infection rate of 46.92%, regardless of citrus species and location. The infected samples gave OD values 3-5 times higher than negative controls. Commercial orchards from the Gharb region were the most infected where 58.67% of the tested trees were positive, followed by Moulouya, Tadla, Loukkos, Souss, and Haouz. Among cultivars, 'Washington Sanguine' orange was the most infected one (73.33%), followed by 'Valencia Late' orange, whereas 'Afourer' mandarin was the lowest infected cultivar (13.33%). This high incidence of CPsV infection in commercial orchards is probably due to the continuous use of infected bud wood material. In addition, natural transmission by a vector cannot be excluded as previously reported by Gottwald et al (2005). Similar results were reported by Afechtal et al (2018) in Morocco with CPsV infection of 33%. High incidence (50%) of CPsV was reported in the Gharb region (Mrani et al 2002). ELISA test revealed the 40% of the tested accessions tested in the varietal collection, located in the Gharb region, were tested positive to CPsV. No CPsV infection was detected in samples collected from citrus nurseries; these results highlight the success of the Moroccan certification program established since 1983 for the production of virus-free citrus plants.

Fig. 2. Typical symptoms of CPsV observed during the survey in commercial orchards. (A) Bark scaling on trunk of a 'Valencia Late' orange tree grafted on 'Citrange Carrizo' rootstock, (B) Bark scaling on twigs of 'Navelina' orange, (C) Bark scaling and gummosis on twigs of 'Washington Navel' orange

To characterize Moroccan CPsV isolates, six positive samples from six regions were chosen. Partial sequences of the CP gene were obtained and deposited in GenBank database under the accession numbers (Table 3). Multiple alignment and phylogenetic analyses of the Moroccan revealed CPsV sequences were carried out together with other 19 CPsV isolates retrieved from the Genbank

Table 2. Detection of CPsV in Morocco as determined by DAS-ELISA

Region	Cultivar	Samples tested		
		No.	Infected No.	Infected %
Gharb	Common clementine	15	6	40
	Sidi Aissa clementine	15	5	33.3
	Valencia Late orange	15	14	93.3
	Washington Navel orange	15	8	53.3
	Washington Sanguine orange	15	11	73.3
	Nursery (5 mother trees of different cultivars)	5	0	-
	Varietal collection	30	12	40
Haouz	Afourer mandarin	15	2	13.3
	Common clementine	15	5	33.3
	Valencia Late orange	15	7	46.7
	Washington Navel orange	15	8	53.3
Loukkos	Common clementine	15	4	26.7
	Peau Fine clementine	15	7	46.7
	Valencia Late orange	15	9	60
Moulouya	Berkane clementine	15	7	46.7
	Marisol clementine	15	6	40
	Nova mandarin	15	6	40
	Washington Navel orange	15	8	53.3
	Valencia Late orange	15	10	66.7
Souss	Isbal clementine	15	6	40
	Larache clementine	15	4	26.7
	Nour clementine	15	7	46.7
	Nules clementine	15	7	46.7
	Ortanique mandarin	15	7	46.7
	Salustiana orange	15	8	53.3
	Nursery (10 mother trees of different cultivars)	10	0	-
Tadla	Common clementine	15	2	13.3
	Valencia Late orange	15	11	73.3
	Washington Navel orange	15	8	53.3
Total		435	195	44.8

Table 3. Moroccan CPsV isolates characterized in this work

CPsV isolate	Accession number	Region	Source
GHB-VaL1	MH707342	Gharb	Valencia Late (*Citrus sinensis* (L.) Osbeck)
HAZ-VaL3	MH707343	Haouz	Valencia Late (*C. sinensis* (L.) Osbeck)
LOK-Clm1	MH707344	Loukkos	Common Clementine (*C. clementine* Hort. Ex Tan.)
MOL-Clm2	MH707345	Moulouya	Berkane Clementine (*C. clementine* Hort. Ex Tan.)
SOS-Man6	MH707346	Souss	Ortanique Mandarin (*C. reticulata* Blanco)
TAD-VaL5	MH707347	Tadla	Valencia Late (*Citrus sinensis* (L.) Osbeck)

Table 4. Sequence identity matrix among the Moroccan CPsV isolates characterized in this work

Sequence	MH707342	MH707343	MH707344	MH707345	MH707346	MH707347
MH707342	ID	99.67%	99.67%	99.67%	99.67%	99.67%
MH707343		ID	99.34%	99.67%	99.34%	99.83%
MH707344			ID	99.34%	99.34%	99.50%
MH707345				ID	99.34%	99.83%
MH707346					ID	99.50%
MH707347						ID

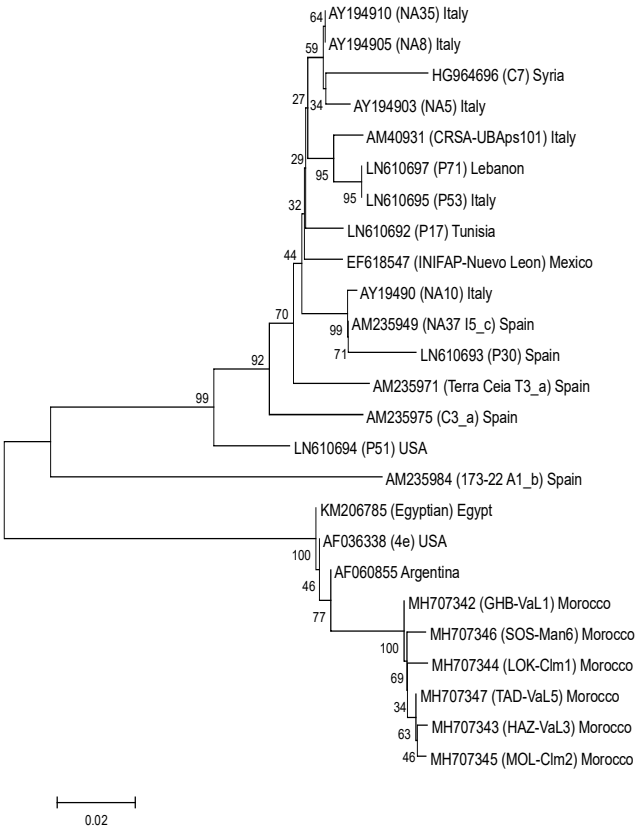

Fig. 3. Phylogenetic tree constructed with nucleotide sequences of the RT-PCR amplified fragments from six Moroccan CPsV isolates and the corresponding region of other 19 isolates retrieved from GenBank. Name of each isolate is shown in parentheses. Boostrap replicates values (percentage) are indicated at the nodes. Scale bar indicates changes per nucleotide

database, giving a total of 25 CPsV sequences. The analysis showed high sequence identity between Moroccan CPsV isolates, which ranged between 99.34 and 99.83% was observed, thus confirming their homogeneous origin (Table 4). This low value of nucleotide diversity of CP gene for Moroccan CPsV isolates highlights a low variability and confirms previous studies of Martín et al (2006) suggesting that low nucleotide diversity value observed in the CP gene region as the result of different selective pressures for nucleotide conservation. No specific sequence was found associated with citrus cultivar or field location, which is in agreement with the findings of Alioto et al (2003). Moreover, nucleotide BLAST analysis showed 99% sequence identity of the Moroccan CPsV isolates with the 4e isolate from USA (AF036338; Barthe et al 1998). Phylogenetic analysis showed that all the Moroccan CPsV isolates were clustered in the same group together with the 4e isolate from USA (AF036338), one isolate from Argentina (AF060855) and the unique Egyptian isolate KM206785 (Fig. 3). The distribution of variants occurred independently from the geographic origin. Despite the fact that Moroccan isolates and one isolate from Tunisia (LN610692) belong to the North Africa region, a clear demarcation appears between CPsV isolates of each country.

CONCLUSION

The objective of this work was to assess the incidence of CPsV in the main citrus production regions of Morocco and provide an insight on sequence variability of local CPsV isolates. Surveys confirmed a realistic picture of the sanitary status of Moroccan citrus orchards that seems rather

compromised because of the high incidence of CPsV. As there are no chemical products against virus and virus-like agents, the only known cure is to provide healthy (virus-free) planting material, usually within the framework of a phytosanitation program based on diagnosis, detection and elimination of the causal agent(s) through sanitation. Sequences comparison revealed high sequence identity between Moroccan CPsV isolates assuming their unique origin. Further biological and molecular studies are very important to determine the type of CPsV distributed in the country.

REFERENCES

Afechtal M 2018. Present status of virus and virus-like diseases of Citrus in Morocco. *Integrated Control in Citrus Fruit Crops IOBC-WPRS Bulletin* **132**: 215-220.

Anonymous 2019. Ministère de l'Agriculture, de la Pêche Maritime, du Développement Rural et des Eaux et Forêts. Note stratégique N°106, 16p.

Alioto D, Malfitano M, Troisi A, Peluso A, Martín S, Milne RG, Guerri J and Moreno P 2003. Variability of the coat protein gene of Citrus psorosis virus in Campania, southern Italy. *Archives of Virology* **148**: 2155-2166.

Altschul SF, Gish W, Miller W, Myers EW and Lipman DJ 1990. Basic local alignment search tool. *Journal of Molecular Biology* **215**: 403-410.

Barthe GA, Ceccardi TL, Manjunath KL and Derrick KS 1998. Citrus psorosis virus: Nucleotide sequencing of the CP gene and detection by hybridization and RT-PCR. *Journal of General Virology* **79**: 1531-1537.

Gottwald TR, Palle H, Miao M, Seyran M and da Graça JV 2005. Assessment of the possibility of natural spread of Citrus Psorosis Disease in Texas. *International Organization of Citrus Virologists Conference Proceedings (1957-2010)* **16**(16): 240-250.

Hall TA 1999. BioEdit: A user-friendly biological sequence alignment editor and analysis program for Windows 95/98/NT. *Nucleic Acids Symposium* **41**: 95-98.

Martín S, Alioto D, Milne RG, Garnsey SM, García ML, Grau O, Guerri J and Moreno P 2004. Detection of Citrus psorosis virus by ELISA, molecular hybridization, RT-PCR and immunosorbent electron microscopy and its association with citrus psorosis disease. *European Journal of Plant Pathology* **110**: 747-757.

Martín S, López C, García ML, Naum-Onganía G, Grau O, Flores R, Moreno P and Guerri J 2005. The complete nucleotide sequence of a Spanish isolate of Citrus psorosis virus: Comparative analysis with other ophioviruses. *Archives of Virology* **150**: 167-176.

Martín S, Garcia ML, Troisi A, Rubio L, Legarreta G, Grau O, Alioto D, Moreno P and Guerri J 2006. Genetic variation of populations of Citrus psorosis virus. *Journal of General Virology* **87**: 3097-3102.

Milne RG, García ML and Grau O 2000. Genus *Ophiovirus*. Type species Citrus psorosis virus (CPsV). **In**: van Regenmortel MHV, Fauquet CM, Bishop DHL, Carstens EB, Estes MK, Lemon SM, Maniloff J, Mayo MA, McGeoch DJ, Pringle CR and Wickner RB (eds), Virus Taxonomy. Proceedings of 7th Report of the *International Committee on Taxonomy of Viruses*, San Diego, CA, USA, Academic Press, pp. 627-631.

Mrani N, D'Onghia AM, Djelouah K, Zemzami M, Frasheri D and Martelli GP 2002. Distribution of citrus psorosis virus in Morocco. *International Organization of Citrus Virologists Conference Proceedings (1957-2010)*, **15**(15): 358-362.

Naum-Onganía G, Gago-Zachert S, Peña E, Grau O and García ML 2003. Citrus psorosis virus RNA 1 is of negative polarity and potentially encodes in its complementary strand a 24K protein of unknown function and 280K putative RNA dependent RNA polymerase. *Virus Research* **96**: 49-61.

Palle SR, Miao H, Seyran M, Louzada ES, da Graça JV and Skaria M 2005. Evidence for association of Citrus psorosis virus with symptomatic trees and an Olpidium-like fungus. *International Organization of Citrus Virologists Conference Proceedings (1957-2010)*, **16**(16): 423-426.

Tamura K, Peterson D, Peterson N, Stecher G, Nei M and Kumar S 2011. MEGA5: Molecular Evolutionary Genetics Analysis using Maximum Likelihood, Evolutionary Distance, and Maximum Parsimony Methods. *Molecular Biology and Evolution* **28**: 2731-2739.

Velázquez K, Alba L, Zarza O, Vives MC, Pina JA, Juáez J, Navarro L, Moreno P and Guerri J 2016. The response of different genotypes of citrus and relatives to *Citrus psorosis virus* inoculation. *European Journal of Plant Pathology* **144:** 73-81.

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Effects of Different Salting and Drying Methods on Allergenicity of Purple Mud Crab (*Scylla tranquebarica*)

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Abstract: Different salting and drying methods were conducted in this study to determine the impacts on the allergenicity of the purple mud crab, Scylla tranquebarica. Crab muscles were treated with the salting and drying methods, and the protein extracts were ready. Sodium dodecyl sulphate-polyacrylamide gel electrophoresis (SDS-PAGE) was used to analyse the extracts to define the profiling of the protein. Immunoblotting tests were conducted by utilizing the sera from 10 to 15 patients who are allergic to crab to detect the allergenic proteins. The outcome showed that the raw crab has 38 proteins fractions ranging from 10 to 245 kDa. In the extracts of dry and wet salted crabs, the majority of the bands disappeared and more prominent bands were noticeable. Meanwhile, in the drying method extracts, the prominent bands were monitored. Five significant allergens at 38, 42, 50, 63, and 73 kDa of the raw crab's immunoblotting were discovered. When comparing the extracts of the raw crab and the treated crab, the treated crabs had fewer allergenic bands. IgE-binding in dried method extracts exhibited to be lesser than the raw and salted crab. Overall, this study had proven that the treated crabs can affect the reaction of the IgE binding at lower capacities. The level of allergenicity is presented as the following treatments; raw > freeze-dried = wet salted > dry salted > sun-dried = oven-dried > microwave-dried. The outcomes of this study may contribute to the development of effective diagnosis and management strategies related to the crab allergy in this nation.

Keywords**:** Allergy, Crab, Drying, Immunoblotting, Salting, SDS-PAGE

Globally, the crucial health issue that had been a major concern is related to the IgE-mediated hypersensitivity reactions. In the United States, a survey had been conducted to report that 1 in 50 Americans will encounter at least one allergy to shellfish, including crabs[1]. Shellfish allergy is estimated to occur commonly between 0.5% - 2.5% in the general population. However, in coastal Asian countries, the occurrence of shellfish allergy is higher as shellfish are consumed in large quantity as part of their diet. In Malaysia, 44% of the local patients are diagnosed with allergic rhinitis and asthma, which indicated the prevalence of shellfish allergy among the locals(Guðjónsdóttir 2011).

Several studies had categorized the shellfish allergens based on dates. The common allergen that frequently discovered is tropomyosin, an abundant of protein muscle that can be found in numerous crab species such as *Charybdis feriatus*, *Eriocheir sinensis*, *Portunus pelagicus*, *Scylla serrata* and *Scylla paramamosain*. Tropomyosin is considered as a pan-allergen among invertebrates such as crustaceans, mollusks, mites, and cockroaches (Sarang and Sastry 2007). Besides tropomyosin, other crab allergens have also been reported such as arginine kinase. It is a new pan-allergen that present in mud crab of *S. serrata*, *S. paramamosain,* and snow crab *Chionoecetes opilio*. Also, α-actin, a sarcoplasmic calcium-binding protein, troponin, and smooth endoplasmic reticulum, Ca^{2+}ATPase, were also identified as allergenic proteins in crabs (Al Ghabshi et al 2012).

Several processing methods were imposed onto the food to preserve them from microbes, to prevent changes in colour, taste, and texture, and also to improve the digestibility (Bellagha et al 2007, Mudhafar and Alsailawi 2019). In many situations, several techniques related to thermal processing such as boiling, frying, steaming, and roasting, and non-thermal processing techniques, for instance acid hydrolysis, drying, and salting methods are used to reduce the impacts on the denaturation of the quality and the nutritional value of the food (Martínez-Alvarez and Gómez-Guillén 2005).

However, since allergens are mainly proteins, different processing methods lead to changes in the structure due to the alteration of the allergenicity during the process (Martínez et al 2009). Food processing may induce allergen alterations

due to epitope destruction or modifications, potentially resulting in either decreasing, enhancing, or having no effect on food allergenicity (Mol et al 2010). Impacts of heat treatments on the reactivity of patients' IgE antibody to numerous shellfish allergens have been widely reported (Murphey 2010). However, information on the effects of non-thermal treatments, such as drying or salting methods on the crab's allergenicity is still insufficient.

The drying method is commonly known to preserve rich protein products. It is an energy-efficient way to protect the functional fractions or the concentrations of the protein. Around 350,000 tons of dried aquatic products around the world were informed in the annual production report. Every year, the annual production of these products is consistently rising to 7% in Asian countries such as China and Malaysia (Alsailawi et al 2019) There are two main methods to preserve the protein products are the hot-drying and freeze-drying method. The hot-drying method is known to be cost-effective compared to the freeze-drying method. However, the quality of the food will degrade during the hot-drying process, and the freeze-drying method will sustain the colour, taste, texture, and the nutrients with less alteration to the actual products (Sobukola and Olatunde 2011). Meanwhile, salting seafood is traditionally an old method that had been used around the world in the past to maintain and enhance shelf life. Three techniques of salting are dry-salting, wet-salting, and the dry and wet salting. Salting method does not require complicated procedures as it only involves dry crystal salts or brine. The duration for the salting process and the level of the salt concentration depends on the outcome of the final products as the NaCl blends into the muscles of the seafood based on the osmotic pressure (Ünlüsayın et al 2010, Mudhafar et al 2020). Based on the SDS-PAGE, they discovered that the number of myosin heavy chain and its band intensity at a molecular weight of 100 kDa had increased.

The purple mud crab, *S. tranquebarica*, is referred to a big marine portunid species and is broadly dispersed along the shores of southeast China and other Asian countries such as India, Pakistan, Taiwan, Singapore, Indonesia, Malaysia, Japan, Vietnam, and the Philippines (Ali and Rosmilah 2019, Misnan et al 2019). In Malaysia, *S. tranquebarica* is greatly discovered along the coastal water of Sabah as there are abundant of mangrove forests and the coastlines are swamped with reduced salinity (Van Nguyen et al 2011). Although *S. tranquebarica* is declared as one of the important commercial species that widely found in Malaysia (Gh et al 2018), their allergenicity is not well studied. Therefore, the allergenicity of dried and salted crab extracts will be examined in this study through two salting methods and four drying methods.

MATERIAL AND METHODS

Extracting the crab proteins: A local provider in Tawau, Sabah has been the main supplier of *S. tranquebarica* for this study. Rosmilah et al (2012), mentioned that the extracted the crab proteins from the flesh. Extraction took place when the crab's flesh was homogenized in purified water and left for overnight at a temperature of 4 ºC. Then, the homogenates were centrifuged, filtered, dialyzed, lyophilized, and stored at -20 ºC until they were used. The allergen extracts from the treated samples were also prepared using the same aforementioned methods after being subjected to the respective treatments.

Drying treatment: In this study, four types of drying processes were conducted such as freeze-drying method, oven-drying method, microwave-drying method, and sun-drying method. Based on Zhang et al (2006), slight changes were made to the freeze-drying method before the examination took plave. By using a freeze dryer, 10g of crab muscles were freeze-dried and left overnight for 16 hours. Based on Kocatepe et al (2011), the oven-drying and microwave-drying methods were conducted, with slight changes to the procedures. In the oven-drying method, 10g of crab muscles were dried using an oven at a temperature of 105°C for 30 minutes. In microwave-drying method, 10g of the crab muscles were dried in a microwave for 10 minutes at the power of 200 W. Meanwhile, based on Jain and Pathare (2007), the sun-drying method was conducted with slight changes. 10 g of crab muscles were arranged in a single layer on a drying tray and positioned directly under the sun for 17 hours to fully utilize the sun under the climate in Tanjong Malim, Malaysia. The temperature of these drying experiments was set between 32.5°C to 42.5°C, and the muscle tissues that had been treated were associated with the extraction of protein.

Salting treatment: In this study, the salting processes were conducted based on the methods that had been mentioned in past studies (Sletten EM and Bertozzi 2009, Patterson et al 2018) but with slight changes to the procedures. The rock salt is used as it is a crystalline mineral that composed mainly of sodium chloride (NaCl). Salting procedure was done in a plastic container, and it was done through two approaches; wet and dry salting. In the process of wet salting, the muscles of the raw crab were treated in a salt solution that consists of sodium chloride (22.5%). Mix parts of crab muscles were immersed in the brine with a ratio of 1:18 w/w (crab to brine) for 72 hours at room temperature. Then, distilled water was used to clean crab muscles and disposable paper towels were used to dry them. In the dry salting process, the crab muscles were placed in a container and were organized in one layer. Salt was then sprinkled

onto the crab muscles, and the container was left and covered for 72 hours at room temperature. Later, the crab muscles were washed with distilled water and dried using paper towels that are disposable. As mentioned previously, the muscle tissues that had been treated were subjected to extraction of protein.

Serum samples: The samples of the serum were taken from 15 patients who are diagnosed with allergy to crab. The sera were confirmed to have IgE antibodies to the crab proteins through the Skin Prick Test or PhadiaCAP. Beforehand, this study was approved by the Medical Research and Ethics Committee (MREC), Ministry of Health Malaysia.

SDS-Page: Sodium dodecyl sulfate-polyacrylamide gel electrophoresis (SDS-PAGE) was conducted to define the profile of the protein in the extracts that had been prepared based on the methods that had been outlined by Rosmilah et al (2012). Firstly, the samples and the pre-stained molecular markers (Bio-Rad, CA, USA) were integrated into the wells that have 12% of resolving gels. Then, it was combined with 5% of stacking gel with the use of the Mini Protean 3 Apparatus. Then, the mixture was separated for 50 minutes. Next, Coomassie Brilliant Blue R-250 was used to stain the gel after underwent electrophoresis, and the gel was unstained in destaining solution I and II. Imaging densitometer was used to estimate the proteins' molecular weights.

Immunoblotting: The properties of the IgE bindings was determined through immunoblotting process using the sera obtained from 10 to 15 patients with allergy to crab, similar to the method that had been mentioned by Rosmilah et al (2012), with small changes. Meanwhile, serum from non-allergic subjects was taken as the negative control in this study. Briefly, SDS-PAGE process was conducted to separate the proteins and transfer to the nitrocellulose membrane using the Mini Transblot System (Bio-Rad, USA) for 70 minutes at 100 V and 250 mA. Subsequent to the immunoblotting process, the proteins were moved to the stained membrane. The nitrocellulose blots were divided into small strips in the size of 4mm and were cleaned with tris buffer solution (TBS) with a pH value of 7.2 and 5% of Tween 20 (TTBS). The strips were then clogged with 5% of low-fat milk in the TBS solution and incubated with the sera taken from 10 patients for 14 to 16 hours at 4 ˚C. The strips' IgE binding proteins can be determined after being incubated in biotinylated goat antihuman IgE antibody (KPL, UK), and later in conjugated streptavidin-alkaline phosphatase (BioRad, CA, USA) at room temperature for half an hour. Lastly, the IgE binding proteins can be identified by using alkaline phosphatase conjugate substrate kit.

RESULTS AND DISCUSSION

SDS-Page: The profile of the protein was identified by using SDS-PAGE. The protein components of all the crab extracts were separated based on their molecular weights. Figure 1 and Table 1 present the evaluation of the protein profile of different form of *S. tranquebarica*'s extracts; raw, dried (microwave-dried, oven-dried, sun-dried, and freeze-dried), and salted (dry-salted and wet-salted). Overall, the outcome reveals that the drying and salting methods can lessen the quantity of protein bands in *S. tranquebarica.*

The raw extract revealed approximately 38 protein bands from 10 - 245 kDa. The bands that demonstrated to be the most prominent were at 135, 100, 75, 50, 43, 42, 38, 20, 18, and 16 kDa. The result agrees with the previous research on local crab species, which reported that the raw extracts of blue crabs, *Portunus pelagicus* and red crabs, *Charybdis feriatus*, exhibited at least 20 protein bands (Rosmilah et al 2012).

Fish quality and proteins from other animals can be maintained and conserved for a long-term by going through the drying process. Generally, the drying process has a significant impact on the crabs' protein profile. When comparing the freeze-dried crab extracts and other extracts that had been dried-treated, it shows that the crab extracts exhibited more protein bands because of the freeze-drying treatment. This technique dries the crab muscles without utilizing any heat as heat will cause the protein to denature. This explains the significant loss of protein bands when the

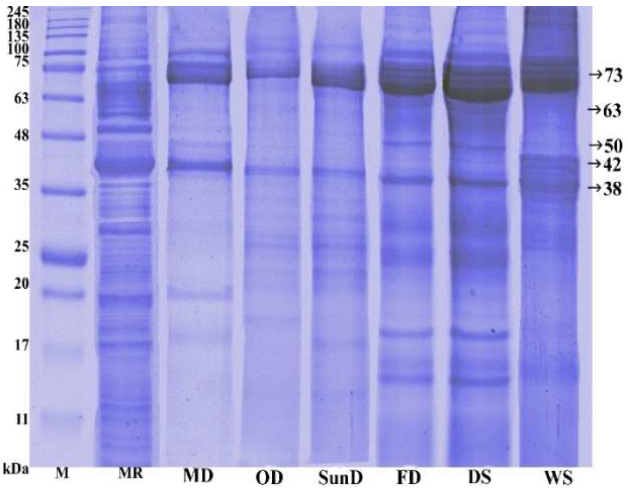

Fig. 1. PP (Protein profiles) of the salted and dried extracts of S. *tranquebarica*in SDS-PAGE gel. Lane M, molecular weight markers in kiloDalton (kDa). Lane MR is raw crab, while lanes OD, MD, FD, SunD, WS andDS are microwave dried, oven dried, sundried, freeze dried, dry salted andwet salted crab extracts. Arrows indicated the major allergen bands in kDa

crab muscles are treated using microwave-dried, oven-dried, and sun-dried methods. Through the different treatment, the sun-dried crabs exhibited the highest protein bands, which is 19 bands, compared to the oven-dried crabs with 16 bands, and microwave-dried bands with 14 bands. This outcome agrees to the previous research that sun-dried treatment will produce higher protein bands than other drying treatments such as solar dryer, oven dryer, and microwave dryer (Aberoumand 2015, Zarein et al 2015). It can be concluded that the differences in the protein bands may be due to the greater amount of moisture that had been removed in other drying methods than the sun-dried method (Sharif et al 2016).

Meanwhile, when comparing the extracts that had been salt-treated and dried, the salt-treated extracts exhibited more protein bands. Both dry-salting and wet-salting were applied, and the outcomes revealed that the patterns of both protein profiles were almost identical. However, some bands, which are 14, 16, 27, 35 to 50, 63 to 67 kDa and 74 to 150 kDa, were not detectable in both profiles from the extracts from the salted crab. The presence of water-soluble medium-molecular-weight proteins and amino acids, such as alanine, glycine, leucine, valine, and glutamic acid caused the reduction, and may hinder the salting process (Lee et al 2003). Due to the osmotic pressure, the NaCl may diffuse into the muscles of the seafood, which can cause greater ionic strength that can cause the myofibrils to contract and the proteins to dehydrate (ALsailawi et al 2019)

Immunoblotting: The components of the IgE-binding protein from the raw extract of *S. tranquebarica* can be discovered through immunoblotting by utilizing the sera

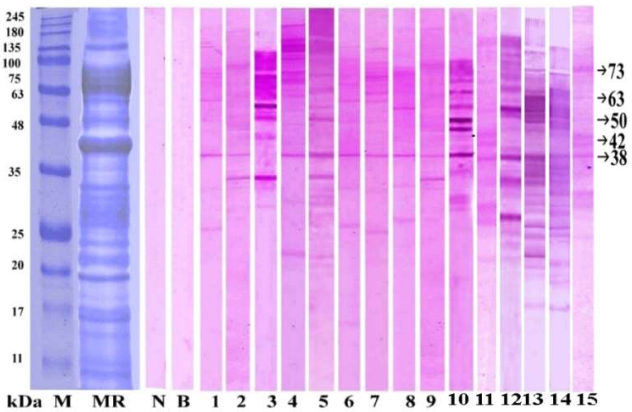

Fig. 2. Immunoblotting results of raw mix *S. tranquebarica* using sera from 15 crab-allergic patients (lane 1 to 15). Lane M is molecular mass markers in kilo Dalton (kDa); lane MR is raw mix crab; lane B is blank and lane N is immunoblot using a negative control serum. Arrows indicated the major allergens molecular weight in kDa

Table 1. MW (Molecular weight) of protein bands of the salted and dried crab extracts of *S. tranquebarica*

Salted			Dried			Raw	Protein molecular weight (kDa)
FD	WS	DS	MD	OD	SunD		
						√	245
√	√	√				√	150
√	√	√		√		√	107
√	√	√	√	√	√	√	100
√	√	√				√	84
√	√	√	√	√	√	√	75
√	√	√	√	√	√	√	74
√	√	√	√	√	√	√	73
√	√				√	√	72
						√	70
						√	69
√	√	√			√	√	67
√	√	√	√		√	√	65
√	√	√	√		√	√	63
√						√	53
√						√	52
√						√	51
√						√	50
√	√	√	√	√	√	√	48
√	√	√	√	√	√	√	43
√	√	√	√	√	√	√	42
√	√	√	√	√	√	√	38
√	√	√	√	√	√	√	37
√	√	√	√	√	√	√	36
√	√	√				√	35
√						√	34
√				√	√	√	31
√	√	√		√	√	√	27
				√		√	25
√					√	√	24
√					√	√	22
						√	20
√			√			√	18
√	√	√	√	√	√	√	16
√						√	15
√	√	√				√	14
						√	11
						√	10
31	21	20	14	16	19	38	Total, n

Note: Protein band = √

taken from 15 patients with crab allergy. Meanwhile, the impact of the IgE-binding protein after being treated with drying and salting treatments were discovered with 10 selected sera. Figure 2 shows the outcome of *S. tranquebarica* raw extract, while Figure 3 and Figure 4 display the IgE-binding proteins of dried and salted crab extracts. In the raw extracts of mixed parts, there are 20 IgE-binding proteins between 14 to 135kDa, indicating that *S. tranquebarica* has numerous allergenic proteins. This finding agrees with Nurul et al (2015), who also detected multiple IgE-binding proteins between 23kDa and 250 kDa in mud crabs, *Scylla serrata*. Five proteins at 38, 42, 50, 63, and 73kDa could attach to IgE antibodies to at least half of the sera that had been tested at frequencies of 83, 51, 58, 68, and 72%, respectively. Therefore, they were discovered to be as the main allergens for *S. tranquebarica*. Meanwhile, another study has successfully identified significant allergens at 38, 63, and 73 kDa as tropomyosin, actin, and hemocyanin, while at 42 and 50 kDa, both were recognized as arginine kinase (unpublished data).

The lesser IgE-binding bands were shown in all dried crab extracts than in the raw crab extracts due to less immunoreactivity (Fig. 3). During the drying process, the proteolysis of antigenic protein was activated. In comparison to the dried crabs, the highest IgE-binding bands were shown by the freeze-dried crab with 16 bands, followed by the sun and oven-dried crabs with 12 bands. Meanwhile, the microwave dried crab exhibited 11 bands, indicating the lowest IgE binding bands among all drying methods. Therefore, based on the number of allergenic bands, the allergenicity of the freeze-dried crab was more stable than the microwave dried crab. The degree of allergenicity can be presented as follows: freeze-dried > sun-dried = oven-dried > microwave dried. As mentioned previously, the protein of the crab muscles will be degraded during the microwave dried, oven-dried and sun-dried treatments as heat will denature the muscles of the crabs and freezing drying treatment will be applied in freezing atmospheres. Akinneye et al (2010) also reported the variations in the concentrations of elements from one sample of fish to another was due to after subjecting the fish to different drying methods. Based on the immunoblotting results onto all the dried extracts, five significant allergens of S. tranquebarica were discovered at 38, 42, 50, 63, and 73 kDa. The allergenicity of the dried crabs was the same, indicating that the major allergens were stable to all the drying methods. Meanwhile, the intensities of the IgE-bindings were determined. The most intense IgE-binding was shown during the immunoblotting of freeze-dried crabs, then by the sun-dried crabs, and almost identical intensities were from the microwave and oven-dried crabs. Therefore, based on the intensities, the degree of the allergenicity can be arranged as follows: freeze-dried > sun-dried > oven-dried = microwave-dried.

The raw *S. tranquebarica* had less reaction than in the dried extracts, due to the reduction of IgE-bindings after being treated with the salt (Fig. 4). During the salting process, the existence of water-soluble medium-molecular-weight proteins had been affected (Telahigue et al 2014). In seafood

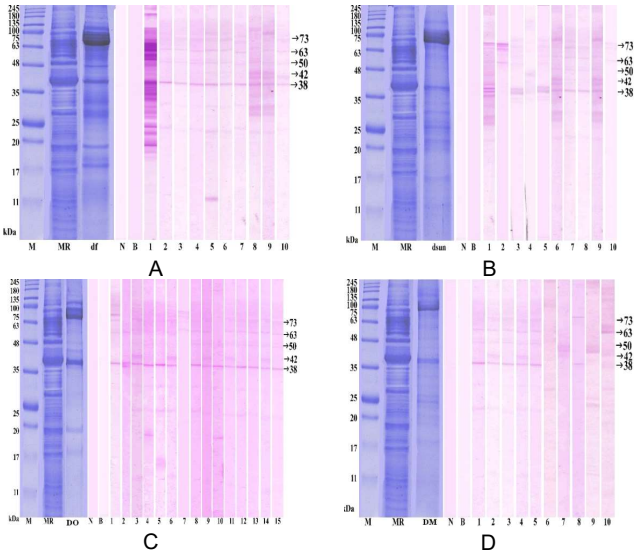

Fig. 3. Immunoblotting results of freeze-dried (A), sun dried (B), oven dried (C) and microwave dried (D) *S. tranquebari ca*using sera from 10 to 15 crab-allergic patients (lane 1 to 15). lane (df) is freeze-dried (SunD) is sun dried, (DO) is oven dried and(DM) is microwave dried treated crab; lane MR is raw crab; lane B is blank and lane N is immunoblot using a negative control serum; Lane M is molecular mass markers in kilo Dalton (kDa). Arrows indicated the molecular weight of major allergens in kDa

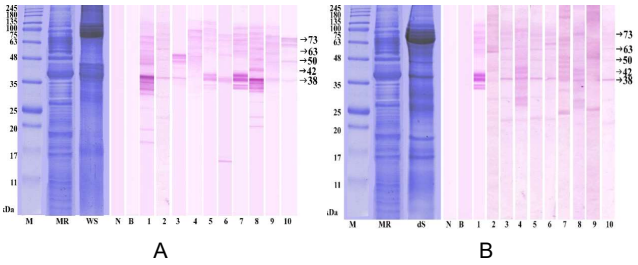

Fig. 4. Immunoblotting results of wet salted (A) and dry salted (B) *S. tranquebari ca*using sera from 10 crab-allergic patients (lane 1 to 10). B is blank and lane N is immunoblot using a negative control serum; lane WS is wet salted and dS is dry salted crab; lane MR is raw crab; Lane M is molecular mass markers in kilo Dalton (kDa). Arrows indicated the molecular weight of major allergens in kDa

that had been salted, the salt concentration can increase to 20% of high ionic strength, causing the myofibrils to contract, and the proteins will dehydrate. In addition, the final product's pH value and the different kinds of salt can have significant influence to the degree of protein denaturation (Aziz et al 2016). After the salting process, some of the proteins were discovered to disappear, and the IgE-binding in the patients' sera was lessened. In comparison to all the salted crabs, the highest IgE-bindings band was shown by the wet-salted crabs with 16 bands and the dry-salted crabs with 14 bands. Both salted crabs exhibited the significant allergen bands at 38, 42, 50, 63, and 73 kDa. Based on the intensity of the IgE-bindings, prominently at 38 kDa, higher intensity of IgE binding was shown by the wet-salted crabs than the dry-salted crabs. Thus, according to the allergenic bands and the IgE-binding intensities, the wet-salted crabs have stable allergenicity than the dry-salted crabs. Overall, different allergenic protein bands were shown by the extracts of *S. tranquebarica* that had been dried and salted. The bands range from 1 to 16 bands between 18 to 75 kDa. Freeze-dried and wet-salted crabs possess the highest IgE-binding bands with 16 bands, followed by the dry-salted crabs with 14 bands, sun and oven-dried crabs with 12 bands, and microwave-dried crabs with 11 bands. The order of the allergenicity was done based on the obtained allergenic bands: freeze-dried = wet-salted > dry-salted > sun-dried = oven-dried > microwave-dried. Meanwhile, five main allergens of *S. tranquebarica* were discovered at 38, 42, 50, 63, and 73 kDa after the immunoblotting of all salted and dried crabs had been conducted. It was discovered that the intensity of the IgE-binding was most noticeable during the immunoblotting of freeze-dried crabs, tailed by the wet-salted crabs, dry-salted crabs, sun-dried crabs, microwave-dried crabs, and finally, oven-dried crabs. Thus, the degree of the allergenicity was arranged based on the obtained intensities of the IgE-binding bands: freeze-dried > wet-salted > dry-salted > sun-dried > microwave-dried > oven-dried.

CONCLUSION

This study concludes that *S. tranquebarica* can retain its allergenic potential even after being treated with various types of dried and salted treatments with different frequencies and strengths. The level of allergenicity is arranged as follows: raw > freeze-dried = wet salted > dry salted > sun-dried = oven-dried > microwave-dried treatments. To reduce the crab's allergenicity in terms of the quantity of the bands, IgE-binding intensity, and the number of major allergens, this study suggested that the most appropriate non-thermal treatment to be applied for future study is the microwave-drying method.

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REFERENCES

Al Ghabshi A, Al-Khadhuri H, Al-Aboudi N, Al-Gharabi S, Al-Khatri A, Al-Mazrooei N and Sudheesh PS 2012. Effect of the freshness of starting material on the final product quality of dried salted shark. *Advance Journal of Food Science and Technology* **4**(2): 60-63.

Ali AH and Rosmilah M 2019. Effects of food processing on the stability and quality of Shellfish Allergens. *Journal of US-China Medical Science* **16**: 149-163.

ALsailawi HA, Mudhafar M, Majhool AA and Asaad A 2019. Study of Cystatin C as early biomarker of nephropathy in patients with type 2 DM and risk stratification in Tarnaka Hospital of Hyderabad City in India. *Journal of US-China Medical Science* **16**: 232-241.

Aziz NSA, Misnan R, Yadzir ZHM, Bakhtiar F, Abdullah N and Murad S 2016. Immediate hypersensitivity to marine snail (*Cerithidea Obtusa*) Allergen among local patients with atopic diseases (22-30). *Educatum Journal of Science, Mathematics and Technology* **3**(2): 22-30.

Bellagha S, Sahli A, Farhat A, Kechaou N and Glenza A 2007. Studies on salting and drying of sardine (*Sardinella aurita*): Experimental kinetics and modeling. *Journal of Food Engineering* **78**(3): 947-952.

Gh Z, Etemadian Y, Khanipour AA and Fahim A 2018. The quality changes of frozen and dried tiny shrimp (*Macrobrachium nipponense*) meat during six months storage. *Journal of Nutrition and Health* **5**(2): 209.

Guðjónsdóttir M 2011. Quality changes during seafood processing as studied with NMRand NIR spectroscopy. *International Journal of food engineering* **42**(2): 378-382.

Jain D and Pathare PB 2007. Study the drying kinetics of open sun drying of fish. *Journal of Food Engineering* **78**(4): 1315-1319.

Kocatepe D, Turan H, Taskaya G, Kaya Y, Erden R and Erdogdu F 2011. Effects of cooking methods on the proximate composition of black sea anchovy (*Engraulis encrasicolus*, Linnaeus 1758). *GIDA* **36**(2), 71-75.

Lee SJ, Shin JH, Sung NJ, Kim JG and Hotchkiss JH 2010. Effect of cooking on the formation of N-nitrosodimethylamine in Korean dried seafood products. *Food Additives & Contaminants* **20**(1): 31-36.

Martínez KD, Sánchez CC, Patino JM and Pilosof AM 2009. Interfacial and foaming properties of soy protein and their hydrolysates. *Food Hydrocolloids* **23**(8): 2149-57.

Martínez-Alvarez O and MC Gómez-Guillén 2005. The effect of brine composition and pH on the yield and nature of water-soluble proteins extractable from brined muscle of cod (*Gadus morhua*). Food Chem **92**: 71-77.

Misnan R, Sockalingam K, Yadzir ZH, Abdullah N, Bakhtiar F and Murad SN 2019. Characterization of major allergens of Macrobrachium rosenbergii and their thermostability in different cooking methods. *Jurnal Teknologi* **81**(1): 163-170.

Mol S, Cosansu S, Alakavuk DU and Ozturan S 2010. Survival of *Salmonella Enteritidis* during salting and drying of horse mackerel (*Trachurus trachurus*) fillets. *International Journal of food Microbiology* **139**(1-2): 36-40.

Mudhafar M and Alsailawi HA 2019. An expression study profile of proinflammatory cytokines in asthma patient. *Journal of Asian Scientific Research* **9**(12): 227-234.

Mudhafar M, Zainoll, Jaafar CA, Alsailawi HA and Arkan A 2020. Phytochemical screening and characterization of meliadubia leaves extract for antimicrobial activity against *Escherichia coli* and Staphylococcus aureus. *Indian Journal of Ecology* **47**(2): 493-499.

Murphey MB 2010. *Spin-Valve Behavior in Aligned Arrays of Carbon Nanotubes* (Doctoral dissertation, The Ohio State University).

Mustafa M, Ismail Z, Che Nor Aiza J, Alsailawi HA and Alhussein AM 2020. Microwave-assisted green synthesis of ag nanoparticles using leaves of *Melia Dubia* (Neem) and its antibacterial activities. *Journal of Advanced Research in Fluid Mechanics and Thermal Sciences* **65**(1): 121-129.

Patterson J, Kailasam S, Giftson H and Immaculate JK 2018. Effect of drying technologies on the biochemical properties of *Stolephorus commersonnii*. *Food Quality and Safety* **2**(3): 153-158.

Rosmilah M, Shahnaz M, Zailatul HM, Noormalin A and Normilah I 2012. Identification of tropomyosin and arginine kinase as major allergens of *Portunus pelagicus* (blue swimming crab). *Trop Biomed* **29**(3): 467-78.

Sarang S and Sastry SK 2007. Diffusion and equilibrium distribution coefficients of salt within vegetable tissue: Effects of salt concentration and temperature. *Journal of Food Engineering* **82**(3): 377-382.

Sharif NA, Kahar NA, Rodrigues K, Ransangan J and Kian AY 2016. Genetic diversity of mud crabs, Scylla tranquebarica in Sabah, Malaysia based on Cytochrome C Oxidase (COI) gene sequence. *Songklanakarin Journal of Science & Technology* **38**(4) 365-372.

Sletten EM and Bertozzi CR, 2009. Bioorthogonal chemistry: fishing for selectivity in a sea of functionality. *Angewandte Chemie International Edition* **48**(38): 6974-6998.

Sobukola OP and Olatunde SO 2011. Effect of salting techniques on salt uptake and drying kinetics of African catfish (*Clarias gariepinus*). *Food and Bioproducts Processing* **89**(3): 170-177.

Telahigue K, Hajji T, Imen R and Sahbi O 2014. Effects of drying methods on the chemical composition of the sea cucumber *Holothuria forskali*. *The Open Food Science Journal* **8**(1): 30.

Ünlüsayın M, Erdilal R, Gümüş B and Gülyavuz H 2010. The effects of salt-boiling on protein loss of *Penaeus semisulcatus*. *Turkish Journal of Fisheries and Aquatic Sciences* **10**(1): 75-79.

Van Nguyen M, Thorarinsdottir KA, Gudmundsdottir A, Thorkelsson G and Arason S 2011. The effects of salt concentration on conformational changes in cod (*Gadus morhua*) proteins during brine salting. *Food Chemistry* **125**(3): 1013-1019.

Zarein M, Samadi SH and Ghobadian B 2015. Investigation of microwave dryer effect on energy efficiency during drying of apple slices. *Journal of the Saudi Society of Agricultural Sciences* **14**(1): 41-47.

Zhang M, Tang J, Mujumdar AS and Wang S, 2006. Trends in microwave-related drying of fruits and vegetables. *Trends in Food Science & Technology* **17**(10): 524-34.

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Reproductive Ecology of an Invasive Cichlid Fish *Oreochromis mossambicus*

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Abstract: Reproductive ecology of an invasive cichlid, *Oreochromis mossambicus* was studied using 654 specimens collected from Vembanad Lake, Kerala state. Females were predominant in the catches and the overall sex ratio was 1:1.40 (X^2=17.83, p< 0.05), which significantly deviated from theoretical 1:1 distribution with 41.74% males and 58.26% females. Males and females in reproductive activity occurred throughout the year, the peak spawning period occurring between May to August and November to December. The length at which 50% (L_{50}) of the fish were mature was 154.88 mm TL for males and 141.72 mm TL for females. The absolute fecundity of *O. mossambicus* varied from 644-2210 eggs/fish with an average of 1469 and the relative fecundity ranged from10.12-19.23 eggs/g with an average of 15.54.Continuous spawning pattern, extreme parental care, fast sexual maturation, comparatively small eggs, predominance of females and tolerance to a wide range of environmental conditions promote the high recruitment of this invasive species in the lake and the adjoining rivers.

Keywords: Cichlid fish**,** Reproductive ecology**,** Sex-ratio, Spawning season, Mozambique tilapia, Fecundity

Mozambique tilapia, *Oreochromis mossambicus* (Peters 1852) is a medium-sized, euryhaline cichlid fish native to the eastward flowing rivers, lakes and lagoons of central and southern Africa (Russel et al 2012b). Owing to high aquaculture demand, the fish has been widely transferred to many part of the world and in most of the locations of introduction, it successfully formed stable invasive populations creating potential ecological threats to native fish fauna (Canonico et al 2005). *O. mossambicus* could adapt to many unsuitable environments due its huge ecological plasticity characterized by trophic flexibility, tolerance to extreme and unfavourable environmental conditions, immense reproductive potential, maternal parental care, high growth rate and aggressive and territorial behaviour (Pe´rez et al 2006, Maddern et al 2007). Considering the ecological impacts that the species could make in natural waters, *O. mossambicus* has been listed as the top 100 invasive alien species in the world (Global Invasive Species Database 2020). It is also categorized by IUCN among those invasive fishes believed to create the most adverse ecological effects. Information on reproductive biology of fishes is helpful to evaluate population structure, potential for recruitment, species establishment and effective stock management of fishes (Adite et al 2017). For invasive fishes, studies on reproductive ecology and recruitment are of greater significance to predict the population status and preparing proper management strategies (Chander 2016). Though information on the reproductive behaviour of *O. mossambicus* is available from different part of the world no detailed study has been reported from India despite the abundance of the species from natural waters. The present study aims to provide the basic information on reproductive ecology such as sex ratio, gonadosomatic index, spawning season, size at first maturity and fecundity of invasive *O. mossambicus* from Vembanad Lakein the state of Kerala, which would be helpful to propose effective management strategy for this invasive species.

MATERIAL AND METHODS

Study area: Vembanad Lake is the largest estuarine system located on the south-west coast of India stretching from Munambam in the north to Alappuzha in the south in the state of Kerala having open permanent connections with Arabian Sea. It is a highly productive monsoon-influenced positive tropical estuarine complex having variable hydrodynamic conditions depending upon saline water intrusion, the freshwater influx from rivers and precipitation patterns. Vembanad Lake owing to high biological productivity and availability of a number of micro-habitats like chain of backwaters, mangrove patches and in warded narrow water channels supports a unique and diverse assemblage of aquatic fauna (Krishnakumar and Priyadarsanan 2012) and was listed as a Ramsar site (No. 1214) by the Convention of Wetlands of UNESCO in 1981 while considering the excellent habitat it provides for migratory waterfowls (Selvam et al 2012).

Sample collection and analysis: The present study is based on a total of 654 fish individuals (273 males and 381

female) of *O. mossambicus* collected from the commercial catch monthly from Vembanad Lake using gill nets (20-80mm) during June 2015 to May 2016. The samples were preserved in 10% formalin and transferred to the laboratory for further analysis. The total length (TL) (to the nearest 1 mm) and body weight (BW) (to the nearest 0.1g.) were estimated. The fishes were then dissected to determine the sex by visual inspection of condition of the gonads. The gonad development stages were determined according to gonad colour, relative size and its position and presence of vitellogenin oocytes in females and milt in males. For each fish, its maturity was classified as (1) I, Immature; (2) II, Maturing; (3) III, Mature; (4) IV, Ripe; and (5) V, Spent. Sex ratio was calculated on a monthly basis as the percentage of males to females (M: F) and a Chi-square (X^2) test was used to determine the significant differences in the frequency of each sex. The spawning season was calculated by analyzing the monthly proportion of maturity stages and monthly variations of the gonadosomatic index (GSI). GSI was calculated using the formula:

GSI= GW/BW x 100 (Zare et al 2015)

Where GW is gonad weight and BW is the total body weight. The size at first maturity (L_{50}) is defined as the length at which 50% of the population had reached sexual maturity (King 2007) and L_{50} was estimated using the equation: $M(L) = e^{(a+bL)}/(1+e^{(a+bL)})$, where M(L) is the proportion of mature fishes, L= length class, and *a* and *b* are parameters (Remyamohan et al 2018). The fecundity was estimated from mature oocytes in both ovaries from a sample of 57 mature females ranging from 112-238 mm TL and with a GSI varied from 2.66 to 4.5 during the spawning season. The ovaries of mature fishes were preserved in Gilson's fluid to facilitate the separation of ova. The ovaries are weighted and from each of them sub-samples from the anterior, middle and posterior regions were weighed and the number of ova in each sub-sample was counted. Absolute fecundity (AF) was estimated by the gravimetric method using the following formula: AF = nG/g, Where, n= number of eggs in the sub-sample, G = Total weight of the ovaries and g = weight of the sub samples (Liu et al 2013). Relative fecundity is expressed as the number of eggs per gram of fish body weight.

RESULTS AND DISCUSSION

Among 654, *O. mossambicus* samples collected, 41.74% constituted male individuals (62–248 mm TL) and 58.26% female individuals (64–250 mm TL) indicating the predominance of females in their population from Vembanad Lake. The overall male to female sex ratio calculated was 1:1.40 (X^2=17.83, p< 0.05) which significantly deviated from hypothetical distribution of 1:1 (Table 1). Furthermore, the sex ratio of *O. mossambicus* population varies depending on the location, environmental factors, season and fishing gears used (Russel et al 2012b). The preponderance of one sex in a population is due to the sexual difference in the growth rate (Gosavi et al 2020). Females require better environmental conditions than male population, suffering in their development when environmental conditions deteriorate (Euphrasia and Kurup 2008, Bindu and Padmakumar 2014).

Table 1. Sex ratio and chi square test of *O. mossambicus* in Vembanad Lake

Months	Male	Female	Total	M:F	Chi Square
June	18	26	44	1:1.44	1.45
July	20	27	47	1:1.35	1.04
August	20	33	53	1:1.65	3.19
September	25	36	61	1:1.44	1.98
October	22	35	57	1:1.59	2.96
November	22	30	52	1:1.36	1.23
December	24	33	57	1:1.38	1.42
January	23	31	54	1:1.35	1.19
February	26	30	56	1:1.15	0.29
March	24	32	56	1:1.33	1.14
April	24	39	63	1:1.63	3.57
May	25	29	54	1:1.16	0.30
Total	273	381	654	1:1.40	17.83

The fishes with immature stage (Stage I) were observed in all the months, although a higher proportion of this fish were observed in March (17.65%) in males and September (16.67%) in females (Fig. 1 and 2). Maturing ovaries (Stage II) made their appearance in all the months with highest contribution from October to April in males and females. Mature males (Stage III) showing their preponderance in May (27.78 and 30.77%) in males and female respectively. Ripe individuals (Stage IV) were appeared in all the months and their highest from May to September and November to December in males and females. Individuals of Stage V of maturity were maximum in August to September and November to December in males and August to September and November to January in females respectively. *O. mossambicus* breeds throughout the year and the occurrence of ripe ovaries from May to August and November to December confirms that the fish has two spawning peaks. In tropical waters where the water temperature remains high throughout the year, tilapiine species can reproduce continuous though the intensity varies seasonally (Hutchison et al 2011). The year-round breeding in *O. mossambicus* was reported earlier from different ecosystems in the world (Russell et al 2012b). Physicochemical environmental conditions, prevailing water levels, altitude and latitude have

important roles to influence the spawning activity in *O. mossambicus* and accordingly the reproductive activity of the species may have limited to a few months or continuous the whole year (Russell et al 2012a).

The GSI showed monthly variations and followed a similar pattern in both the sexes, overall GSI value for females was much higher than those recorded in males (approximately, 3 times) and the ripe ovaries in the fish were larger than ripe testes (Fig. 3). GSI provides information on the development of gonads with respect to time (Singh et al 2018). The GSI increases with the maturation of the fish, being highest during the peak period of maturity and declines after the spawning (Renjithkumar et al 2020). In the present study, the testicular weight showed an increase from May (0.81) and attained the peak in August (1.28). After September, the GSI showed a declining trend and then increasing from November (0.9) and attained the peak in January (1.1). After January, testicular weight showed a declining trend.In females index values were lowest in March (1.3) and steadily increased to a peak in August (4.9). The GSI value showed a declining trend from September onwards and reached the lowest during October and after that the GSI value increased with a peak in January (4.4). The GSI values reached at peak in the month of May to August and November to January, which indicate the peak breeding period of *O. mossambicus* that coincides with the South west and North east monsoon in Kerala state of India. There is a general tendency for the GSI of *O.mossambicus* increase during the rainy season comes and then value decreases in tropical areas(Hutchison et al 2011). In tropical belt, one of the most important factors triggering spawning of fishes is onset of monsoon and related flooding (Bindu et al 2012). Habitat expansion in the wet season decreases crowding and predation pressure and provides better food availability and optimum temperature which facilitate fishes to initiate the breeding activities (Russel et al 2012b).

The male *O. mossambicus* reached their first maturity at the length of 154.88 mm whereas the first maturity of the

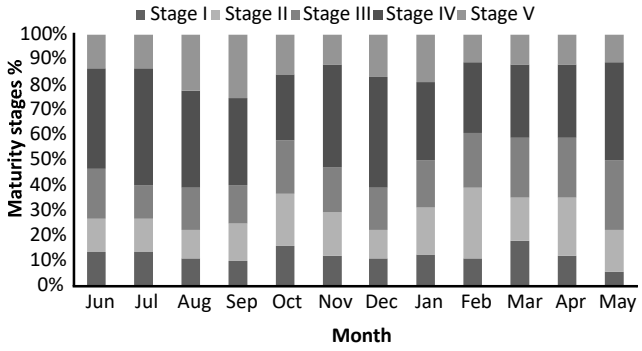

Fig. 1. Monthly distribution of maturity stages of male *O. mossambicus* from Vembanad Lake

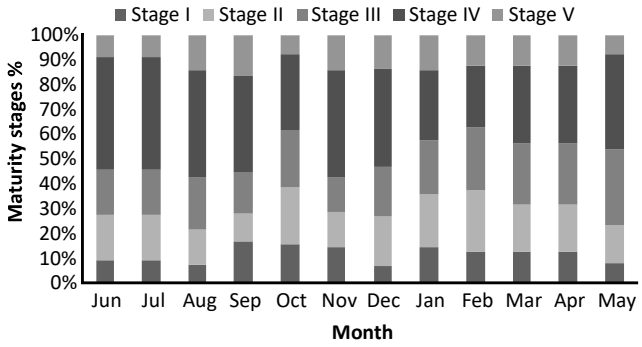

Fig. 2. Monthly distribution of maturity stages of female *O. mossambicus* from Vembanad Lake

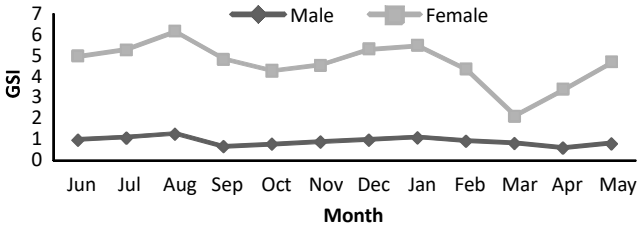

Fig. 3. Monthly variation of gonado-somatic index of *O. mossambicus* in Vembanad Lake

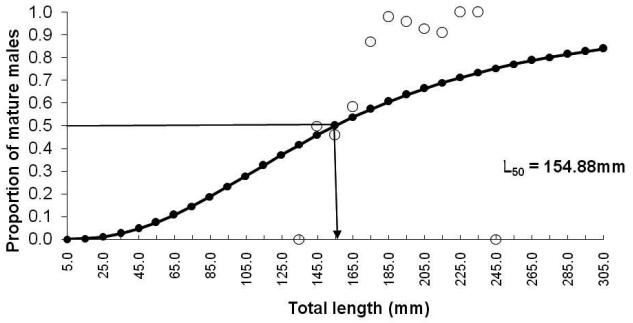

Fig. 4. Maturity curve of male *O. mossambicus* from Vembanad Lake

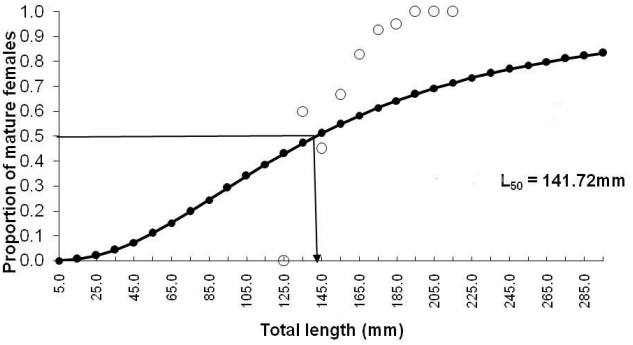

Fig. 5. Maturity curve of female *O. mossambicus* from Vembanad Lake

Table 2. Estimated fecundity parameters of *O. mossambicus* from Vembanad Lake

Length group (mm)	Average fish length (mm)	Average fish weight (g)	No. of specimen	Average ovary weight (g)	GSI	Absolute fecundity	Relative fecundity
110-119	115	41	2	1.3	2.66	711	17.34
120-129	124	55	4	1.7	3.09	918	16.69
130-139	136	63	3	2.1	3.33	1180	18.73
140-149	143	70	5	2.3	3.29	1265	18.07
150-159	155	76	6	2.6	3.51	1356	17.84
160-169	164	82	8	3.1	3.83	1412	17.22
170-179	176	88	8	3.6	4.50	1498	17.02
180-189	182	110	5	4.0	3.89	1560	14.18
190-199	196	125	5	4.1	3.54	1655	13.24
200-209	206	130	4	4.34	3.34	1766	13.58
210-219	215	141	3	4.6	3.26	1855	13.16
220-229	226	155	2	4.7	3.03	1921	12.39
230-239	235	160	2	4.7	2.94	2010	12.56

female ones was observed to be 141.72 mm (Fig. 4 and 5). Thus, females were mature at a lower size than their male counterpart. Mozambique tilapia can adopt an 'altricial' strategy (early maturation at small size) when environmental conditions are harsh or a 'precocial strategy' (late maturation at large size) when conditions are more favourable which forms the basis of different size of maturation in varying environments (Russel et al 2012b). Greater size at maturity have been recorded in stable environmental conditions and smaller size at maturity in harsher habitats such as smaller dams and reservoir in which food is limiting factor and temperature fluctuation was high (Hutchison et al 2011). Fecundity was estimated from 57 mature ripe ovaries and TL ranged from 112-238 mm. The absolute fecundity ranged from 644-2210 eggs/ fish with an average of 1469 (Table 2). Relative fecundity ranged from 10.12 to 19.23 eggs/g with an average of 15.54.

CONCLUSIONS

This study aims to describe the reproductive ecology of an invasive fish, *O. mossambicus* from Vemband Lake- a Ramsar wetland in India. *O. mossambicus* breeds throughout the year and the occurrence of ripe ovaries from May to August and November to December confirms that the fish has two spawning peaks. Females mature at smaller size than the males. The monthly sex ratio showed a dominance of females over males in the population. *O. mossambicus* is reported to be an exceptionally invasive fish owing to phenotypic plasticity that allows the fish to shift its life-history characteristics according to the available environment. The reproductive advantages like continuous spawning pattern, extreme parental care, early size at first maturity and predominance of females have ensured high recruitment of the species in the lake and the adjoining rivers which may pose severe threat to the survival of other native cichlids.

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REFERENCES

Adite A, Gbaguidi HMGA and Ategbo JM 2017. Reproductive biology and life history patterns of the Claroteid, *Chrysichthys nigrodigitatus* (Lacépède: 1803) from a Man-made lake in Southern Benin. *Journal of Fisheries and Aquatic Science* **12**: 106-116.

Bindu L and Padmakumar KG 2014. Reproductive biology of *Etroplus suratensis* from Vembanad Wetland system, Kerala. *Indian Journal of Geo Marine Science* **43**: 646-654.

Bindu L, Padmakumar KG, Sreerekha PS and Joseph N 2012. Reproductive biology of the golden catfish, *Horabagrus brachysoma* (Gunther 1864), an endemic species of the Western Ghats, India. *Journal of Applied Ichthyology* **28**: 772-777.

Canonico GC, Arthington A, McCrary JK and Thieme ML 2005. The effects of introduced tilapias on native biodiversity. *Aquatic Conservation-Marine and Freshwater Ecosystems***15**: 463-483.

Chander J 2016. African Cat fish, *Clarias gariepinus*: A Eco-terrorist destroying delicate ecological balance in Aquatic ecosystem of National Parks and Wild life Sanctuaries in India. *Indian Journal of Ecology* **43**(1): 378-381.

Euphrasia CJ and Kurup BM 2008. Maturity and spawning of *Osteobrama bakeri* (Day): A threatened endemic ornamental fish of Kerala, India. *Indian Journal of Fisheries* **55**(3): 273-280.

Global Invasive Species Database 2020. Downloaded from http://www.iucngisd.org/gisd/search.php on 11-03-2020

Gosavi SM, Kharat SS, Tapkir SD and Kumkar P 2020. The

Reproductive biology of *Pachypterus khavalchor* (Kulkarni 1952) in the Panchagana River of the Western Ghats, a Biodiversity Hotspot in India. *Asian Fisheries Science* **33**: 79-90.

Hutchison M, Sarac Z and Norris A 2011. *Mozambique tilapia, The potential for Mozambique tilapia Oreochromis mossambicus to invade the Murray–Darling Basin and the likely impacts: A review of existing information*. Murray–Darling Basin Authority, Australia, p 65.

King M 2007. *Fisheries Biology. Assessment and Management* Blackwell Publishing Ltd. Oxford, UK, p 382.

Krishnakumar K and Priyadarsanan DR 2012. *Fish and Fisheries in Vembanad Lake: Consolidated report of Vembanad Fish count 2008-2011*, Ashoka Trust for Research in Ecology and the Environment (ATREE), Kerala, India, p 50.

Liu C, Gao X, Wang H, Liu H, Cao W and Danley PD 2013. Reproductive characteristics of *Ancherythroculter nigracauda*, an endemic fish in the upper Yangtze River, China. *Fisheries Science* **79**: 799-806.

Maddern MG, Morgan DL and Gill HS 2007. Distribution, diet and potential ecological impacts of the introduced Mozambique mouth brooder *Oreochromis mossambicus* Peters (Pisces: Cichlidae) in Western Australia. *Journal of the Royal Society of Western Australia* **90**: 203-214.

Pe´rez JE, Nirchio M, Alfonsi C and Munoz C 2006. The biology of invasions: The genetic adaptation paradox. *Biological Invasions* **8**: 1115-1121.

Renjithkumar CR, Roshni K and Kurup BM 2020. Reproductive biology of the endemic cyprinid fish *Hypselobarbus thomassi* (Day 1874) from Kallada River in the Western Ghats, India. *Journal of AppliedIchthyology* **36**(5): 604-612.

Remyamohan S, Harikrishnan M and Sherly WE 2018. Reproductive biology of a Gobiid fish *Oxyurichthys tentacularis* (Valenciennes 1837) inhabiting Ashtamudi Lake, S. India. *Journal of Applied Ichthyology* **34**(5): 1099-1107.

Russell DJ, Thuesen PA and Thomson FE 2012a. Reproductive strategies of two invasive tilapia species *Oreochromis mossambicus* and *Tilapia mariae* in northern Australia. *Journal of Fish Biology* **80**: 2176-2197.

Russell DJ, Thuesen PA and Thomson FE 2012b. A review of the biology, ecology, distribution and control of Mozambique tilapia, *Oreochromis mossambicus* (Peters 1852) (Pisces: Cichlidae) with particular emphasis on invasive Australian populations. *Review in Fish Biology and Fisheries* **22**: 533-554.

Selvam PA, Priya L, Banerjee K, Hariharan G, Purvaja R and Remesh R 2012. Heavy metal assessment using geochemical and statistical tools in the surface sediments of Vembanad Lake, Southwest Coast of India. *Environmental Monitoring and Assessment* **184**: 5899-5915.

Singh A, Datta SN and Singh A 2018. Biometric Characteristic of Giant River- Cat fish *Aorichthys seenghala* (Sykes 1839) from Harike Wetland- A Ramsar Site. *Indian Journal of Ecology* **45**(3): 627-631.

Zare P, Naderi M and Asghari 2015. Reproductive biology of the Geno hot spring tooth-carp (*Aphanius ginaonis* Holly 1920) in Southern Iran. *Environmental Biology of Fishes* **98**: 1365-1371.

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Sex Ratio and Spawning Season of Blue Swimming Crab (*Portunus pelagicus*, Linnaeus, 1758) in North Java Sea, Indonesia

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Abstract: High value economy of blue swimming crab (*Portunus pelagicus*) increases its capture in nature done continuously without regard to biological phases, so that it might overfishing occurrence. This study aimed to analyze the sex ratio and spawning season of blue swimming crab (Portunus pelagicus) in the North Java Sea of Indonesia. The research sampling was collected during October 2016 to September 2017. The total sample obtained was 424 males and 790 females of blue swimming crab. The sex ratio of P. pelagicus was 1:1.86 (males: females) where the amount of female was higher than male, the result of chi square test of ratio for overall samples of blue swimming crab (*P. pelgicus*) was significantly different from the expected 1:1 value. The spawning season occurred throughout the year, ovigerous females were every month except in July, and the highest percentage of ovigerous females was in February (30.2%).

Keywords: *Portunus pelagicus*, Sex ratio, Spawning season, *Ovigerous* female, North Java sea

Blue swimming crab, *Portunus pelagicus* (Crustacea: Decapoda: Brachyura: Portunidae), is widespread throughout the coastal regions and tropical estuaries of the Western Pacific and the East Indian Ocean (Xiao and Kumar 2004). The essential areas in Indonesia for blue swimming crab fisheries are in the northern part of the Java Sea, South Sulawesi, the eastern part of Sumatra, and the Malacca Strait (USAID 2015). Paciran is a coastal area of the North Java Sea. It is located in Lamongan, East Java, where the majority of the population works as fishermen, one of the mainstay fisheries commodities is crab. Its export is currently in between third and fourth rank after tuna, shrimp, and seaweed (BPBAP 2013). The *Portunus pelagicus* export value increased by 6.15% per year during the period of 2012-2017 and export value of *P. pelagicus* increased by 27.81% during the period of 2016-2017 (KKP 2018). The National Commission for the Assessment of Marine Fish Resource Stocks also states that there are difficulties in collecting data on fisheries commodities. It causes difficulties to know potential conservation, one of which is crab. The decrease in the blue swimming crab population in nature is because of the fishing fleet and its high economic value that makes fishery continuously without regard to biological phases. It is necessary to maintain the blue swimming crab population in nature by maintaining and preserving its resources through fisheries management. It is not only oriented to produce results but also to ecosystem preservation. Several biological processes, such reproduction and migration of *ovigerous* females may influence distribution in crabs (Rohmayani et al 2018). Sex ratio and proportion of *ovigerous* females will give information about productivity, spawning season and sustainability of crabs in nature. Research on the sex ratio and spawning season of blue swimming sea was rarely conducted primarily in the North Java Sea. The sea was one of the crucial waters in Indonesia. Thus, it was necessary to research the sex ratio and spawning season of blue swimming crab in the Java Sea (North of Lamongan).

MATERIAL AND METHODS

Study site: This research was conducted in the Java North Sea of at Paciran Lamongan with the eastern boundary of S 6° 54'13.1688 "and E 112° 27'16.9596", the western boundary of S 6° 52'58.3356 "and 112° 16'7.6116".

Data collection: The method used in this study was the observational method. The sampling was done by using a random sample method. Sampling was carried by local fishermen. The sample for study was collected for one year from October 2016 to September 2017. Sampling was carried by using the bubu net, which contained 0.5 inch (width 32 cm, length 49 cm and height 19 cm).

After that was identified on the sample, sex ratio identified by looking at the morphological characteristics of abdomen (Fig. 1), while *ovigerous* females crabs are females who carry fertilized eegs in the abdomen that attach to their pelopod (Romimohtarto and Juwana 2009). The *Ovigerous* females can be divided in three stages (Fig. 2).

Data analysis: The sex ratio was analyzed using the *Chi-square* test (Walpole 1993) at a significant level of 0.05 (Steel and Torrie 1992).

$$X^2 \text{count} = \sum_{i=1} \frac{(oi - ei)^2}{ei}$$

Explanation:

χ^2 value: *Chi-square* value

Oi : frequency to-i

ei : expectation frequency to-i.

Morphological differences in male and female crab were in Figure 1 as follows:

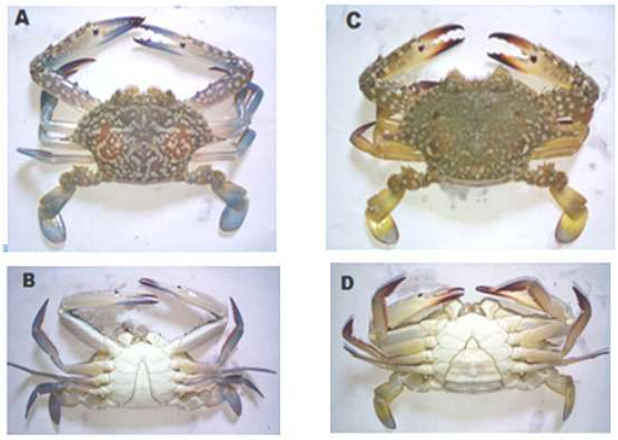

Fig. 1. Morphological Differences in male and female *Portunus pelagicus*. A: appearance from male crab, B: an appearance from male crab, C: an appearance from female crab, D: appearance from female crab

Spawning season of blue swimming crab: The spawning season was through the presence of *ovigerous* female crabs. The equation formula for determining the proportion of *ovigerous* female is as follows:

$$\text{Percentage ovigerous female} = \frac{\text{The number of ovigeous female}}{\text{Number of female overall}} \times 100$$

Ovigerous female crabs can be divided into three stages, as shown below:

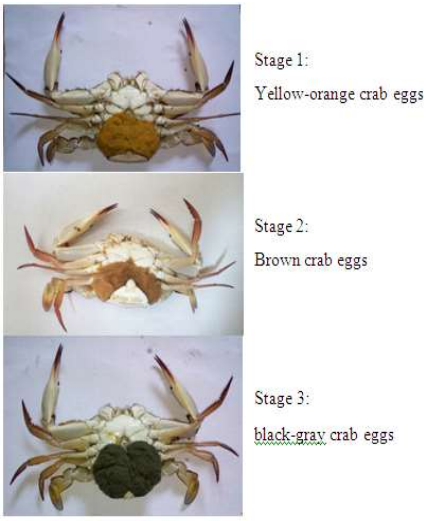

Fig. 2. Morphology of egg development of *Portunus pelagicus ovigerous*

RESULT AND DISCUSSION

Sex ratio: The total crab sample of 1214 tails, 424 were males and 790 females (34.9:65.1% males: females) with male to female was 1:1.86 (Table 1) Test results χ2 overall sex ratio of the blue swimming crab (*Portunus pelagicus*) for one year was significantly different from the 1:1 ratio ($p < 0.05$). This result is similar to the research conducted in Brebes and Betahwalang waters (Sunarto 2012, Ningrum et al 2015). They were different from the obsevation in Iran (Hosseini et al 2012) and in Lasongko Bay in Southeast Sulawesi (Hamid et al 2016), where were males more than females. The sex ratio imbalance because the presence of different habitat preferences (salinity characteristics and temperature distribution) between males and females, and tended to form the aggregation of sex segregation (Xiao and Kumar 2004). Mature females usually migrate in several periods of the year (Kamrani et al 2010).

Spawning season: there were 128 *ovigerous* females, the highest percentage of female *ovigerous* was in February, which was 30.2%. Sampling is during in the bright moon conditions, except in july sampling obtained in the drak moon conditions. In july the proportion of females obtained was hight, but not find any *ovigerous* females (Table 3). There were two hypotheses related to the absence of *ovigerous* females that occurred in July. The first hypothesis was that all egg might be released because it coincided with a dark moon in July. While the second hypothesis, it might be in every July, there was no female *ovigerous* since, at that time, there was a seasonal change from rainy to summer. Osaka and Takemura (2019) report that in the *Coenobita rugosius* species in Okinawa Japan shows that larval release is related to the lunar cycle, he also stated that ovarian development and larval release influenced by external factory, such as habitat change over several periods.

The absence of *ovigerous* females was not only observed in blue swimming crabs, but also in *Portunus sanguinolentus* in Honghai Bay, South China Sea, (Ping Yang et al 2014) and also found in the *Varuna litterata* in cochin backwater, Kerala, India (Devi et al 2013). In present study, percentage of *ovigerous* females fluctuates (Fig. 3) based on the difference of egg development stage and did not show mutually sustainable fluctuations between stages 1, 2, and 3. It occurred due to *ovigerous* female eggs hatching occurred in less than 1 month. Susanto et al (2005) observed that *ovigerous* females need about 5-8 days, depending on the stage of embryonic development. The blue swimming crab with yellow eggs took longer to hatch than those with brown and black eggs. The *ovigerous* females were generally found throughout the year indicating that this species was spawning continuously. The difference in the

Table 1. Sex ratio of *Portunus pelagicus* in the Java Sea (North of Lamongan)

Year	Month	Proportion (%)		Sex Ratio	χ^2 *value*
		J	B	J: B	
2016	October	29.36	70.64	1: 2.41	17.06*
	November	53.47	46.53	1:0.87	0.49
	December	46.6	53.4	1: 1.15	0.47
2017	January	20.79	79.21	1: 3.81	34.47*
	February	37	63	1: 1.70	6.76*
	March	41	59	1: 1.44	3.24
	April	48	52	1: 1.083	0.16
	May	49	51	1: 1.04	0.04
	June	25	75	1: 3	25*
	July	26	74	1: 2.85	23.04*
	August	36	64	1: 1.78	7.84*
	September	7	93	1: 13.29	73.93*
Total		34.9	65.1	1:1.86	110.34*

Explanation: Df=1, χ^2 table = 3.84 ($p<0.05$) *significant = χ^2 value > χ^2 table

Table 2. Sex ratio of *Portunus pelagicus* in various waters location

Location	Sex ratio J:B	Source
Trang Beach, South Thailand	1:0.85	Nitiratsuwan et al (2013)
Persian Gulf, Iran	1:0.88	Hosseini et al (2012)
Pati Waters	1:0.85	Ernawati (2013)
Lasongko Bay	1:0.94	Hamid (2015)
Brebes Waters	1:1.22	Sunarto (2012)
Betahwalang Waters	1:1.10	Ningrum et al (2015)
Java Sea (North of Lamongan)	1:1.86	This research

Table 3. Percentage of *ovigerous* female *P. pelagicus* in the North Jave Sea

Year	Month	Female overall	*Ovigeruos* female	Percentage of *ovigerous* female (%)
2016	October	77	19	24.7
	November	47	10	21.3
	December	55	13	23.6
2017	January	80	14	17.5
	February	63	19	30.2*
	March	59	7	11.9
	April	52	7	13.5
	May	51	3	5.9
	June	75	3	4
	July	74	0	0
	August	64	13	20.3
	September	93	20	21.5
Total		790	128	16.2

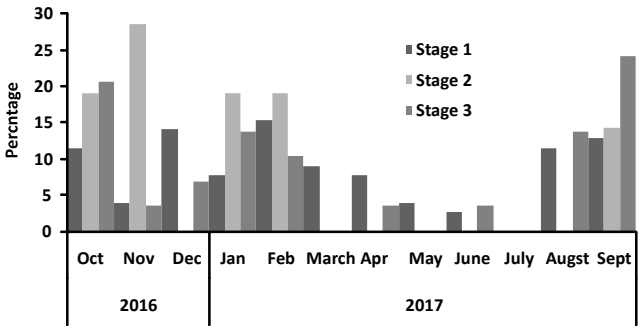

Fig. 3. Percentage of *ovigerous* female *Portunus pelagicus* abundance based on egg maturity stage in the North Java Sea

spawning time was affected by different water locations. It indicated that in every month, there would be copulation and was marked by the presence of *ovigerous* females and also hatching or releasing eggs.

CONCLUSION

The sex ratio of *Portunus pelagicus* in the North Java Sea showed fluctuation. sex ratio was significantly different from the ratio 1:1, where the amount of female was higher than male. *Portunus pelagicus* spawning season occurred throughout the year. Every month a sample of *ovigerous* females was obtained except in July. The highest percentage of *ovigerous* females was in February (30.2%).

REFERENCES

Balai Perikanan Budidaya Air Payau 2013. *Teknologi Pembenihan Rajungan (Portunus Pelagius Linnaeus, 1758)*. Kementrian dan Perikanan, Direktorat Jenderal Perikanan Bididaya, Takalar.

Devi PL, Nair DG and Joseph A 2013. Habitat ecology and food and feeding of the herring bow crab *Varuna litterata* (Fabricius, 1798) of Cochin backwater, Kerala, India. *Arthropods* **2**(4): 172-188.

Emmerson WD 1994. Seasonal breeding cycles and sex ratios of eight species of crabs from Mgazana, a mangrove estuary in Transkei, South Africa. *Journal of Crustacean Biology* **14**(3): 568–578.

Ernawati T 2013. *Dinamika Populasi dan Pengkajian Stok Sumberdaya Rajungan (Portunus pelagicus) di Perairan Kabupaten Pati dan Sekitarnya*, Tesis, Sekolah Pascasarjana, Institut Pertanian Bogor, Bogor.

Hamid A 2015. *Habitat, Biologi Reproduksi Dan Dinamika Populasi Rajungan (Portunus Pelagicus Linnaeus 1758) Sebagai Dasar Pengelolaan Di Teluk Lasongko, Sulawesi Tenggara,* Disertasi, IPB, Bogor.

Hamid A,Wardiatno A, Batu DTFL and Riani E 2016. Distribution, body size, and eggs of *ovigerous* swimming crab (*Portunus pelagicus* Linnaeus, 1758) at various habitats in Lasongko Bay, Central Buton, Indonesia. *International Journal of Aquatic Biology* **4**(2): 115-124.

Hosseini M, Vazirizade A, Parsa P and Mansori A 2012. Sex ratio, size distribution and seasonal abundance of blue swimming crab, *Portunus pelagicus* (Linnaeus, 1758) in Persian Gulf Coasts, Iran. *World Applied Sciences Journal* **17**(7): 919-925.

Kamrani E, Sabili AN and Yahyavi M 2010. Stock assessment and reproductive biology of the blue swimming crab, in Bandar Abbas Coastal Waters, Northern Persian Gulf. *Journal of the Persian Gulf (Marine Science)* **11**(2): 11-22.

Kementrian Kelautan dan Perikanan 2018. Materi paparan Drirjen PDSPKP pada Forum Merdeka Barat. Avaible at: *https://kkp.go.id/wp-content/uploads/2018/01/kkp-Drirjen-PDSPKP-FMB-kominfo-19-januari-2018.* Pdf Accessed on April 24, 2020.

Ningrum VP, Ghofar A and Ain C 2015. Beberapa aspek biologi perikanan rajungan (*Portunus Pelagicus*) di perairan betahwalang dan sekitarnya. *Jurnal Saintek Perikanan* **11**(1): 62-71.

Nitiratsuwan T, Nitithamyong C, Chiayvareesajja S and Somboonsuke B 2010. Distribution of blue swimming crab (*Portunus pelagicus* Linnaeus, 1758) in Trang Province. *Songklanakarin Journal of Science and Technology* **32**(3): 207-212.

Osaka N and Takemura A 2019. Annual and lunar breeding rhythmicity in females of the Terrestrial Hermit crab *Ceonobita rugosus* H. Milne Edwards, 1837 (Decapoda: Anomura: Coenobitidae) in Okinawa, Japan. *Journal of Crustacean Biology* **39**(4): 493-499.

Ping Yang C, Xiang Li H, LuLi, JingXu and YanYan 2014. Population structure, morphometric analysis and reproductive biology of *Portunus Sanguinolentus* (Herbst, 1783) (Decapoda: Brachyura: Portunidae) In Honghai Bay, South China Sea. *Journal of Crustacean Biology* **34**(6): 722-733.

Rohmayani V, Pahlevi M R, Irawan B and Soegianto A 2018. Length-weight relationship, sex ratio andcondition factor of blue swimming crab (*Portunus pelagicus* Linnaeus, 1758) from Java Sea Indonesia. AIP Conference Proceedings of 5th *International Conference on Biological Science,* September 15-16, 2017, Gadjah Mada University, Yogyakarta, Indonesia.

Romimohtarto K and Juwana K 2009. *Biologi Laut.* Jakarta: Djambatan.

Sunarto 2012. *Karakteristik Bioekologi Rajungan (Portunus pelagicus) di Perairan Laut Kabupaten Brebes,* Disertasi, Sekolah Pascasarjana, Institut Pertanian Bogor, Bogor.

Susanto BI, Setyadi Haryanti and Hanafi A 2005. *Pedoman Teknis Teknologi Perbenihan Rajungan (Portunus pelagicus)*, Pusat Riset Perikanan Budidaya, Jakarta.

Steel RGD and Torrie JH 1992. *Prinsip dan Prosedur Statistika: Suatu Pendekatan Biometrik.* Sumantri B, Penerjemah. Jakarta (ID), Gramedia, Terjemahan dari, Principles and Procedure of Statistic, Biometric Aproach.

United States Agency International Development (USAID) 2015. *Protokol Pengumpulan Data Perikanan Rajungan (Portunus pelagicus),* USAID Indonesia.

Walpole RE 1993. *Pengantar Statistik*, Sumantri. Penerjemah, PT. Gramedia Jakarta.

Xiao Y and Kumar M 2004. Sex ratio, and probability of sexual maturity of females at size, of the blue swimmer crab, *Portunus pelagicus* Linneaus, off southern Australia. *Fisheries Research* **68**(1-3): 271-282.

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Eolian Sand Deposition Induced Constrains and Seedling Strategies in *Blepharis sindica* T. Anders: An Endangered Serotinous Medicinal Herb of Indian Thar Desert

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Abstract: *Blepharis sindica* T. Anders (Acanthaceae) is an endangered medicinal herb from Indian arid zone. Due to serotinous habit, dried plants get buried under eolian sand deposition during summer and so the germplasm experiences difficulties to establish potential seedlings. Patchy occurrence of the populations restricts the gene exchange and the germplasm reflects local habitat limited adaptations. Canopy height enables the plants to escape from deep burial at growing sites but with a cost of seed weight reduction. Highest canopy (53.6 cm at site-I for 2017) was found with lowest seed weight (1.11g for 100 seeds). *In-vitro* seedling shoot lengths from stored seeds of site-I were higher where plants faced greater load of eolian burial during last generations. Seedling responses revealed the genetically tuned strategies to withstand against eolian pressure by local germplasm in the species.

Keywords: Eolian sand, Plant canopy, Germplasm, Seedling strategies, Endangered

Besides high temperature, summer months in Indian Thar desert are also characterized by frequent windblown sand shifting. Water paucity limits the vegetation development in desert and hence leaving the top soil prone to shift by hot winds. Habitat associated abiotic factors play important role in seed germination and subsequently determine the distribution of natural species (Mohammed and Mohamed 2019, Fakhfakh et al 2018). Eolian shifting is considered as a major ecological problem regarding vegetation development. Interestingly, this sand shifting feature plays a critical role in localized colonization of *Blepharis sindica* T. an endangered desert species of Acanthaceae, which is medicinally important for aphrodisiac and invigorating benefits (Khare 2007). During vegetative growth, *B. sindica* plants attain 10-55 cm above ground height with a characteristic dichotomously branching habit. The plants thrive well at sand dunes and undisturbed margins of field fencings.

To replenish soil seed pool, *B. sindica* plants have high seed output and viability. In order to reduce seed losses due to biotic and abiotic constrains, the species retain their seeds in hard capsules being compactly attached and wrapped by spiny bracts on lignified inflorescences (spikes). Such serotiny provides an efficient way to release seeds in a time lapsing way and suggests about its perpetuation tendencies in desert areas (Peters et al 2011, Santini and Martorell 2013). Green plants culminate their lives during December - January and the dried lignified plants have to face subsequent months (till monsoon showers) with frequent soil translocation by wind currents. Although, wind is an efficient seed dispersal agency for several arid plants (Gutterman et al 2007) but compactly packaged spikes, serotiny and lignifications of entire plants of *B. sindica* plants resist them to uproot and blown by winds (Mathur 2014, Lal et al 2014a). During summer, the eolian shifting regularly deposits loose sand over dried plants and making them buried at dunes (Fig. 1, B-F). Explosively released hygroscopic seeds germinate in vicinity of buried plants during early spells of rainy season. In the present study, germplasm with differentially faced eolian sand burial loads were collected and evaluated for germination responses. *In-vitro* germination behaviours by fresh and stored seeds were correlated with that of ongoing sand burial conditions at natural sites as adaptive strategies of the species.

MATERIAL AND METHODS

Regular field studies were undertaken during December 2017 to January 2019 at two different sites in Churu region, *viz*. Shyampura village (Site-I; 28.2647533 N, 74.8945098 E) and Buntia village (Site-II; 28.3528630 N, 75.0090939 E).After seed maturation, fully dried plants were sampled from both sites and used to calculate plant canopy parameters (height, breadth, thickness and volume), spikes plant^{-1} and seeds plant^{-1} values. Plant seeds from both study sites were collected during each year, air dried and stored in paper bags along with insecticides. Viability of fresh and one-

year-old (O-Y-O) seeds was estimated by 2, 3, 5-triphenyl tetrazolium chloride (TTC) method (Porter et al 1947). Seeds from both sites were subjected to evaluate their germination responses (fresh and one-year-old seeds) under controlled laboratory conditions [alternate white light and dark (12h) obtained from three fluorescent tubes of 40 watts each fitted at a height of half meter from the petridishes (1000 Lux)at 28 °C in seed germinator]. The experiments were performed in triplicate with each petridish containing 10 seeds and repeated twice for confirmation of results. After one week, seed germination percentage and seedling axis lengths (root and shoot) were recorded. The sites were periodically visited during January to June each year to check eolian deposition over dried plants.

RESULTS AND DISCUSSION

Morphological parameters (canopy, spikes and seeds) of dried plants collected from both study sites during consecutive years 2017 and 2018 were higher for site-I plants in comparison to site-II plants (Table 1). Canopy height was maximum (53.6 cm) in 2017 while canopy breadth, thickness and volume amounts were highest (61.1 cm, 38.6 cm and 148.20 x10^3 cm^3, respectively) in 2018. Highest (103.7) number of spikes $plant^{-1}$ was in 2017 while maximum (1731.12) seeds $plant^{-1}$ were in 2018. Seed weight values were greater for site-II germplasm than of site-I and measured highest (1.37 g for 100 seeds) in year 2017. Statistically all data were found non-significant except spikes $plant^{-1}$.

Fig. 1. *Blepharis sindica*: Single dried plant after collection from site-I (A), dried plants in March-April months with initial sand deposition at dune slopes (B), gradually increasing sand deposition over dried plants (C-E), completely buried plants at dune in month of June (F) and dispersed seeds in early growth after first rain fall (G). Site-II plants with compact canopy (H), dried plants without sand deposition (I, J) and young seedlings after first rainfall over unburied spikes (K)

The plants at site-I were taller (having slightly larger inter nodal growth) with greater canopy length than of somewhat compact plant with lesser canopy growth on site-II. These morphological variations in canopy development seems to be local ecology limited as both study sites differ in eolian shifting patterns. During present study, site-I was reported with higher amount of eolian shifting in summer months which poses more sand deposition over dried plants in contrast to site-II (Fig 1., A-F & I-J). Both study sites are located with an approximate distance of 19 km with differing eolian shift tendencies. Clear differences in canopy parameters and germplasm production during both consecutive years of study support the habitat related adaptive growth behaviour in this endangered species at both sites (Fig.2). Further the study also provides a positive correlation between canopy growth and amount of eolian deposition. The reported values of spikes per plant and seed weight were in negative correlation with that of seeds per plant at both sites indicating about better investment for progeny development under prevailing sand deposition pressure. Under elevated risk of sand burial, the plants seem to develop more seeds with lighter weight.

Cent percent seed viability (fresh and O-Y-O seeds of both years from sites-I and II) during present study was found supportive to the high seed viabilities in the species as previously reported by Lal et al (2014b). Growth parameters of *in-vitro* seedlings from fresh and O-Y-O germplasm of both study sites revealed that stored seeds were associated with increased shoot and root lengths in contrast to fresh seeds of

Table 1. Various parameters associated with dried plants of *B. sindica* and their germplasm collected from both sites during 2017 and 2018

Parameter	Site-I		Site-II		CD
	2017	2018	2017	2018	
Plant canopy height (cm)	53.6	47.4	43.2	47.5	NS
Plant canopy breadth (cm)	48.5	61.1	50.8	58.9	NS
Plant canopy thickness (cm)	26.6	38.6	20.7	22.1	NS
Plant canopy volume (HxBxT; x $10^3$$cm^3$)	69.15	148.20	45.43	65.69	NS
Spikes $plant^{-1}$	103.7	45.7	35.5	27.5	0.5#
Seeds $plant^{-1}$	1356.40	1731.12	531.08	587.95	NS
Weight of 100 seeds (g)	1.11	1.15	1.37	1.36	NS

NS = non-significant, # = Significant at p<0.05

Table 2. Seedling axis growth responses as *in-vitro* germination behaviour by fresh and O-Y-O seeds of *B. sindica* collected from both sites

Parameter	Site-I				Site-II			
	2017 (fresh)	2017 (O-Y-O)	2018 (fresh)	2018 (O-Y-O)	2017 (fresh)	2017 (O-Y-O)	2018 (fresh)	2018 (O-Y-O)
Average shoot length (cm)	5.13±0.14	9.67±0.09	8.60±0.25	10.06±0.11	7.57±0.41	9.73±0.19	10.93±0.36	11.46±0.33
Average root length (cm)	47.63±3.41	39.13±2.12	35.43±1.56	45.73±7.25	25.77±7.44	33.53±3.48	34.60±6.21	51.76±2.57

respective year and site (except seeds of 2017 from site-I). *In-vitro* seedlings of O-Y-O seeds from site-II (2018 germplasm) exhibited maximum shoot (11.46 cm) and root (51.76 cm) axis lengths. Furthermore, highest impact of one year storage (increase of 17.89 cm against seedlings of respective fresh germplasm) on axis growth was reported for 2018 seeds of site-II.

These findings of *in-vitro* seedlings growth indicate that old seeds produce larger axis that may be helpful to overcome sand burial induced seedling emergence difficulties at natural sites. Greater values of root lengths (than of shoots) by seedlings reflect the desertic adaptation in the species (Liu et al 2011). Exceptionally reduced seedling growth (in root axis) by site-I germplasm after one year of storage and its relation to seed weight (being lowest; 1.11 g for 100 seeds) supports biomass controlled axis development in seedlings. The fact of biomass fueled axis growth is again confirmed by germination behaviour of site-II seeds as they were heavier (Table 1) in weight and exhibited higher axis lengths during *in-vitro* germination (Table 2).

CONCLUSION

Sand shifting is a regular problem in Indian arid zone and plants of *B. sindica* grow with this eolians and deposition pressure. Sand burial of dried plants poses constrains on seedling emergence and subsequently leads to decline in young populations. Taller canopy helps the species to minimize the sand burial load but at the cost of reduction in seed number and seed weight (as reported for site-I plants). Germplasm collected from local sites varied in morphological feature as well as their *in-vitro* germination responses indicating a clear gene exchange barrier due to patchy occurrence of the species. In contrast to fresh seeds, stored seeds (one-year-old) of both sites produced longer shoots reflecting the inherent tendency of the species to compete eolian deposition during seedling emergence. This eolian burial of germplasm is a natural limiting factor of the local habitat but the species tolerates it by adjusting biomass allocation for canopy dimensions and seed parameters.

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REFERENCES

Fakhfakh LM, Anjum NA and Chaieb M 2018. Effects of temperature and water limitation on the germination of *Stipagrostis ciliate* seeds collected from Sidi Bouzid Governorate in Central Tunisia. *Journal of Arid Land* **10**(2): 304-315.

Gutterman Y, Gendler T and Huang ZY 2007. Plant dispersal strategies, seed bank distribution and germination of Negev desert species, pp 407-415. In: Adkins SW, Ashmore SE and Navie SC (eds). *Seeds: Biology, development and ecology*. Cromwell Press, Trowbridge, UK.

Khare CP 2007. *Indian Medicinal Plants: An Illustrated Dictionary*, Springer-Verlag, Berlin, New York, USA, p 812.

Lal P, Mohammed S and Kasera PK 2014 (a). Ecological evaluation of some physiochemical parameters in *Blepharis sindica* T. Anders: A vulnerable medicinal plant of the arid region. *Journal of Indian Botanical Society* **93**(1 & 2): 94-99.

Lal P, Mohammed S and Kasera PK 2014 (b). High adaptability of *Blepharis sindica* T. Anders seeds towards moisture scarcity: A possible reason for the vulnerability of this medicinal plant from the Indian Thar desert. *Journal of Research in Biology* **4**(2): 1293-1300.

Liu HL, Shi X, Wang JC, Yin LK, Huang ZY and Zhang DY 2011. Effects of sand burial, soil water content and distribution pattern of seeds in sand on seed germination and seedling survival of *Eremosparton songoricum* (Fabaceae), a rare species inhabiting the moving sand dunes of the Gurbantunggut desert of China. *Plant Soil* **345**: 69-87.

Mathur M 2014. Does adaptive strategy for delayed seed dispersion affect extinction probability of a desert species? An assessment using the population viability analysis and glass house experiment. *Brazilian Archives of Biology and Technology* **57**(5): 774-781.

Mohammed D and Mohamed T 2019. Effect of abiotic factors on seed germination of *Anacyclus pyrethrum* (L.) Link, and modeling of habitat suitability in Saida (Algeria). *Indian Journal of Ecology* **46**(4): 777-782.

Peters EM, Martorell C and Ezcurra E 2011. The effects of serotiny and rainfall-cued dispersal on fitness: Bet-hedging in the threatened cactus *Mammillaria pectinifera*. *Population Ecology* **53**: 383-392.

Porter RH, Durrell M and Romm HJ 1947. The use of 2, 3, 5-triphenyl tetrazolium chloride as a measure of seed germinability. *Plant Physiology* **22**(2): 149-159.

Santini BA and Martorell C 2013. Does retained-seed priming drive the evolution of serotiny in drylands? An assessment using the cactus *Mammillaria hernandezii*. *American Journal of Botany* **100**: 365-373.

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Performance Assessment of Fisherwomen Self Help Groups in Kerala Enabling Financial Opportunities

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Abstract: This study was undertaken with an objective of assessing the performance of fisherwomen Self Help Groups (SHGs). Six SHGs which were actively functioning in the fisheries sector in each district were selected purposively and leader from each SHG was interviewed with the checklist developed by National Bank for Agriculture and Rural Development (NABARD), comprising a sample of eighteen respondents. The NABARD checklist included sixteen parameters. As per NABARD checklist, SHGs with 12-16 "very good" factors can get loans immediately and in the present study 11.1 % of SHGs were eligible for immediate loan. A total of 66.7% SHGs scored 10-12 very good factors and could get loan only after an improvement period of 3-6 months. The rest of SHGs rated less than 10 very good factors and these groups were not considered for loan. SHGs scored very high in few parameters like amount to be saved, accumulated savings and education level and unsatisfactory score in timing of meetings. There is scope for improving the performance of SHGs by adopting the norms of NABARD as it is the major agency promoting the formation of SHGs.

Keywords: Fisheries, Fisherwomen, Performance, Self help groups, Checklist

Fisheries sector is recognised as a powerful income and employment generator and is enriched with immense resource potential, engaging over 14.50 million people at the primary level and many more along the value chain. Constituting about 6.30% of the global fish production and 5% of global trade, India has attained the second largest fish producing and second largest aquaculture nation in the world (DAHDF 2016). A total of 5.4 million people are fully engaged in fisheries activities, out of which 3.8 million are fishermen and 1.6 million are fisherwomen. Women, who constitute approximately half of India's population, play an important role in the fisheries sector also and the contributions of the fisherwomen were visible in every aspect of post-harvest handling, preservation, processing, and marketing of seafood products (Shyam et al 2011). The SHGs organized by fisherwomen perform a vital role in fisheries sector of maritime states of Indian coastal belts (Vipinkumar and Asokan 2014). SHGs are small, informal, economically homogenous affinity group with an average size of about fifteen people from a homogeneous class with a purpose of addressing their needs or common problems through self-help and mutual help (NABARD 2007).

Kerala is one of the leading fish producing states of India and fisheries form an important sector contributing to the economic development of the State. The fisherwomen in Kerala were actively engaged in fish vending, fish drying, prawn peeling, sorting, grading, fish packing, and net making (Shyam et al 2011). Due to the emergence of SHGs, women were able to work in various fields including agriculture, forestry, fisheries and aquaculture seeking income generating activities with the help of microcredit. The SHG programme in Kerala was taken up by the state government and SHGs in Kerala is around 2, 79,527 with a savings of Rs 51268.95 lakhs (NABARD 2016) and majority are exclusively women SHGs. The diverse fisheries institutions and agencies have encouraged the SHGs to initiate fisheries related enterprises. Keeping the importance of fishery based SHGs in the creation of income employment among fisherwomen, an attempt was made to assess the performance of fishery based women led SHGs in Kerala.

MATERIAL AND METHODS

The study was undertaken with the leaders of 18 SHGs drawn from northern, central and southern parts of Kerala State represented mainly by three districts *viz.,* Kasargod, Ernakulam and Kollam respectively. Six SHGs which were actively working in the fisheries sector from each district were selected for the study. Performance of fisherwomen SHGs in Kerala were assessed using the NABARD checklist method. The checklist is specifically used for assessing the performance of a SHG to get loan. In this checklist there are 16 factors and they are group size (X1), type of members (X2), Number of meetings (X3), Timings of meetings (X4), Attendance of members (X5), Participation of members(X6), savings collection within group (X7), amount to be saved (X8), interest on internal loan(X9), utilization of savings by

SHG (X10), loan recoveries (X11), maintenance of books (X12), accumulated savings (X13), knowledge of the rules of SHG (X14), educational level (X15) and knowledge of government programme (X16). The 16 factors of the checklist were measured on a three point continuum of very good, good and unsatisfactory with scoring pattern 3, 2 and 1, respectively. As per NABARD checklist SHGs with 12 to 16 "very good" factors can get loans immediately, whereas, 10 to 12 "very good" factors need 3 to 6 months' time to improve, before loan is given and those SHGs with rating of less than 10 "very good" factors will not be considered for loan. The fisheries activities undertaken by SHGs were documented through discussion with respective registered authority and leaders of each SHGs. To achieve the objectives of the study, information on all sixteen individual parameters were collected from the leaders of eighteen SHGs.

RESULTS AND DISCUSSION

Profile of SHGs: Mussel farming, oyster farming, cage culture, preparation of ready to cook fish products and ready to eat fish products were the income generating activities adopted by fisher women SHGs in the study area. The activities vary across the districts depending upon the resource availability, extension activities and technical support received from the Department of Fisheries and various institutes in the locality. In Kollam and Kasargod district, mussel farming was the major income generating activity undertaken by fisherwomen SHGs. Mussel farming has been successfully adopted by the women's SHGs in Kasargod district for the past few years (Vipinkumar et al 2013). Ready to cook fish products were equally distributed in all the three districts surveyed as it is a traditional practice. Oyster farming and ready to eat fish products was only in the Ernakulam district since this activity was supported by Central Marine Fisheries Research Institute (CMFRI), Kochi and Society for Assistance to Fisherwomen (SAF). On an average the SHGs were found to be 8 years old.

Performance assessment of fisherwomen SHGs in Kerala using NABARD checklist method

Group size: Only two SHGs from central Kerala (Ernakulam district) had 15-20 members in their group and scored very good as regard to group size. But for the rest of the SHGs there is a scope of improvement and it is suggested that they may increase the group size to 15-20 members. Dev (2008) found that only three SHGs scored very good factors for group size while others need improvement.

Type of members: In order to increase the interaction among members and thus the better performance of SHG, NABARD gives very good score if there are only poor members in the SHG. 88.9% SHGs had only poor members in their group and scored very good.

Number of meetings: In the present study majority (72.2%) of SHGs conducted four meetings in a month and scored very good followed by unsatisfactory (16.7%) while a fewer portion (11.1%) of SHGs scored good as they conducted two meetings in a month. There is a scope of improvement in this regard as they may increase the number of meetings to 4 in a month so that the interaction between the members is frequent. Care has to be taken for active participation of members in the meetings. The study conducted by Bora and Talukdar (2012) observed that a total of 76.6% SHGs under study held meetings every week.

Timings of meetings: SHGs were rated as unsatisfactory since the timing of meeting as per NABARD checklist is very good at night or after 6 pm. The timing of the meetings were decided as per the convenience of its members which seems to be acceptable by all members in the group.

Attendance of members: 83.3% of SHGs scored very good as in these groups full attendance of members were observed in the meetings and relatively small portion (16.7%) of SHGs had only 70-90% attendance and scored good. In this aspect there is a scope of improvement for the SHGs which have scored good by relooking the timings of the meetings. Veenapani (2012) reported that in the study area most of the SHGs had above 90% of attendance of its members in the meetings.

Participation of members: 72.2 % of SHGs scored very good followed by rest 27.8% SHGs as good. The SHGs which have scored good can improve by ensuring high level of participation of members.

Savings collection within the group: The members of SHGs had to contribute compulsorily towards a common fund which can be lent to its members in order to meet emergency credit needs (Nune 2008). The amount may be small, but savings have to be a regular. In the study, 50% of SHGs scored very good score as the group collected savings from its members more than 4 times a month followed by unsatisfactory for the reason that the savings collection was less than three times a month.

Amount to be saved: The amount to be saved by members of SHGs was categorized as fixed amount or varying amount. Those SHGs having fixed amount of savings rated as very good and varying amount as good. All the SHGs under study had a fixed amount and scored very good. Moreover, it was reported that the amount saved ranged from of Rs. 50-100 per month.

Interest on internal loan: In the present study all the SHGs scored good as they charged 24-36% per annum as the interest rate on internal loan. As reported by the SHGs their financial condition is not strong so they are unable to provide

loans depending on purpose. To improve on this aspect the SHGs have to improve in a holistic manner based on factors mentioned in the checklist so as to improve their performance.

Utilization of savings amount by SHG: It was observed in the study that 77.8% SHGs utilized the savings fully for loaning to its members and scored very good and the rest 22% of SHGs utilized a portion of savings for meeting the emergencies related to the income generating activity undertaken by the group. Regarding the utilization of savings amount, SHGs reported that they were giving loans to members as and when required and saving the money for future use.

Loan recoveries: With reference to loan recoveries more than 90% repayment is considered as very good followed by 70-90% as good and less than 70% as unsatisfactory. In the present study more than 90% loan recovery were observed in 88.1% of SHGs and it is observed to be the outcome of better management of the income generating activities. The rest of the SHGs (11.9%) had only 70-90% loan recovery. The SHGs which have been scored as good can improve in this aspect by motivating the members to pay their loans on time. This will also inculcate good financial practices in the members. Edward (2005) opined that about 90% were regular in loan repayment.

Maintenance of books: The regular maintenance and update of all books is considered very good, update of most important registers as good and irregular maintenance and update of books as unsatisfactory. 77.8% SHGs updated most important registers and scored good and relatively a small portion of 22.8% SHGs scored very good. It is suggested that training should be provided to SHGs related to handling accounts and book keeping. This will bring confidence as well as transparency in the financial dealings.

Accumulated savings: All the SHGs under the study had accumulated savings of more than Rs 5000 and scored very good on this factor.

Knowledge of rules of SHG: If all the members in the group know about the rules of SHG then the group is rated as very good and if it is not known to all members then the group is rated as unsatisfactory. In the present study majority (83.3%) of SHGs reported that all the members in their group were aware of the rules of SHG. For some groups scores were unsatisfactory. So there is an immediate need of

Table 1. Performance assessment of fisher women SHGs in Kerala

Factors to be checked	Very good as per NABARD checklist	% of SHGs	Good as per NABARD checklist	% of SHGs	Unsatisfactory as per NABARD checklist	% of SHGs	Average score
Group size	15 to 20	11.1	10 to 15	88.9	Less than 10	0.0	2.11 ± .076
Type of members	Only very poor members	88.9	2 or 3 not poor members	11.1	many not poor members	0.0	2.88 ± .762
Number of meetings	4 meetings in a month	72.2	2 meetings in a month	11.1	< 2 meetings in a month	16.7	2.56± .18.4
Timings of meetings	Night or after 6 p.m.	0.0	Morning between 7 and 9 am	0.0	Other timings	100	1.00 ± .000
Attendance of members	More than 90%	83.3	70 to 90%	16.7	Less than 70%	0.0	2.83 ± .090
Participation of members	Very high level of participation	72.2	Medium level of participation	27.8	Low level of participation	0.0	2.72 ± .108
Savings collection within the group	Four times a month	50	Three times a month	11.1	Less than three times a month	38.9	2.11 ± .227
Amount to be saved	Fixed amounts	100	Varying amounts	0.0	-	-	3.00 ± .000
Interest on internal loan	Depending upon the purpose	0.0	24 to 36%	100	More than 36%	0.0	2.00 ± .000
Utilization of savings amount by SHG	Fully used for loaning to members	77.8	Partly used for loaning	22.2	Poor utilization	0.0	2.78 ± .100
Loan recoveries	More than 90%	88.1	70 to 90%	11.9	Less than 70%	0.0	2.88 ± .076
Maintenance of books	All books are regularly maintained	22.2	Most important registers are updated	77.8	Irregular in maintaining and updating	0.0	2.22 ± .100
Accumulated savings	> Rs. 5000/-	100	Rs. 3000-5000/-	0.0	< Rs.3000/-	0.0	3.00 ± .000
Knowledge of the rules of SHG	Known to all	83.3	-		Not known to all	16.7	2.66 ± .180
Education level	> 20 % of members can read and write	100	-		< 20 % know to read and write	0.0	3.00 ± .000
Knowledge of Govt. programs	All are aware	44.4	Most of the members know	55.6	No one knows	0.0	2.44 ± .120

Table 2. Overall performances of SHGs working in fisheries sector

Performance	Number of SHGs	Percentage (%)
Very good	2	11.1
Good	12	66.7
Unsatisfactory	4	22.2

improvement regarding this by providing training on this aspect. This is necessary for sustainability of the group.

Education level: The education level, the group is considered as very good if more than 20% of members in the group can read and write whereas unsatisfactory if less than 20% of members can read and write. In this study all the SHGs reported that more than 20% of members can read and write and scored very good.

Knowledge of Government programmes: If all the members of SHG are aware of Government programs it is scored as very good. If most of the members know then it is scored as good and if no one knows then it is unsatisfactory. 55.6% SHGs scored good and the rest (44.4%) scored very good. NGOs in the areas can create awareness about the government programmes. SHG leaders and members can also play a proactive role and enquire about the government programmes from different organisations.

The average score of SHGs was 2.23 indicating a good score. SHGs achieved very high score in few parameters like amount to be saved (average score 3), accumulated savings (average score 3) and education level (average score 3) and unsatisfactory score only in timing of meetings (average score 1) (Table 1). The 11.1 % of SHGs were eligible for immediate loan as they scored “12-16” very good factors. A total of 66.7% SHGs scored 10-12 "very good” factors and these SHGs could get loan only after an improvement period of 3-6 months and the rest 22.2% of SHGs rated less than 10 "very good” factors and these groups are not considered for loan (Table 2). The emergence of SHGs helped women to undertake income generating activities in fisheries sector as well resulted in the socio economic development of fisherwomen. The role of SHGs is very crucial for the development of fisheries sector. Support from the Government, NABARD, NGOs and Banks are highly essential for enhancing the performance of SHGs. Presently a number of SHGs are working in the fisheries sector and their performance should be assessed on a periodic basis for the better utilization of available resources. There is scope for improving the performance of SHGs by adopting the norms of NABARD as it is the major agency promoting the formation of SHGs. The checklist parameters must be popularised among NGOs and SHGs so that in the long run the performance of SHGs gets improved.

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REFERENCES

Bora P and Talukdar R K 2016. Functioning and sustainability of women self help groups of Assam: An analysis based on credit system and income generation. *Indian Research Journal of Extension Education* **12**(2): 107-112.

Department of Animal Husbandry, Dairying and Fisheries (DAHDF) 2016. *Guidelines*. Central Sector Scheme on Blue Revolution: Integrated Development and Management of Fisheries.

Dev T 2008. *Social and Economic Impact Study of Selected SHGs in Fisheries and Allied Sector in Madhubani* (Bihar). MFSc dissertation, ICAR-*Central Institute of Fisheries Education, Mumbai.*

Edward L 2005. Fisherwomen's self help groups their empowerment for fisheries development: A case study in Thoothukudi district of Tamilnadu. *Fishing Chimes* **25**(6): 26-28.

NABARD 2007. *SHG Bank linkage programme*, status as on March 31 2007, National Bank for Agriculture and Rural Development, Mumbai.

NABARD 2016. Status of Microfinance in India 2016-17, *National Bank for Agriculture and Rural Development*, Mumbai.

Nune SR 2008. Role of aquaculture in poverty reduction and empowerment of women in India through the medium of self-help groups, pp.1-12. *IIFET 2008 Vietnam Proceedings*.

Shyam SS, Antony B and Geetha R 2011. *Women Empowerment and Fisheries Sector in Kerala. ICAR-Central Marine Fisheries Research Institute,*,Kochi.

Veenapani 2012. Performance of self help groups: A case study of Mahbubngar District in Andhra Pradesh. *Radix International Journal of Research in Social Science* **1:** 1-28.

Vipinkumar VP and Asokan P K 2014. Study of self help group dynamics of women in Malabar fisheries sector. *Indian Research Journal of Extension Education* **14**(2): 25-30.

Vipinkumar VP, Sahoo PK, Srinath K, Ambrose TV and Jiban Dash SS 2013. Gender perspectives and dynamics of bivalve farming self help groups. *Indian Journal of Fisheries* **60**(3): 59-66.

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Changes in Color Attributes of Mock Meat Nuggets Prepared from Oyster Mushroom, Flaxseed and Amaranth in Response to Storage

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Abstract: A study was *conducted* to evaluate the changes in color attributes of mock meat nuggets formulated from oyster mushroom, flaxseed and amaranth during storage period of six months. The product was prepared from different combinations of defatted flaxseed, freeze dried oyster mushroom and amaranth grain flour. The physical attributes of mock meat nuggets viz., Lightness value observed a decrease with the increasing levels of partially defatted flaxseed and amaranth grain flour. The highest mean Lightness value of 55.94 was recorded in chicken nuggets while 00:100:00::Oyster mushroom powder: Partially defatted flaxseed flour: Amaranth grain flour recorded least mean Lightness of 22.90. The redness and yellowness values increased with the increase in addition of partially defatted flaxseed and amaranth grain flour. Furthermore in response to storage period of six months mean Lightness value decreased from 45.78 to 42.39 while as redness and yellowness values increased from 4.78 to 6.46 and 22.81 to 24.35, respectively indicating a deteriorative effect of storage on colour attributes of meat analog nuggets.

Keywords: Amaranth, Color attributes, Defatted flaxseed, Mock meats, Oyster mushroom, Storage

Imitation/mock meat acts as an alternative to calorie dense animal foods. Traditionally these mock meats were formulated from soybean but recently formulation of mock meats from foods rich in functional ingredients have increased. These are functional mock meats not only cater the needs of vegetarian segments also act as source of functional ingredients like crude fibre and anti-oxidants thereby confer health benefits (Joshi and Kumar 2015). Oyster mushrooms being rich source of proteins (17-42%) with all the essential amino acids can act as a promising ingredient in formulation of mock meat. The low fat content (0.8-7.0%) presence of non-starchy carbohydrates, dietary fiber, minerals and vitamins increases its suitability for meat analog preparation. *Pleurotus* mushrooms can also act as functional ingredient owing to its rich content of biologically active substances like alkaloids, phenols, terpenes, antioxidants. The fibrous texture of mushrooms and its unique umami mushrooms after cooking (Umami/meaty flavour) makes it well suited substrate for development of meat analogs.

The high meat prices and increasing malnutrition rates especially in developing countries demands the development of low cost meat alternative. The low cost, easy availability and rich nutritional profile of flaxseed and amaranth grain makes them good substrates for development of mock meat. The flaxseed are rich in polyunsaturated fatty acids line alpha-linolenic acid, lignans and dietary fibers minimizing the disease risks thereby acting as a nutraceutical. Similarly, amaranth grains are rich in methionine (a sulphur containing amino acid which is the limiting amino acids in pulses) and minerals like calcium (250 mg/100g) and iron (15 mg/100 g) (Sousa and Farfan 2012). It can also serve as source of functional ingredients like polyphenolic compounds, flavonoids, antioxidants, dietary fiber thereby conferring health benefits like curtailing plasma cholesterol levels, lowering blood sugar levels, exhibiting anti-tumor, anti-allergic effects and prevention of anaemia and hypertension (Bhat et al 2015).

Color is an important parameter of food product determining its acceptability (Bansal et al 2013). During storage a number of biochemical reactions occur which results in color deterioration and thus affect the consumer acceptability. The aim of this study was to formulate a functional meat analog from oyster mushroom, flaxseed and amaranth grain and determine the effect of storage on their colour attributes viz., Lightness, redness and greenness values.

MATERIAL AND METHODS

Ingredients of mock meat nuggets: The imitation meat nuggets were formulated from freeze dried oyster mushroom, defatted flaxseed and amaranth grain flour. The cleaned sliced oyster mushroom (*Pleurotus florida*) was freeze dried (Martin Christ Type 101041) with chamber temperature of -60°C, under vacuum and a condenser temperature of -50°C) followed by grinding. Meanwhile the

amaranth grain was roasted and ground while as flaxseed after roasting was defatted, ground and screened to obtain flour streams.

Preparation of nuggets: A protocol given by Nisha (2008) with slight modification was used for nugget preparation (Fig. 1). These composite imitation meat nuggets were formulated by mixing the three ingredients in different amounts (Table 1). The imitation meat nuggets were compared with the chicken nuggets formulated from deboned chicken meat.

Analysis of Mock Meat Nuggets

Color analysis (L*, a*, b*): The colour of sample was measured using a Hunter's lab colour analyzer (Hunter Lab Colour Flex Reston VA, USA). The equipment was calibrated using white and black standard ceramic tiles (Younis and Ahmad 2015). In the Hunter's lab colorimeter, the colour of a sample is denoted by the three dimensions. L*, a* and b*. L* refers to lightness of the colour of the sample and ranges from black=0 to white=100. A negative value of a* indicates a green colour whereas, the positive value indicates red-purple colour. A positive value of b* indicates a yellow color and negative value a blue colour.

RESULTS AND DISCUSSION

Hunter color values: The highest mean L* value of 55.94 was in treatment T_1 (control chicken nuggets) and lowest mean L* (22.90) was in T_6 (00:100:00::MP:PDF:AF). The highest mean a* value of 7.67 was in T_6 whereas, lowest mean a* value of 3.89 was observed in T_1 (control chicken nuggets). The highest b* (26.99) was also in T_6 while least mean b* (18.39) was in T_1. In comparison to control chicken nuggets, meat analog nuggets formulated with higher levels of freeze dried oyster mushroom reflected lower L* values

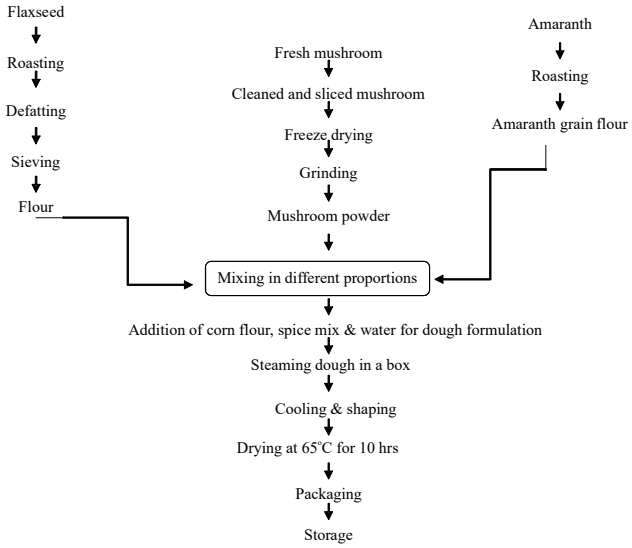

Fig. 1. Flow sheet for formulation of imitation meat nuggets

Table 1. Effect of treatment and storage on L* (lightness) value of meat analog nuggets

Treatment	Storage period (months)				Mean (Treatment)
	0	2	4	6	
T_1 (Control chicken nuggets)	59.83	59.00	54.64	50.28	55.94
T_2 (100:00:00::MP:PDF:AF)	55.71	54.91	53.81	52.70	54.28
T_3 (75:25:00::MP:PDF:AF)	47.62	46.87	45.86	44.66	46.25
T_4 (50:50:00::MP:PDF:AF)	39.89	39.26	38.37	37.23	38.69
T_5 (25:75:00::MP:PDF:AF)	31.78	31.28	30.35	29.30	30.68
T_6 (00:100:00::MP:PDF:AF)	23.83	23.43	22.65	21.67	22.90
T_7 (75:00:25::MP:PDF:AF)	54.23	53.31	52.22	51.09	52.71
T_8 (50:00:50::MP:PDF:AF)	52.87	52.03	50.94	49.77	51.40
T_9 (25:00:75::MP:PDF:AF)	51.03	50.14	49.16	48.03	49.59
T_{10} (00:00:100::MP:PDF:AF)	49.48	48.65	47.61	46.42	48.04
T_{11} (25:25:50::MP:PDF:AF)	44.19	43.42	42.42	41.27	42.83
T_{12} (50:25:25::MP:PDF:AF)	46.38	45.49	44.41	43.23	44.88
T_{13} (25:50:25::MP:PDF:AF)	38.26	37.53	36.63	35.47	36.97
Mean (Storage)	45.78	45.02	43.77	42.39	

CD

Effects	CD (p=0.05)
Storage	0.25
Treatment	0.45
Storage ×Treatment	0.90

MP: Oyster mushroom powder; PDF: Partially defatted flaxseed flour; AF: Amaranth grain flour

consistent with the findings of Rosli et al (2011) who reported a decrease in L* and b* values in chicken patties formulated from oyster mushroom in contrast to chicken patties without oyster addition. With the increase in incorporation levels of partially defatted flaxseed, mean L* values followed a decreasing trend while as mean a* and b* values increased. This might be due to the darker color of flaxseed in contrast of freeze dried oyster mushroom and amaranth grain flour.

Table 2. Effect of treatment and storage on a* (redness) value of meat analog nuggets

Treatment	Storage period (months)				Mean (Treatment)
	0	2	4	6	
T_1 (Control chicken nuggets)	3.31	3.57	4.07	4.60	3.89
T_2(100:00:00::MP:PDF:AF)	4.03	4.35	4.96	5.56	4.73
T_3 (75:25:00::MP:PDF:AF)	4.66	5.03	5.72	6.39	5.45
T_4(50:50:00::MP:PDF:AF)	5.35	5.78	6.42	7.07	6.16
T_5(25:75:00::MP:PDF:AF)	6.04	6.52	7.11	7.80	6.87
T_6(00:100:00::MP:PDF:AF)	6.83	7.26	7.93	8.64	7.67
T_7(75:00:25::MP:PDF:AF)	4.09	4.40	5.01	5.66	4.79
T_8(50:00:50::MP:PDF:AF)	4.18	4.54	5.12	5.77	4.90
T_9(25:00:75::MP:PDF:AF)	4.26	4.65	5.31	5.94	5.04
T_{10}(00:00:100::MP:PDF:AF)	4.36	4.74	5.39	6.04	5.13
T_{11}(25:25:50::MP:PDF:AF)	4.83	5.26	5.94	6.61	5.66
T_{12}(50:25:25::MP:PDF:AF)	4.76	5.20	5.88	6.57	5.60
T_{13}(25:50:25::MP:PDF:AF)	5.45	5.89	6.63	7.33	6.32
Mean (Storage)	4.78	5.17	5.81	6.46	

CD

Effects	CD (p=0.05)
Storage	0.02
Treatment	0.03
Storage ×Treatment	0.06

Table 3. Effect of treatment and storage on b* (yellowness) value of meat analog nuggets

Treatment	Storage period (months)				Mean (Treatment)
	0	2	4	6	
T_1(Control chicken nuggets)	17.78	18.13	18.58	19.07	18.39
T_2(100:00:00::MP:PDF:AF)	19.90	20.30	20.77	21.29	20.57
T_3 (75:25:00::MP:PDF:AF)	21.48	21.88	22.39	22.93	22.17
T_4(50:50:00::MP:PDF:AF)	23.06	23.51	24.01	24.57	23.79
T_5(25:75:00::MP:PDF:AF)	24.90	25.38	25.89	26.52	25.67
T_6(00:100:00::MP:PDF:AF)	26.22	26.71	27.21	27.83	26.99
T_7(75:00:25::MP:PDF:AF)	21.15	21.57	22.02	22.63	21.84
T_8(50:00:50::MP:PDF:AF)	22.42	22.85	23.32	23.97	23.14
T_9(25:00:75::MP:PDF:AF)	23.67	24.14	24.65	25.27	24.43
T_{10}(00:00:100::MP:PDF:AF)	24.94	25.43	25.91	26.56	25.71
T_{11}(25:25:50::MP:PDF:AF)	23.99	24.47	24.98	25.58	24.76
T_{12}(50:25:25::MP:PDF:AF)	22.75	23.19	23.71	24.30	23.49
T_{13}(25:50:25::MP:PDF:AF)	24.32	24.80	25.32	25.98	25.11
Mean (Storage)	22.81	23.26	23.75	24.35	

CD

Effects	CD (p=0.05)
Storage	0.02
Treatment	0.03
Storage ×Treatment	0.06

Similar results were reported by Singh et al (2011) while studying the effect of addition of linseed oil on the color values of chicken patties. Koca and Anil (2007) also reported a decrease in L* and an increase in a* and b* value of bread with increase in substitution levels of flaxseed flour. Lemos et al (2012) also reported a decrease in L* value of cheese bread with the increase in incorporation levels of amaranth grain flour, thus supporting our findings.

Storage studies of meat analog nuggets revealed a significant decrease in L* value from initial mean level of 45.78 to 42.39 while as a* and b* increased from 4.78 to 6.46 and 22.81 to 24.35, respectively during 6 months of storage. This might be due to maillard reaction resulting in increase in formation of brown pigments (melanoidins) that led to darkening of meat analog nuggets (Jan 2018). Kortei et al (2015) also reported decrease in L* and an increase in a* value during storage of mushroom powder. Parnsakhorn and Langkapin (2013)also reported an increase in b* value during storage of brown rice.

CONCLUSION

The storage had a significant impact on colour attributes of mock meat nuggets. The formation of inter-mediate products (melanoidins) during storage that are catalyzed by storage temperature and humidity degrade the appearance of foods during storage. The meat analogs corresponding to treatment T_7(75:00:25::MP:PDF:AF) recorded highest mean Lightness value of 52.71 and least mean redness and greenness values of 4.79 and 21.84 respectively, indicating colour attributes similar to that of control nuggets.

REFERENCES

Bansal S, Kumar S, Alam MS and Kumar M 2013. Optimization of Process Parameters for Multi-Layer-Cum Microwave Drying of Oyster Mushrooms (*Pleurotus sajor caju*). *International Journal of Engineering Research and Applications* **3**(5): 206-217.

Bhat A, Satpathy G and Gupta RK 2015. Evaluation of Nutraceutical Properties of *Amaranthus hypochondriacus* L. Grains and Formulation of Value Added Cookies. *Journal of Pharmacognosy and Phytochemistry* **3**(5): 51-54.

Ja A 2018. *Effect of Gamma-Irradiation on Quality Characteristics of Brown Rice Based Weaning Food*. Ph.D thesis. Sher-e-Kashmir University of Agricultural Sciences and Technology of Jammu, Jammu and Kashmir, India.

Joshi VK and Kumar S 2015. Meat analogues: Plant Based Alternatives to Meat Products-A Review. *International Journal of Food and Fermentation Technology* **5**(2): 107-119.

Koca AF and Anil M 2007. Effect of Flaxseed and Wheat Flour Blends on Dough Rheology and Bread Quality. *Journal of the Science of Food and Agriculture* **87**(6): 1172-1175.

Kortei NK, Odamtten GT, Obodai M, Appiah V and Akonor PT 2015. Determination of color parameters of gamma irradiated fresh and dried mushrooms during storage. *Biotechnology and Nutrition* **6**(1-2): 66-71.

Lemos A, Dos R, Capriles VD, Pinto e Silva MEM and Areas JAG 2012. Effect of Incorporation of Amaranth on the Physical Properties and Nutritional Value of Cheese Bread. *Food Science and Technology* **32**(3): 427-431.

Nisha 2008. *Standardization of green gram based meat analogues*. M.Sc. thesis. Kerala Agricultural University, Kerala, India.

Parnsakhorn S and Langkapin J 2013. Changes in Physicochemical characteristics of germinated brown rice and brown rice during storage at various temperatures. *Agricultural Engineering International CIGR Journal* **15**(2): 293-303.

Rosli WIW, Solihah MA, Aishah M, Fakurudin NNA and Mohsin SSJ 2011. Color, textural properties, cooking characteristics and fibre content of chicken patty added with oyster mushroom (*Pleurotus Sajor-caju*). *International Food Research Journal*, **18**(2): 612-618.

Singh R, Chatli MK, Biswas AK and Sahoo J 2011. Quality and storage stability of chicken meat patties incorporated with linseed oil: Quality and storage stability of chicken meat patties. *Journal of Food Quality* **34**(5): 352-362.

Sousa VM and Farfan JA 2012. State of Knowledge on Amaranth Grain: A Comprehensive Review. *Journal of Food Science* **77**(1): 93-104.

Younis K and Ahmad S 2015. Waste utilization of apple pomace as a source of functional ingredient in buffalo meat sausage. *Cogent Food and Agriculture* **1**: 1-10

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