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Suitability of Ground Water for Irrigation Purpose in Omalur Taluk, Salem, Tamil Nadu, India

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Abstract: In India, agriculture plays a vital role in socio-economic and in worldwide, India secured seventh place to export agriculture products. In a study area, agriculture based on sources of groundwater for irrigation purpose, therefore 50 groundwater samples were collected from study area to evaluate the suitability for irrigation purpose. The groundwater samples were analyzed for 12 parameters are Electrical conductivity, total dissolved solids, pH, Major cation like calcium, Sodium Magnesium, Potassium, fluoride and major anion like Sulphate, Chloride, Carbonate, Bicarbonate. The most effective irrigation indices are Sodium Absorption Ratio, Permeability Index, Residual Sodium Carbonate, Magnesium hazards, Kelly ratio and USSL, Wilcox diagram to evaluate the quality of groundwater for irrigation purpose. In the study area, Piper Diagram shows that Ca-Mg-Cl, Ca-Cl type of water and naturally in alkaline state. Based on indices value majority of groundwater samples were suitable for irrigation and some sample locations are unfit for irrigation use due to anthropogenic activities like excess amount of fertilizers and pesticides used for crop yield. Gibbs plot reveals that, rock and evaporation domination affect the quality of groundwater. Based on Wilcox and USSL diagram Classification of groundwater shows that 98% of the samples were fit for irrigation purpose.

Keywords: Groundwater quality, Irrigation indices, Wilcox diagram, USSL diagram, Sodium absorption ratio

Sub surface water plays a decisive role in constant water supplies for all living organisms in the world under different climate conditions. Due to increase in population, urbanization, growth of industries, consuming level of food and energy demands causes the over utilization of sub surface water and consequently decrease the level of groundwater **(**Zumlotet al 2016, Khan et al 2017, Purushotham et al 2017 and Kant et al 2018). Characteristic of groundwater, soil texture, salt concentration, climatic condition, rainfall are the factors which affects quality of groundwater for irrigation purpose. Presence of mineral ions and soluble salts in the rock strata and soil structure gets naturally dissolved into groundwater. Permeable strata and external source for recharge of groundwater affects the concentration of soluble salts. Yield of crop may be affected by the excess amount of soluble salts present in the groundwater. Accordingly, for a detailed study of hydro-chemistry of groundwater is very crucial to assess the quality of groundwater for agriculture purpose (Chaurasia 2018). Granite and pyroxenite are rich in a study area. Tomato, snake gourd, ridge gourd, paddy, green gram, onion, maize are the most cultivable crops in the study area. As on 2011, OmalurTaluk is over exploited of groundwater in Salem district. In a study area, canal and other tank sources are not available irrigation use. Even at the critical stage of crop growth, Surface sources of water (lake and ponds) are not capable to regulate the water for agriculture use. For all these aspects, the study of groundwater for agriculture use is necessary in a study area. Over utilization of fertilizers for agriculture purpose, rock-water weathering and dumping of municipal waste are the sources of pollutant and it does modify the quality of groundwater (Nagaraju et al 2014, Pazand et al 2018, Rivett et al 2018 and Singh et al 2018). Percolation rate of pollutants from the point of application into groundwater is a behavior of soil, permeable rock strata and the type of pollutant. An objective of the present study is to assess the suitability of groundwater for agriculture purpose by using various indices.

MATERIAL AND METHODS

Study area: Omalurtaluk in Salem is a second largest taluk in the district. It has more than ninety-five villages. Omalur is bounded by Dharmapuri district on north, Namakkal district on south, and erode district on west. It is located at $11°73'$ latitude and $78°07'$ latitude, at an average altitude of 298m from the mean sea level. Generally, climatic condition in a taluk is blazing and arid. Summer starts from February at an average temperature of $30°C$ and it rises to $37°C$ in the month of April and May. During summer time, occasionally it gets rainfall due to higher temperature. Winter starts from in the month of august and September, during this month the average rainfall intensity in taluk is 100mm. The peoples in

majority depend on the agriculture, handloom and leather business for their growth and survival (Table 1).

Sample collection: In a study area, sample locations data and groundwater samples collected near by the dumping yards, industrial zone and gradually covered the entire study area. Totally 50 sample locations were identified and groundwater samples were collected in a specified location. A sample was collected from bore wells at a depth ranging between 80 feet to 210 feet at an average of 140 feet below surface level in pre-monsoon during the month of February 2017.Groundwater samples were collected in two bottles like polythene bottles and glass bottle at a capacity of 1000ml (Agca et al 2013 and Tiwari et al 2017).

Sample analysis: The hydro chemical properties of groundwater were analyzed for concentration of hydrogen ions (pH), total dissolved solids, alkalinity, hardness, major cation like calcium magnesium, sodium, potassium and anion concentrations like chloride, sulphate, bicarbonate using Standard procedure APHA 1995 (Table 2).

Irrigation purpose: Groundwater quality for irrigation purpose is mainly assessed to estimate the concentration and composition of excess level of chemical contamination. Salt concentration, and salinity problems are major factor to affect the crop yield and soil texture. Higher concentration of salts originated from weathering of rock, Soil and presence of natural minerals dissolved into water (Nageswara et al 2015, Mahato et al 2016, Jhariya et al 2017, Bouderbala 2017 and Behera et al 2018). The purpose of evaluating the suitability of groundwater quality for irrigation purpose is not only the presence of salts. In a study area, problems arise like over utilization of fertilizers and pesticides for crop, dumping of solids waste into open area and effluent from the industries are major reason for this examination. Total Dissolved Solids (TDS) and major cations like calcium, magnesium, sodium in a groundwater are the major parameters to evaluate the suitability for irrigation purpose. SAR, PI, RSC, MH indices are helpful to estimate the excess amount of contamination in water(Sharma et al 2015, Li et al 2017 and Al-Harbi et al 2014). Gibbs plot is representing the dominate source of contamination by rock, evaporation and precipitation in the groundwater. The following formula has been used to calculate the indices value:

Table 1. Latitude and longitude of sample location

Villages	Latitude	Longitude	S.no	Villages	Latitude	Longitude
Alagusamudram	11.67044	78.02374	26	Kottakkavundampatti	11.74801	78.05666
Amarakundhi	11.73437	77.96673	27	Kullamanayakanpatti	11.73678	78.05665
Anaikavundanpatti	11.70556	78.07804	28	Kurukkuppatti	11.68675	77.98029
Ariyampatti	11.72097	77.91248	29	Mailappalaiyam	11.72370	78.01098
Arurpatti	11.70450	77.95388	30	Mallikuttai	11.74951	78.09095
Balbakki	11.75941	78.04457	31	Manattal	11.73986	77.94745
Chellapillaikuttai	11.71125	78.04808	32	Mankuppai	11.76335	77.95676
Chettipatti	11.73163	78.10085	33	Mungilpadi	11.69711	78.07803
Dasavilakku	11.67774	77.96602	34	Muthunayakanpatti	11.74124	78.11297
Dasavilakku north	11.81339	78.09729	35	Naranampalayam	11.71477	78.03238
Ettikuttaipatti	11.73774	78.07946	36	Omalur	11.75683	78.07625
Gobinathapuram	11.76681	78.10227	37	P.kalippatti	11.74368	78.04759
Gollappatti	11.73163	78.10085	38	Pachchanampatti	11.74465	78.03101
Idaiyappatti	11.67628	77.94818	39	Pagalpatti	11.68934	78.05949
Ilavampatti	11.68091	77.92532	40	Panikkanur	11.66311	77.91688
Jagadevempatti	11.75479	78.11798	41	Pappambadi	11.64698	77.94960
Kamalapuram	11.77195	78.06091	42	Periyerippatti	11.72855	77.99385
Kaminayakkanpatti	11.74651	78.12082	43	Puliyampatti	11.72716	78.06091
Karukkalvadi	11.67808	78.02333	44	Ramireddipatti	11.70376	77.93675
Karuppanampatti	11.76259	78.02168	45	Reddipatti	11.73841	77.99528
Karuppur	11.71764	78.09224	46	Sakkarasettipatti	11.77231	78.10227
Kasuvireddippatti	11.84511	78.08107	47	Saminayakkampatti	11.70626	78.08278
Kattaperiyampatti	11.76397	78.00385	48	Sangitappatti	11.72824	78.08659
Konagapadi	11.63413	77.95887	49	Sekkarapatti	11.93524	78.07807
Kottaimettupatti	11.71491	78.06804	50	Selavadai	11.70592	77.92246

Sodium absorption ratio equation: $SAR = Na / \sqrt{(Ca + Mg)/2}$
Residual sodium carbonate equation: $RSC = (HCO_3^- + CO_3) - (Ca^{2+} + Mg^{2+})$
Permeability index equation: $PI = (Na + \sqrt{HCO_3}) / \sqrt{(Na + Mg + Ca)}$
Kelly ratio equation: $KR = Na / (Ca + Mg)$
Magnesium hazards equation: $MH = Mg*100 / (Ca + Mg)$
Percentage sodium equation: $\%Na = (Na^+ + K^+ / (Ca^{2+} + Mg^{2+} + Na^+ + K^+)) \times 100$
Gibbs anion plot equation: $Gibbs_{anion} = Cl / (Cl + HCO_3)$
Gibbs cation plot equation: $Gibbs_{cation} = (Na + K) + (Na + K + Ca)$
Chloroalkalis indices equation: $CAI = (Cl - (Na + K)) / Cl$

RESULTS AND DISCUSSION

Piper diagram: The concentration of cation and anion in the groundwater samples can be evaluated by plotting the piper diagram. Diagramme software was used to plot this piper diagram. piper diagram represents the concentration of cation and anion in meq l⁻¹. In present study, 75% of the samples fell in the mixed category of Ca-Mg-Cl type, 15% of the groundwater samples fell in the category of Ca-Cl type of water and remaining 10% of the samples fell in the Ca-SO₄. Sixty-five percent of the sample locations were having excess concentration of alkalis, rock-water interaction dominates the quality of water and alkaline in nature (Fig. 1).

USSL diagram: US Salinity laboratory diagram plotted to represent the relationship between conductivity of water versus sodium absorption ratio. In a study area, Sodium Absorption Ratio ranges between 1.18 to 10.98meq/L at an average of 2.92meq/L (Table 3). For the purpose of irrigation, 98% of the sample locations were excellent category for irrigation USSL diagram shows that 80% of the sample locations fell in the C3-S1(high salinity / low sodium hazards) and 20% of the samples fell in the C2-S1 category (medium salinity / low sodium hazards). Majority of the samples in a study area are suitable for irrigation for semi-tolerant crops

Table 3. Classification of groundwater samples for irrigation purpose in study area

Irrigation parameter	Type of water	No. of samples	Percentage
Sodium Absorption Ratio			
>10	Excellent	49	98
10 to 18	Good	1	2
18 to 26	Permissible	Nil	0
>26	Unsuitable	Nil	0
Residual Sodium Carbonate			
<1.25	Good	49	98
1.25-2.5	Marginal	1	2
>2.5	Unsuitable	Nil	0
Kelly Ratio			
>1	Suitable	37	74
<1	Unsuitable	13	26
Magnesium Ratio			
<50	Suitable	49	98
>50	Unsuitable	1	2
Percentage Sodium			
<60	Suitable	43	86
>60	Unsuitable	7	14
Permeability Index			
>75%	Good	24	48
75-25%	Permissible	24	48
<25%	Unsuitable	2	4
Chloro-Alkaline Indices			
Negative	Ion Exchange	50	100
Positive	No ion	Nil	0

like sunflower, wheat, Triticale and 20% of the groundwater samples were may affects the soil health and crop yield (Fig. 2).

Wilcox diagram: Wilcox diagram shows that relationship

Table 2. Standard procedure for each parameter

| Parameter	Field kit	Instruments	Titration
pH	pH meter (Elico)	-	-
Electrical Conductivity	EC meter (Elico)	-	-
Calcium	-	-	Standardized EDTA
Magnesium	-	-	Standardized EDTA
Total Dissolved Solids	TDS Meter (Aqua read)	-	-
Total Hardness	-	-	Standardized EDTA
Total Alkalinity	-	-	Sulfuric acid
Chloride	-	-	Standardized silver nitrate
Potassium	-	Flame photometer	-
Sodium	-	Flame photometer	-
Sulphate	-	UV spectrophotometer	-
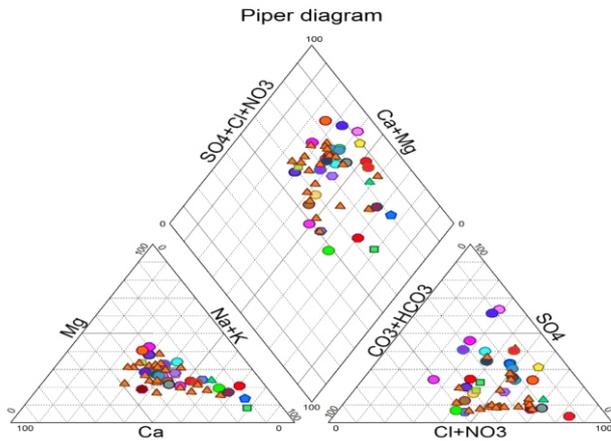
Fig. 1. Piper diagram classification of groundwater samples
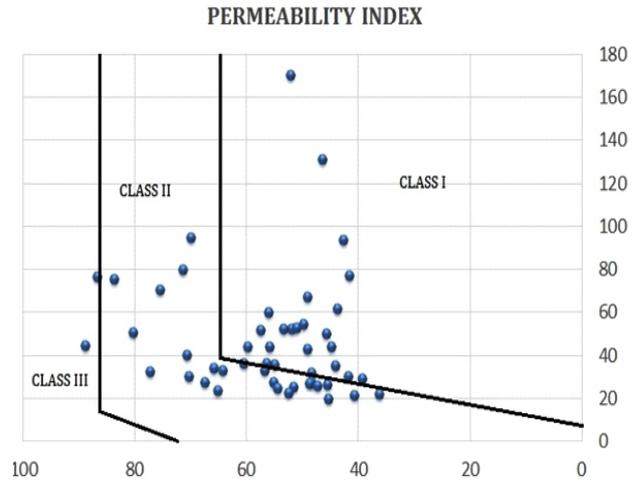

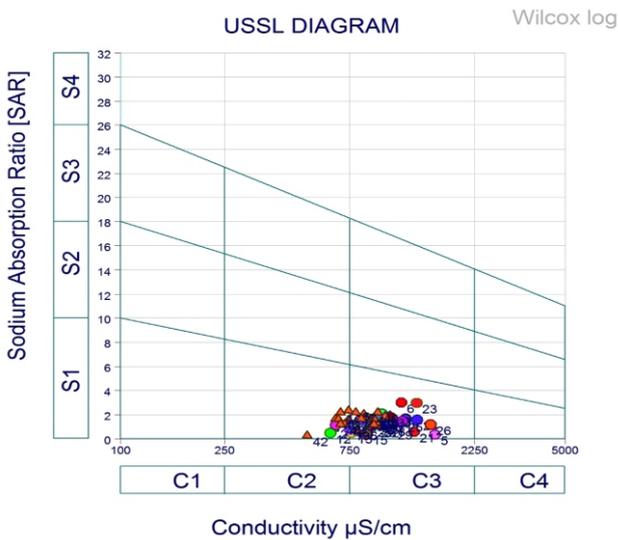**Fig. 4.** Doneen diagram classification of groundwater samples

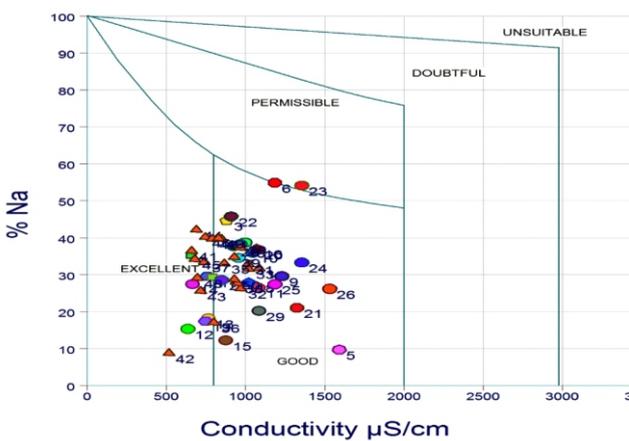**Fig. 2.** USSL classification of groundwater samples

Fig. 3. Wilcox diagram classification of groundwater samples

between electrical conductivity and percentage sodium of groundwater samples. The Navalue greater than 60% affects the physical properties of soil and reduces the rate of permeability. Higher concentration of sodium results that to increase the alkali and salinity of water. Na value range between 25.64 to 79.20% with an average value of 43.75%. In Wilcox Diagram shows that 28% of the samples fell in the category of excellent to good and 68% of the samples fell in the good to permissible category and 4% of the samples fall in the permissible to doubtful category (Fig. 3). It shows that 96% (48 locations) of the groundwater samples suitable for irrigation purpose.

Permeability index: Doneen (1964) suggested that classify the groundwater samples based on concentration calcium, magnesium, sodium and bicarbonate of the soil. The value of permeability index range between 29.87-77.95% at an average of 51.92%.Doneen diagram of study area shows that 48% of the samples fell in the Class I (>75%), 48% of the samples fell in the Class II (25-75%) and 4% of the samples fell in the Class III (<25%). It shows that 96% of the samples were fit for irrigation purpose . Due to disposal of municipal waste and usage of fertilizers affects the soil texture and permeability rate of soil (Fig. 4).

Gibbs plot: The concentration of anion and cation in groundwater sample location of the study area is plotted in Gibbs diagram. It represents the relationship between TDS versus total cation and TDS versus total anion concentration in water. In a study area, Gibbs plot reveals that a majority of the samples influenced by rock domination and some of the sample locations fell in the evaporation domination category. It shows that earth metal influence for concentration of cation and anion in the groundwater. The groundwater parameter like calcium, sodium, potassium and chloride concentration indicates of calcite, clay minerals, halite and feldspars

weathering are rich in the study area.

Magnesium hazards: Higher concentration of magnesium ion in water samples seriously affects the soil quality and it cause the less yield of crop. it leads to interact the sub surface water with rock. Calcium and magnesium are the major cation to decide the quality of groundwater for irrigation purpose. Excess level of magnesium affects the state of equilibrium of water. Magnesium ratio value greater than 50% has unfit for irrigation purpose and it affect the physical properties of soil. In a study area, 98% of the sample location having less than 50% magnesium hazards and remaining 2% exceed the 50%. It shows that groundwater interaction with highly rich mineral rocks like granite and charnockite.

Residual sodium carbonate (RSC): Excess concentration of carbonate and bi carbonate have reacted with calcium and magnesium to cause precipitation in a soil surface. From the reaction, it will increase the concentration of sodium ions in soil leads to reduce the rate of permeability. RSC less than 1.25meq l^{-1} fit for irrigation purpose, 1.25 to 2.5meq l^{-1} taken as initial state of contamination and greater than 2.5meq l^{-1} unfit for irrigation use. In a study area, the value of RSC range between -7.013 to 3.69 with an average of -3.327, 98% of the sample locations are fit for irrigation .

Kelly ratio: Kelly (1963) introduced the equation, which is related to evaluate the suitability of groundwater for irrigation use by using concentration of sodium, calcium and magnesium. Based on this equation, Kelly ratio greater than 1 is unsuitable and less than 1 is fir for irrigation purpose. In a study area, 74% of the sample location fit for irrigation and remaining unfit for irrigation use.

Chloro-Alkaline Indices (CAI): CAI value range between positive to negative. The negative value of CAI indicates that the ion exchange between bed rock and groundwater, excess concentration of sodium and potassium exchange between Calcium and magnesium in the rock. The positive value of CAI indicates that no ion exchanges between these minerals. All the samples recorded negative value of CAI, it shows that groundwater interaction with bed rock and ion exchange between sodium, potassium, calcium and magnesium.

CONCLUSION

Piper diagram for groundwater samples in a study area shows that 65% of the location were suitable for irrigation purpose and clearly evident that the excess concentration of alkalis, rock-water interaction dominates the quality of water and alkaline in nature. Based on the USSL diagram, 20% of the locations showed danger level and it's not suitable for agriculture purpose due to presence higher concentration of salts. Wilcox diagram shows that 2 sample locations exceeds

the permissible level of sodium ions in groundwater and it indicates the rock water interaction in some specified locations. Doneen diagram of groundwater samples suggest that two sample locations were very poor rate of permeability of soil due to salt accumulations. Gibbs diagram revealed that all the samples fell in the rock domination category and it is the major reason for excess concentration of chemical dissolved into the groundwater. Based on the Magnesium hazards, 98% of the samples suitable for irrigation due to interaction with country rocks like granite and charnockite. RSC value for majority of groundwater samples range below 1.25meq l^{-1} and based on the residual sodium carbonate, 49 sample locations were fit for irrigation purpose. Based on Kelly ratio, 13 sample locations were unfit for irrigation use due to presence of higher concentration of cation like sodium, calcium and magnesium ions in the groundwater. Chloro-alkaline indices value for groundwater in study area recorded as negative, which indicates that major possibilities of higher concentration of ion in groundwater due to base exchange of ion with bed rock and soil. From all the indices value for irrigation use indicates majority of the groundwater samples were fit for agriculture use and few sample locations were highly contaminated due to interaction with rock strata, anthropogenic activities like municipal waste disposal, higher consumption of fertilizers and pesticides for crop yield. The present study will be helpful for future researcher to evaluate and predict the characteristic of groundwater in Omalurtaluk, Salem district.

REFERENCES

Agca N, Karanlik S and Odemis B 2014. Assessment of ammonium, nitrate, phosphate, and heavy metal pollution in groundwater from Amik Plain, Southern Turkey. *Environmental Monitoring and Assessment* **186**(9): 5921-5934.

Al-HarbiM, Al-RuwaihFM and Alsulaili A 2014. Statistical and analytical evaluation of groundwater quality in Al-Rawdhatain field. *Environmental Progress and Sustainable Energy* **33**(3): 895–904.

Behera B and Das M 2018. Application of multivariate statistical techniques for the characterization of groundwater quality of Bacheli and Kirandul area, Dantewada district, Chattisgarh. *Journal of the Geological Society of India* **91**(1): 76-80.

Bouderbala A 2017. Assessment of water quality index for the groundwater in the upper Cheliff plain, Algeria. *Journal of the Geological Society of India* **90**(3): 347-356.

Chaurasia AK, Pandey HK, Tiwari SK, Prakash R, Pandey P and Ram A 2018. Groundwater quality assessment using Water Quality Index (WQI) in parts of Varanasi District, Uttar Pradesh, India. *Journal of the Geological Society of India* **92**(1): 76-82.

Doneen LD 1964. Water quality for agriculture, Department of Irrigation, University of Calfornia, Davis: p 48.

Kant N, Singh PK and Kumar B 2018. Hydrogeochemical characterization and groundwater quality of Jamshedpur Urban Agglomeration in Precambrian Terrain, Eastern India. *Journal of the Geological Society of India* **92**(1): 67-75.

Khan R and Jhariya DC 2017. Groundwater quality assessment for drinking purpose in Raipur city, Chhattisgarh using water quality index and geographic information system. *Journal of*

the Geological Society of India **90**(1): 69-76.

Li P, He S, He X and Tian R 2017. Seasonal hydrochemical characterization and groundwater quality delineation based on matter element extension analysis in a paper wastewater irrigation area, Northwest China. *Exposure and Health* 1-18.

Mahato MK, Singh PK and Tiwari AK 2016. Hydrogeochemical evaluation of groundwater quality and seasonal variation in East Bokaro coalfield region, Jharkhand. *Journal of the Geological Society of India* **88**(2): 173-184.

Nageswara Rao PV, Appa Rao S and Subba Rao N 2015. Suitability of groundwater quality for drinking, irrigation and industrial purposes in the Western Delta Region of the River Godavari, Andhra Pradesh. *Journal of the Geological Society of India* **86**(2): 181-190.

Nagaraju A, Kumar KS and Thejaswi A 2014. Assessment of groundwater quality for irrigation : A case study from Bandalamottu lead mining area, Guntur District, Andhra Pradesh , South India. *Applied Water Science* **4**: 385–396.

Pazand K, Khosravi D and Reza M 2018. Groundwater for sustainable development identification of the hydrogeochemical processes and assessment of groundwater in a semi-arid region using major ion chemistry : A case study of Ardestan basin in Central Iran. *Groundwater for Sustainable*

Development **6**: 245-254.

Sharma AK and Shuklar J 2015. A remote sensing and GIS based approach to evaluate the ground water prospects of Baghain watershed, Panna and Satna districts of M.P, India : A case study. *Journal of Geologic Society of India* **86**: 733-741.

Sankaran S Sundararajan N and Khadija S 2015. Geochemical analysis of groundwater samples in the vicinity of lakes and drainage network. *Journal of the Geological Society of India* **86**(4): 459-467.

Singh A, Kumar A, Andotra U and Dass B 2018. Groundwater for sustainable development geoinformatics based groundwater quality assessment for domestic and irrigation uses of the Western Doon valley, Uttarakhand, India. *Groundwater for Sustainable Development* **6**: 200-212.

Tiwari K, Goyal R, Sarkar A, Selvakumar S, Ramkumar K, Chandrasekar N and Sarkar S 2017. Seasonal hydrochemical characterization and groundwater quality delineation based on matter element extension analysis in a paper wastewater irrigation area, Northwest China. *Journal of the Geological Society of India* **86**(1): 1-18.

Wilcox LV 1948. *The Quality of Water for Irrigation Uses*. US Department of Agricultural Technical Bulletin, Washington, p 9.

Spatio-temporal Salinity and Mapping of Irrigated Perimeter of Abadla Bechar, SW Algeria

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Abstract: The present study evaluated the spatial variability of soil salinity. This variability was used in the frame of a non-parametric geostatistical interpolation method in order to assess the risk of the soil salinity. A study on a 580 ha field located in the eastern region of Abadla, Sud-West of Algeria,238 soil samples were taken from irrigated fieldsat depth of 0.60 cm (the root layer). The statistical analysis showed a high spatial variability with significant differences throughout the experimental field on the parameters, EC, ESP and PH. The EC variogram increased up to distance of 1.22 km or reaches a plateau of 1395 ms /cm, the nugget effect of the order of 120 ms /cm, is small that it represents 8.5% . The pH increased up to a distance of 0.448 km corresponding to a plateau of 1.952. The effect of nugget of 0.256 represented 13.11%. The ESP at a range of 0.42 km, a nugget of 83.3 and a nugget effect of 0.3, weak as compared 0.36% of the landing. The structure and the permeability caused a reduction of the speed of infiltration of waters.

Keywords: Soil salinity, Irrigated perimeter, Abadla, Algeria

Salinity is one of the major causes of soil degradation worldwide, but to varying degrees. The arid and semi-arid regions are the most degraded compared to wetlands, due to high levels of salinity. The quality of the irrigation water and the method of drainage over hostile climatic conditions play a major role, which has led to a significant accumulation of salts (Genxiang et al 2017), so excessive exploitation can also create problems of salinity (Alavi et al 2008), which results in a static lowering of the water table (Dubost 2002, Cote 2005, Senoussi et al 2011). This result in low fertility and profitability, which prevent economic and social development, for sustainable production (Ildefonso PlaSentís 2014).One of the main causes of salinity, the irrational exploitation of irrigation water and failure of the application of scientific standards for irrigation (CengizKoç 2008). Despite the accumulation of salts vary depending on the quality of the water and the type of soil are not clear (Mathias et al 2018) and even as the accumulation of salts has limited the efficiency of irrigation systems. For these reasons, most studies conducted by researchers (Madero et al 2004, Aragüés et al 2011, Mohammad et al 2017) aimed at preventing deterioration and degradation of soils and maintain its constituents. In addition to the development of irrigation systems, the objective of this study is the establishment of a digital database and analysis to redevelop lands

MATERIAL AND METHODS

Study area: The area is located in South-west of Algeria, in geographical coordinate between north longitudes 31° 01' 00"and 02° 44' 00" west latitude, intersected by the Oran-Béchar -Tindouf road which divides it into two parts. In the north, or upstream of the road, the little widened valley is 5 km long and 2 km wide. It represents the perimeter of irrigation to be developed in the first place. To the south, or downstream of the road, the valley widens up to 15 km. This second part will not be irrigated in this first stage, but will receive directed floods. The dam of Djorf Torba under construction and several kilometers will be responsible for retaining the water of Guir, regularize supply of water to the irrigated area (part lower of the plain). The protected area is located in a desert zone where temperatures are very high due to hot summers whose maximum reached 40°C. Minimum temperatures do not fall below 5°C in winter. The annual average is 29.08 mm and rarely exceeds 100mm. Rainfall is concentrated in winter and spring. These values reflect the desert character of the climate. The aridity indices of DeMartonnesignifies the hyper-aridity of the region and almost permanent drought .

Data collection: The soil samples were collected by square mesh sampling from 240 sampling locations covering the entire experimental field (Fig. 1). The GPS receiver was used to locate the sampling points in the field during December 12, 2017 to January 15, 2018. Soil samples were collected at a depth of 60 cm (root layer) and analyzed for conductivity (EC), soil pH and physicochemical parameters (Cl-, Na$^+$ and Ca^{2+} + Mg^{2+}). Soil samples were dried in the open air and
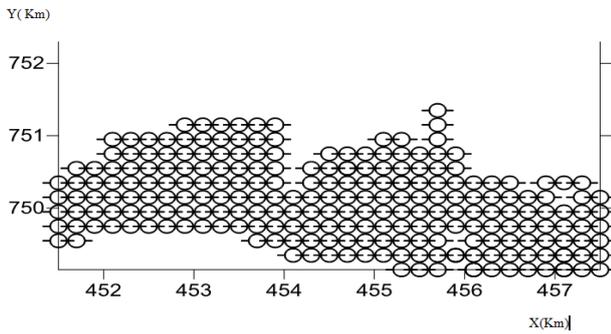
Fig.1. Sampling plan

sieved using a 2 mm square mesh sieve (Standard AFNOR). The chemical analyses will be carried out on the fraction of elements smaller than 2mm.

Physical parameters: 200 gm of dry soil screened to 2mm in a 100ml plastic box and saturated paste was prepared by gradually adding distilled water to moisten the soil till dough becomes shiny and was kept for 12 hours to allow the diffusion of soluble soils. After rest of 12 hours, the paste is put in a device connected to vacuum pump that makes the filtration of the soil solution. By using a centrifuge the saturated extract was obtained, according to the method recommended by the laboratory of Riverside (US Salinity Laboratory Staff 1954). Electrical conductivity was measured by conductivity meter and were corrected to the same temperature scale (25 °C).

Chemical parameters: The analysis of sum of $[Ca^{2+} + Mg^{2+}]$ were performed with an automatic titrator (Titrando 809, Metrohm), Ion Selective Calcium Electrode (ISE-Ca) and reference electrode Ag/AgCl (saturated KNO_3 electrolyte bridge) to titrate a solution containing 10 mL KCl 1 mol L-1 (blank) or soil extract, 0.5 mL magnesium sulfate heptahydrate $(MgSO_4.7H_2O)$ and calcium chloride dihydrate $(CaCl_2.2H_2O)$ solutions, all at a concentration of 0.0125 mol L^{-1}, as well as 4 mL ammonia buffer solution pH = 10.0 (aqueous solution containing 60 % of NH_4OH and 1.26 mol L^- ^{1} NH4Cl) and 50 mL of deionized water. The dynamic titration was performed by automatic dispenser (Dosino 800, Metrohm) with a solution of Ethylenediaminetetraacetic Acid disodium salt (EDTA-Na_2) 0,0125 mol L^{-1}, at a dose rate of 5 mL min^{-1} and a sign of deviation of 20 mV min^{-1} was established. The cation Na+ was determined by flame photometry spectroscopy, and the anion Cl^- is measured by the MOHR method known as "argentometry", chlorine is precipitated by silver nitrate titrated in the presence of chromate. The SO_4^{2-} ions of each soil paste extract are precipitated as $BaSO_4$ by adding a solution of barium chlorideBaCl$_2$. The reaction takes place in a slightly acidified environment. The SO_4^{2-} concentrations of the different

solutions are measured using a spectrophotometer whose calibration curve was first performed. The sodium adsorption ratio (SAR) was calculated with analysis results of the Na+, Ca^{2+}, and Mg^{2+}. In the following equation the values of the ions are equivalent concentrations for calculating the

$$SAR = \frac{Na^+}{\sqrt{\dfrac{Ca^{2+} + Mg^{2+}}{2}}}$$

The exchangeable sodium percentage (ESP) is calculated with the exchangeable cations of the soil. ESP is the percentage for the exchangeable sodium of the cation exchange capacity as the follow equation:

ESP= 1.02 *SAR+1.71 (Loi de DAOUDE)

Geostatistical analysis: The collected soil physicochemical data (EC, pH, Cl-, Na+ and $Ca^{2+} + Mg^{2+}$) were assigned to geo-coordinates and exported to a SURFER domain (SURFER32 software, 2010geostatistical analysis). The longitude and latitude of each sampled location were designated with the variables x and y, respectively. Program geostatistical software (gamma design software) was used to construct semi-variograms and to address spatial structural analysis for variables. The maps obtained by KRIGEAGE describe the main trends of variation of CE, PH, and ESP. They make it possible to detect areas where observations are generally strong or weak.

Statistical methods: The geostatistical analysis was done as described method as described by Vieira et al (1983).

$$Y(h) = \frac{1}{2N(h)} \sum_{i=1}^{N} [Z(xi) - Z(xi + h)]^2$$

Where N (h) is the number of value pairs Z (xi), Z (xi + h) separated by a vector h. If the semi-variogram increases with distance and stabilizes at the a priori variance value, this means that all neighbours in the correlation range can be used to interpolate unmeasured values and that the studied variable is spatially correlated. To measure the semivariograms can be divided each semivariance value by a constant such as the variance value and the square of the mean (Vieira et al 1997). The application of equation to calculate the semivariograms shows a set of discrete values as well as the corresponding semivariance distances. Because any geostatistical calculation will require semivariance for any distance within the intervention zone. It is necessary to apply the mathematical domain to describe the model adjustment process and the cross adjustment process (Vieira 2000). The semivariograms used were all adjusted to the spherical scale.

model Spherical: Y(h) = C_0 +C [1.5 (h /a) - 0.5 (h /a)^3]if h≤a

$$Y(h) = C_0 + C \ \text{if} \ H > a$$

Where C_0 is the nugget effect, C is the structural variance and a the range of spatial dependence. These are the three parameters used in the semivariogram model fitting. Models were fit using least squares minimization and judgement of the coefficient of determination. Using the values interpolated by the kriging method, contour or tri-dimensional maps can be precisely built, examined and compared for each of the crop yield and soil properties variables (Sidney and Antonio 2003).

RESULTS AND DISCUSSION

Irrigation water: The EC of irrigation water from the Djorf Torba dam ranged between 2.04 and 2.35 ms/cm. According to Riverside International Standards (USSL 1954), the high salinity of the water carries a high risk (class C3) and will prohibit its use on certain soils and normally unusable for irrigation (Hegui et al 2017), because the use can lead to negative consequences on soil properties such as high soil alkalinity and degradation of agricultural soils (Kathrin et al 2017).

Spatial variability and mapping of saline soils: The salinity of soil varies from 1.98 to 177.78 ms / cm, which expresses a very serious salinity, exceeds the global standards, due to the excessive presence of soluble salts i.e. more soluble gypsum and/or a high level of exchangeable sodium. This results in unfavorable physical, chemical and biological properties. The pH range from 6.17 to 9.01,rarely above 8.5, the type of soil is alkaline saline. The pH between 8 and 9. The spatial behavior of the soil EC, pH and ESP parameters was assessed using their semivariograms and adapted models (Table 2 and Fig. 2 to 4). The variogram is increased up to a distance of 1.22 km or reaches a plateau of 1395 (ms /cm). The nugget effect of the order of 120 (ms / cm) is small that it represents 8.5% of the value reached at the level andfor the pH, the variogram is increased up to a distance of 0.448 Km corresponding to a plateau of 1.952. The effect of nugget of 0.256 representing 13.11%.The ESP variogram at a range of 0.42 Km, a nugget of 83.3 and a nugget effect of 0.3, weak then that it represents 0.36% of the landing.
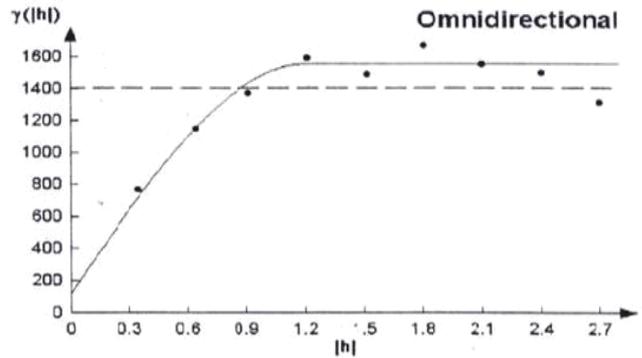
Fig. 2. Semivariogram for the EC
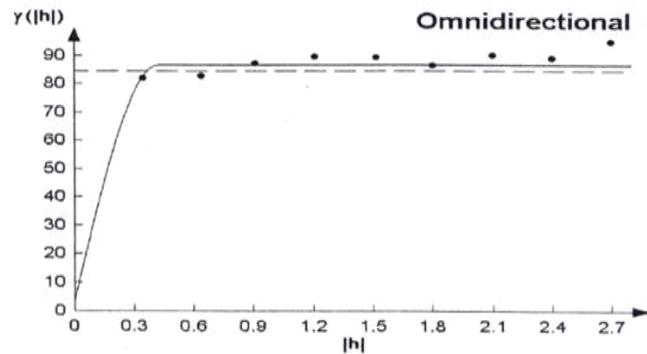
Fig. 3. Semivariogramforthe percent exchangeable sodium(ESP)
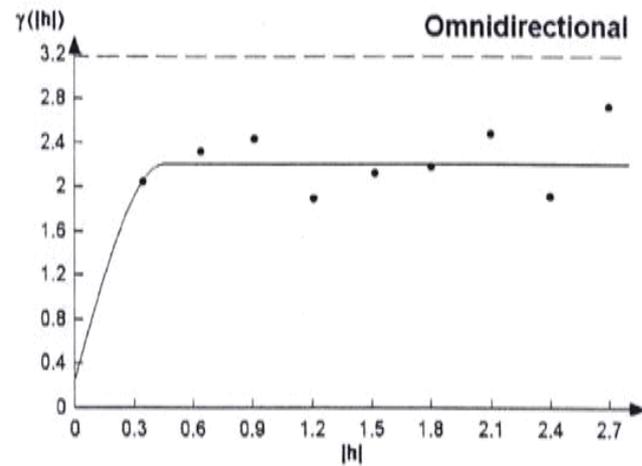
Fig. 4. Semivariogram for the pH

Table 1. Descriptive statistics of the measured soil physicochemical properties

Description	EC(ms /cm)	Na+ (mg/l)	Ca2+ + Mg2+ (mg/l)	SAR	ESP (%)	pH
Minimum	1.98	2.43	0.28	0.89	2.61	6.03
Maximum	177.78	67.82	52	91.1	94.63	9.01
Mean	44.41	12.46	7.86	08.10	10.03	7.50
Standard deviation (SD)	37.57	10.03	8.24	08.72	9.01	0.63
CV, %	0.84	0.80	1.04	1.07	0.89	1.08
Skewness	0.64	1.67	2.67	5.29	5.15	0.37

Krigeage maps: Based on this threshold, an indicator variable was created taking either (ECE≤4 dS m^{-1}) or (ECE> 4 dS m^{-1}). The iso conductivity map shows a general trend towards northwest, which indicates the increase of salinity (Fig.5). The soil near the oued Guir is less salty, the only resemblance observed for this map is the increase in salinity as a function of the topography of soil. The slope of the

Type of soil	EC	ESP	pH
Alkaline saline soils	>4,5	> 4,5	> 8,5 rarely above 8.5
Alkaline soils	<4,5	> 15	8,5 à 10

irrigation canals explains the accumulation of salts in the Northwest and center of the zone and the particle size and geomorphology of the terrain. Concerning the pH map, there
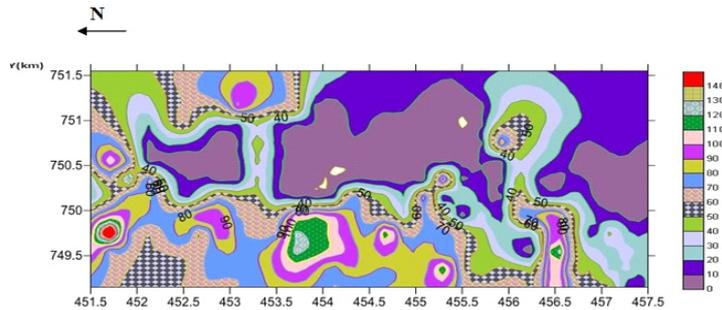
Fig. 5. Map of the salinity of the irrigated perimeter D'ABADLA
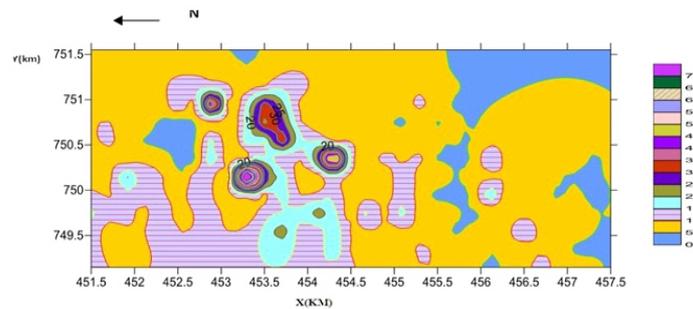
Fig. 6. Map of Percent Exchangeable Sodium (ESP)
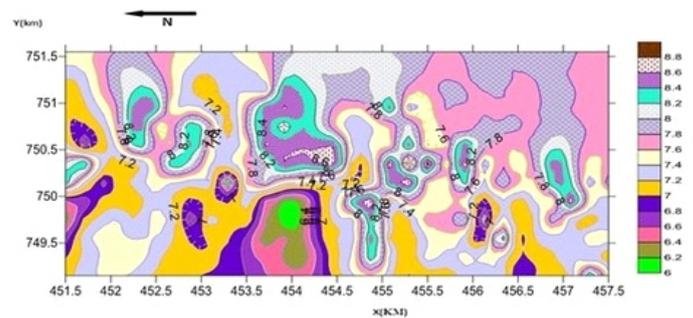
Fig. 7. Map of PH
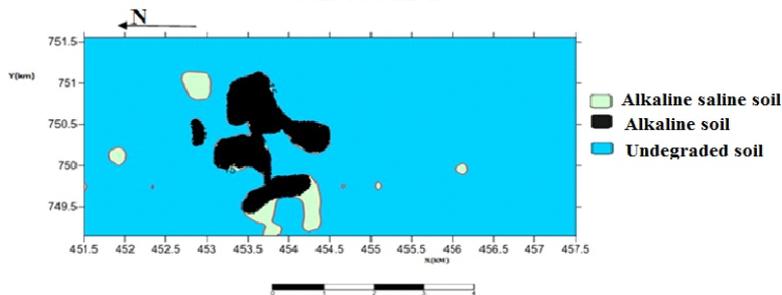
Fig. 8. Map of degraded soil

Table 2. Parameters for semi-variogram spherical models for some of the chemical properties and soil alkalinity

Data	Fitted model	Model parameter			Definition of the model
		C_0	C	A	
EC	Spherical	120	1320	1.22	$20+1320 [1.5 (h /1.22) - 0.5 (h /1.22)^3]$
PH	Spherical	0.256	1.696	0.448	$0.256+1,696 [1.5 (h /0.448) - 0.5 (h /0.448)^3]$
ESP	Spherical	0.33	82.67	0.42	$0.33+82.67 [1.5 (h /0.42) - 0.5 (h /0.42)^3]$

is a discontinuity of the contours (Fig. 7). There was general assessment towards the south - east of the zone, with values following the direction of transects north-east to south. The ESP map shows a general evolution towards the North (Fig. 6) with values in the center of the area. For the classification of soils of the alkaline the American classification was used (USSL 1954).

Saline-alkaline soils and alkaline soils account for less than 10% of the soil in the study area (Fig. 8). As regards the alkaline soil the ESP and the pH to describe the degree of alkalinity with limit of IT. For classification of the alkaline soil, it is necessary to limit class of ESP because exchangeable Na, destroyed and degraded the structure from a threshold which is fixed to 15 % of CEC. Soils with high alkalinity are the ones of which the average ESP is upper to 20 %. In the majority of the cases, the ESP is between 5-20 % (modern Alkalinity) is to smolder a large surface. But the higher values are not rare.

CONCLUSION

The soil salinity can be estimated well using geostatistical tools to identify the spatio-temporal variability of soil salinity with both field and laboratory measurements and as a good auxiliary variable in the spatial estimation and mapping salinity in irrigated land. Low to moderate spatial variability in soil physic chemical properties was observed across the experimental field. The four soil properties that showed a considerable degree of variation were SAR, ESP, pH and soil EC. The semivariograms showed a high spatial variability with significant differences throughout the experimental field on the parameters, EC, ESP and PH.

REFERENCES

Alavi PSK, Goossens R, Matinfar HR, Mohamadi H, Ghadiri M, Irannegad H and Alikhah Aslm 2008. The efficiency of landsat TM and ETM+Thermal data for extracting soil information in arid regions. *Journal of Agricultural Science and Technology* **10**: 439-460.

Aragüés R, Urdanoz V, Çetin V, Kirda C, Daghari H, Ltifi WL and Douaik M 2011. Soil salinity related to physical soil characteristics and irrigation management in four Mediterranean irrigation districts. *Agricultural Water Management* **98**(6): 959-966.

Bowers CA and Wilcox LV 1965. Soluble salts. In: Black CA (ed).*Methods of Soil Analysis,* Monograph 9. American Society of Agronomy, Madison. pp. 933–951.

CengizKoç 2008. The influence of drainage projects on environmental and wetland ecology. *Environmental Progress* **27**(3): 353-364.

Côté M 2005*. The city and the desert*. The Algerian Bas-Sahara. Karthala (Publisher). Paris, France. 307 P.

CPSM 1967. Commission of pedology and soil mapping. National Institute of Agricultural Research (NIAR). Paris: Geology and Pedology Laboratory of NHAS, 87p

Dubost D 2002. *Ecology, planning and development of Algerian oases.* Center for Scientific and Technical Research on Arid Regions (C.R.S.T.R.A). Biskra, Algeria, 423 p.

Genxiang F, Zhanyu Z, Changyu W, Peirong L and Ahmad B 2017. Effects of saline water irrigation on soil salinity and yield of summer maize (*Zea mays* L.) in subsurface drainage system. *Agricultural Water Management* **193**: 205-213.

Hegui H, Mohamed N and Cherif R 2017. Laboratory experiments and mathematical model were conducted to investigate the effects of overexploitation water irrigation quality in Lahmaroasis in Bechar, Algeria. *Ecology, Environment and Conservation* **23**(3): 138-141.

Ildefonso P 2014. Advances in the prognosis of soil sodicity under dryland irrigated conditions. *International Soil and Water Conservation Research* **2**(1): 50-63.

Kathrin S, Juliane D, Désiré JPL and Andreas B 2017. Effects of waste water irrigation on soil properties and soil fauna of spinach fields in a West African urban vegetable production system. *Environmental Pollution* **222**(1): 58-63.

Mathias M, Hussain S, Stephen RG and Bruce AL 2018. Spatio-temporal salinity dynamics and yield response of rice in water-seeded rice fields. *Agricultural Water Management* **195**(1): 37-46.

Madero E, Malagón D and García A 2004. Una mirada al origen y las propiedades de los suelosmagnésicos en el Valle del Cauca- Colombia. *Acta Agronómica* **53**(3): 1-21.

Maas EV and Grattan SR 1999. Crop Yields as Affected by Salinity pp. 55-108. In: R. W. Skaggs and J. van Schilfgaarde (Eds). *Agricultural Drainage*, Publisher: American Society of Agronomy.

Mohammad AB, Grewal MS, Dinesh, Inderpal S and Grewal KS 2017. Geoinformatics for quantifying salt affected soils in Gohana, Haryana using soil techniques. *International Journal of Current Microbiology and Applied Sciences* **6**(9): 835-858.

Senoussi A, Bensania M, Moulaye S and Telli N 2011. A multisecular hydraulic system in decline. *Bio Resources Review* **1**(1): 47-54.

Sidney RV and Antonio PG 2003. Analysis of the spatial variability of crop yield and soil properties in small agricultural plots. *Bragantia, Campinas* **62**(1): 127-138.

USSL 1954. *Salinity Laboratory: Diagnosis and improvement of saline alkali soil*. U.S.S.L U: SDA. Hand books- no 60. Washgton, 160p.

Vieira SR, Nielsen DR , Biggar JW and Tillotson PM 1997. The scaling of semivariograms and the kriging estimation. *Revista Brasileira de Ciência do Solo* **21**(4): 525-533.

Assessment of Tannery Wastewater Based on OLR using Anaerobic cum Aerobic Sequential Batch Reactor (SAAR)

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Abstract: The usage of aerobic cum anaerobic process can produce more efficiency rather than single biological process. The lab-scale setup of up-flow sequential aerobic-anaerobic batch reactor with anaerobic granular media followed by aerated packed polyhedral polypropylene spherical balls is used. The chemical oxygen demand removal efficiency was achieved 75% by maintaining organic loading rate of 1kg of COD/m^3d with constant hydraulic retention time of 20 hours and gas production of 1.42L. The achievement of the reactor is adjourned by ambit like chemical oxygen demand, pH, alkalinity, volatile fatty acids.

Keywords: Organic loading rate, HRT, Sequential Aerobic-Anaerobic batch reactor, COD, Tannery waste water

The industrialization in the developing countries like India generates pollution problems on discharging the industrial effluents. The direct discharge of effluents from the industries leads to contamination of natural resource that supports the life on earth. One such prospective threatening industry is the tannery leather processing industry and this leads to serious issues like hindrance in agriculture, irritation to skin of human beings and animals, odourness is due to nitrogen, sulfur components and Cr_3^+ accumulation in aquatic life etc. The principal reason for pollution by the leather processing industry is utilization of chemicals like slaked lime, sodium sulfide, hydrochloric acid, sulfuric acid, chromium sulfate, chromium chloride etc for soaking, derailing and liming, declaiming and bating, pickling, tanning and finishing. These pollutants results in DO reduction in water bodies, bio magnifications of chromium and algal bloom. The discharge of nitrogenous compounds without treatment leads to eutrophication (Leta 2004). In this study a lab-scale sequential anaerobic aerobic bioflim based reactor is used for the effective treatment of tannery wastewater which shows combined effect on chemical oxygen demand removal over single column. The main objective of the study is to reduce the COD level and asses the performance of the tannery effluent by aerobic and anaerobic treatment using sequential Anaerobic cum Aerobic biofilm based batch reactor with variations in organic loading rate.

MATERIAL AND METHODS

A laboratory scale up-flow sequential anaerobic-aerobic biofilm based reactor was set up with the total volume of 7.7l.

(Prabhu et al 2017). The reactor was designed with internal diameter of 100mm and a height of 1500cm (Fig. 2). The effective volume of the reactor is 6.5land the reactor is separated as anaerobic zone of 40 cm packed by granular media of 20 cm depth and aerobic zone is 40 cm depth packed by polyhedral polypropylene media of 25 cm depth. Effluent ports are provided for sample accumulating and hoods are provided at the top and the basal of the reactor for gas discharge and carrion accession respectively. Anaerobic channel (AF) is comprised of at least one vertical channel beds containing some dormant material, (rocks, or plastic media, which go about as a stationary help surface for microbial film connection. AFs were accounted for good appended development elective process for treatment of high-quality wastewaters (Masse2000). For the most part, wastewaters are drawn upward through the help media permitting contact between the connected micro-organisms and the wastewater. Microbial development additionally happens in the voids between the help media. This sort of framework tends to allow a satisfactory solids maintenance time (SRT) for the methane creating microscopic organisms (Switzenbaum 1983). The aeration inlet port is provided just above the granular media at rate of 3.2l/min which is connected to the aerator pump. The gas collected was measured by downward displacement of water (Yue Zhang et al 2009).

The sample was collected from the three effluent ports for every 20 hours of HRT, and continuous feeding of tannery wastewater is given for the fixed flow rate and following parameters like COD, pH, Alkalinity, VFA were analyzed. The

Table 1. Specification of polypropylene polyhedral spherical media

Particulars	Result
Diameter	36mm
Weight	4.41 g/piece
Height	30mm
Specific surface area	$365 m^2/m^3$
Specific gravity	0.92

Fig. 1. Photograph of the polypropylene hexagonal inert media (for packing media)

parameter analysis is done by standard APHA method.

Operation of the SAAR: Organic loading rate in anaerobic procedures vary from 1 to 50 kg COD (chemical oxygen demand/m^3day), whereas run of the mill OLRs utilized for high-impact forms shift from 0.5 to 3.2 kg COD/m3day (Metcalf And Eddy 2014). In the present study the OLR is fixed as 1 kg of cod/m3/d and HRT is maintained as constant of 20 hours. The parameters analyzed were pH, alkalinity, volatile fatty acids and the performance was monitored by measuring COD removal, volatile fatty acids, alkalinity, pH, gas collection. The reactor was operated at the organic loading rate of 1kg of cod/m^3/d with 20 hours HRT. The aeration takes place continuously at rate of 3.4l/min. The start-up of the reactor is done using appropriate mixing of rumen liquid of goat, cow-dung and tannery waste water. The achievement of the pilot calibration anaerobic sequence batch reactor was evaluated at OLR of 1.03, 1.23, 1.52 and 2.21 kg/m^3/d the COD abatement ability was acquired as 68% (Mekonnen et al 2017).

RESULTS AND DISCUSSION

Cod removal efficiency: The removal of COD is about 75% on third effluent port and steady state was attained in the reactor at about 30th days. The port 1 shows about 75% removal efficiency while the port 2 and 3 shows 71 and 65% respectively (Fig. 3). The operation showed that the COD removal efficiency was higher at effluent port 2 and port 3 when compared to the anaerobic zone of port1.Various anaerobic and aerobic systems works has been compared with combined anaerobic cum aerobic used for the removal of COD. The maximum of 60% of COD has been achieved using raw tannery wastewater reported by (Preethi et al 2009), in the other work pre-alkalized tannery wastewater has been used and maximum removal of COD from 30 to 70% was achieved by Houshya et al (2012) and 70% of maximum COD removal of raw tannery wastewater by Kurt et al (2007) while compare with above few studies the present work based on combined anaerobic cum aerobic gives the maximum removal of COD 75%.

Alkalinity: There is an increase in alkalinity up to 4600 mg/l as $CaCo_3$ and the increase in alkalinity is essential for the neutralization of VFA generated during the process. This guarantee bicarbonate alkalinity ought to be kept in the scope
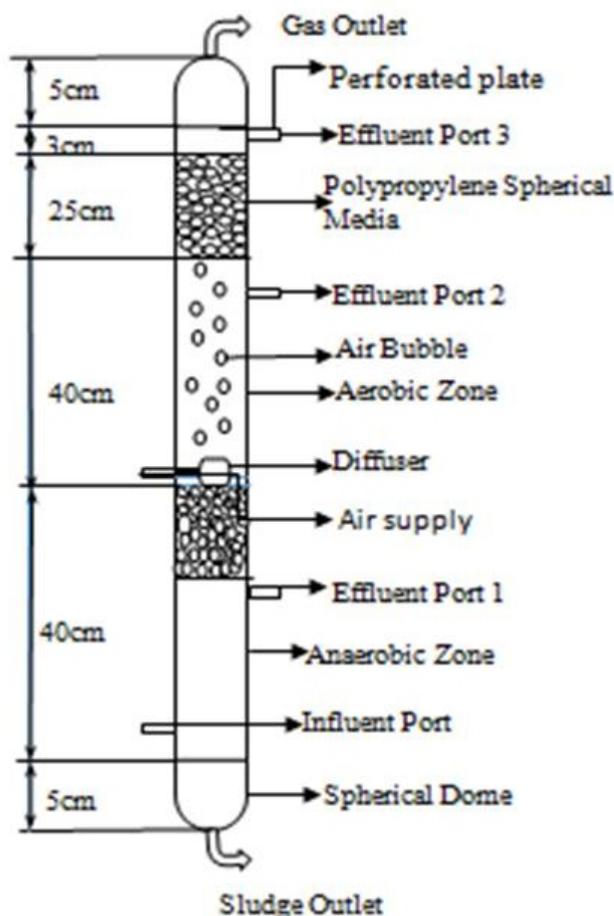
Fig. 2. Schematic representation of sequential anaerobic-aerobic batch reactor

of 2500– 5000 mg l^{-1} (Fig. 4). The subsequent cradle limit is sufficient to deal with the effect of unpredictable unsaturated fat development. Bicarbonate is typically utilized to control alkalinity and pH in anaerobic reactors (Tauseef et al 2013) for the maintenance of fruitful biological activity there must be sufficient alkalinity to neutralize acids generated during the treatment.

Variation pH: The pH varied between of 7.1 to 8.6 indicating the degradation of micro organisms. The microorganisms that play vital role in wastewater treatment are highly efficacious at pH of 6 to 8.3 (Erlon Lopes Pereira et al 2013).The pH must not be permitted to fall beneath 6.2 (Fig. 5) as it obstructs the methanogenic microorganisms (Tauseef et al 2013*)*.

Volatile fatty acids: Fatty acids varied between 3000 to 2400mg (Fig.6) and as fatty acid produced from microbial action is responsible for the biodegradation process of

organic compounds. They are the important compounds in the metabolic pathway of methane fermentation and causes microbial stress if present in high concentrations *(*SpellMan 2009 and Grady et al 2011*)*.

Cumulative gas production: The reduction in VFA and gas production starts at 11th day onwards, it slightly increase in the 13th day and gradually increased and it reaches the highest value on the 29 day at a capacity of 1420 ml (Fig.7) due to decrease in Volatile Fatty Acids on the same day.

Variation in VFA and Alkalinity Ratio: The value of VFA and alkalinity ratio ranges from 0.82 to 0.43 (Fig. 8). The VFA 0.82 at day 1 gradually decrease and it ends on 0.43 on day 29. Due to presence of anaerobic micro organisms, it causes the significant amount of buffering capacity in the port and increases the gas production in the outlet. On day 8, 17, 20, it was slightly increased and suddenly decreased on next day.

Fig. 3. Performance curve of SAAB reactor for variations in COD removal for 1kg/m^3/d OLR

Fig. 4. Performance curve of SAAB reactor for variations in Alkalinity for 1kg/m^3/d OLR
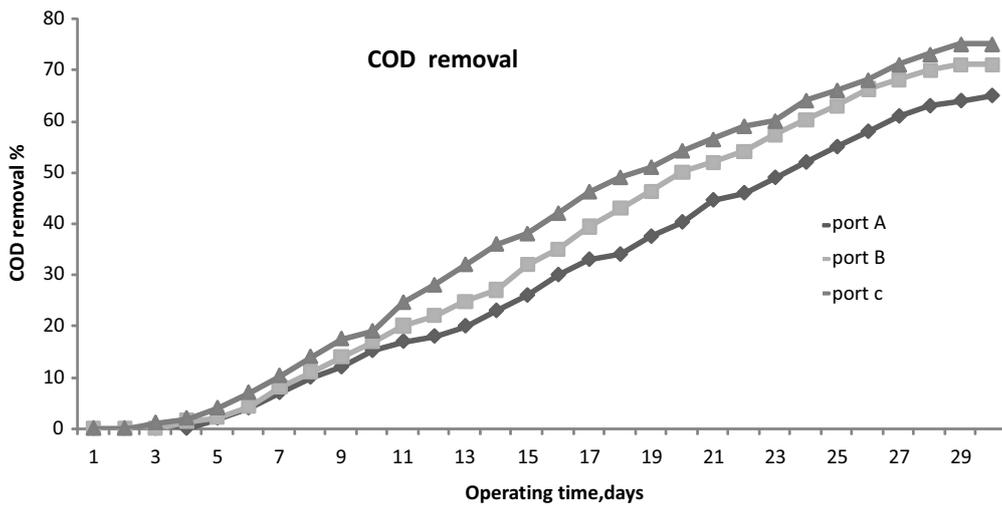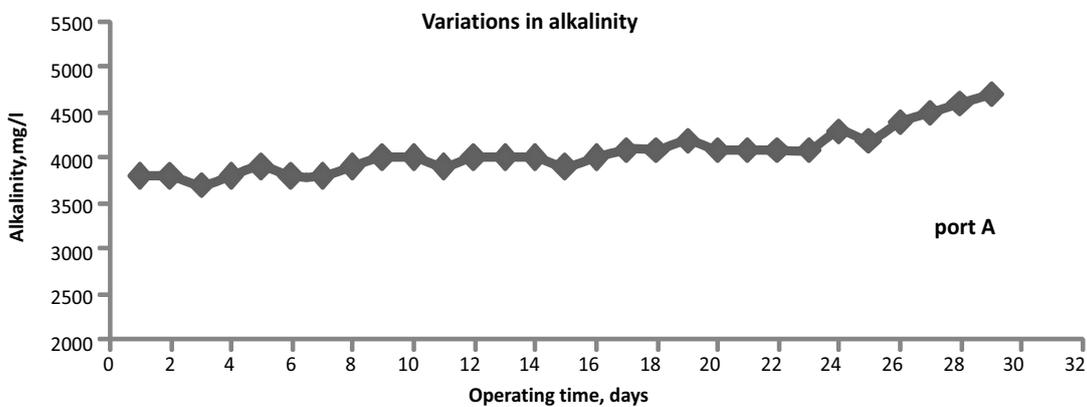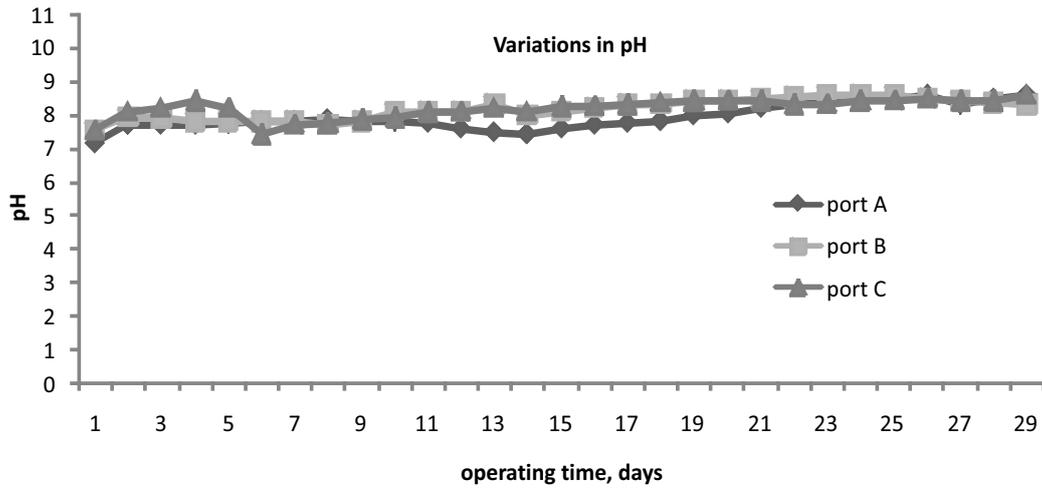
P. Prabhu and S. Ramesh

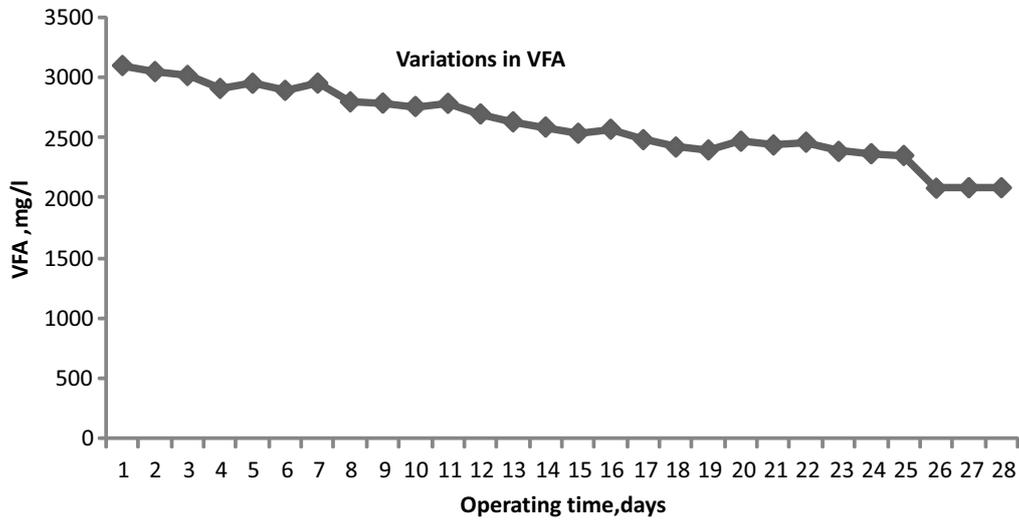**Fig. 5.** Performance curve of SAAB reactor for variations in pH for 1kg/m³/d OLR

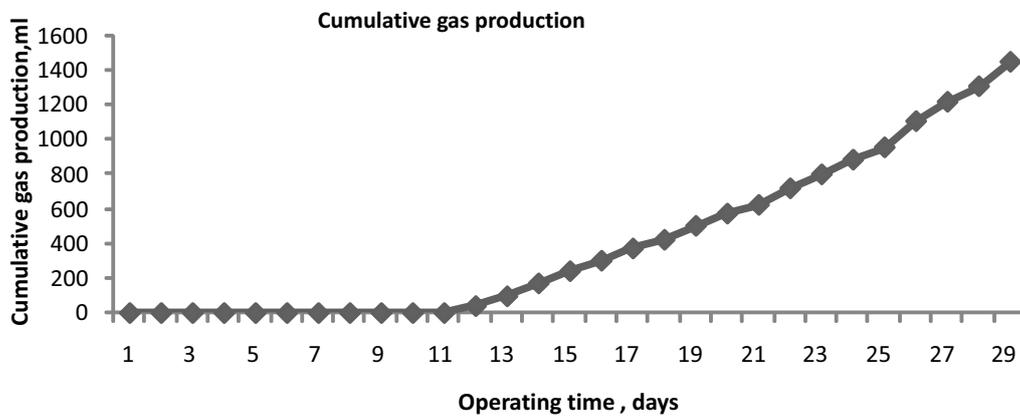**Fig. 6.** Performance curve of SAAB reactor for variations in VFA for 1kg/m³/d OLR

Fig. 7. Performance curve of SAAB reactor for cumulative gas production for 1kg/m³/d OLR
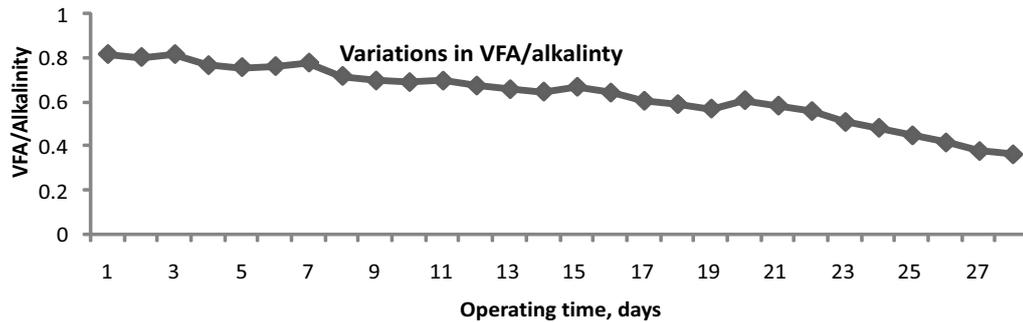
Fig. 8. Performance curve of SAAB reactor for variations in VFA/alkalinity for 1kg/m³/d OLR

It represents the concentration of anaerobic micro organisms re growth in the port.

CONCLUSION

The SAAB reactor is appropriate in treating tannery wastewater. The performance assessment of treatment of tannery wastewater based on 1kg of cod/m³/d of organic loading rate using the sequential anaerobic cum aerobic biofilm based batch reactor showed the COD removal of about 75,71, 65% at 3,2,1 port. There is a high correlation between VFA and Alkalinity. The reactor yields a most extreme gas generation of 1.42l in the whole time of activity and the polypropylene polyhedral round balls are fittingly appropriate as pressing material in the bio film zone of SAAB reactor.

REFERENCES

Adav SS, Lee DJ and Lai 2009. Functional consortium from aerobic granules under high organic loading rates. *Bioresource Technol*olgy **100**(14): 3465-3470.

Ahammad SZ, Bereslawski JL, Dolfing J, Mota C and Graham DW 2013. Anaerobic–aerobic sequencing bioreactors improve energy efficiency for treatment of personal care product industry wastes. *Bioresouce Technol*olgy **139**: 73-79.

APHA 2017. *Standard Methods for the Examination of Water and Wastewater*. American Public Health Association.

Andualem Mekonnena, Seyoum Letaa and Karoli Nicholas Njaub 2017. Anaerobic treatment of tannery wastewater using ASBR for methane recovery and greenhouse gas emission mitigation. *Journal of Water Processing Engineering* **19**: 231-238.

Baloch MI and Akunna JC 2002. Simultaneous denitrifiction and Anarobic digestion in Granular Bed Baffled Reactor. *ASCE Environmental Engineering Conference,* 24 July 2002.

Bernet N, Delgenes N and Akunna C 2000. Combined Anaerobic-Aerobic SBR for the treatment of Piggery wastewater. *Elsevier Science* **34**: 611-661.

Chan YJ, Chong MF and Law CL 2012. An integrated anaerobic–aerobic bioreactor (IAAB) for the treatment of palm oil mill effluent: start-up and steady state performance. *Process Biochemistry* **47**: 485-495.

Clark RM and Speece RE 1971. The pH tolerance of anaerobic digestion. *Israel Journal of Zoology* **18**(1): 124-133.

Grady CPL, Daigger J, Glen T, Love NG and Filipe CDM 2011. *Biological Wastewater Treatment,* IWA Publishing, *Newyork* 295-339.

Gaspikova, Kapust S and Bodik I 2005. Evaluation of anaerobic-aerobic wastewater treatment plant operations. *Polish Journal of Environmental Studies* **14**: 29-34.

Houshyar Z, Khoshfetrat AB and Fatehifar E 2012. Influence of ozonation process on characteristics of pre-alkalized tannery effluents. *Chemical Engineering Journal* **191**: 59-65.

Kurt U, Apaydin O and Gonullu MT 2007. Reduction of COD in wastewater from an organized tannery industrial region by Electro-Fenton process. *Journal Hazard Mater* **143**: 33-40.

Liu Y and Tay JH 2004. State of the art of biogranulation technology for wastewater treatment. *Biotechnology Advance* **22**(7): 533-563.

Leta S, Assefa F and Gumaelius I 2004. Biological nitrogen and organic matter removal from tannery waste water in pilot plant operations in Ethiopia. *Environmental Biotechnology* : DOI 10.1007/s00253-004-1715-2.

Masse DI and Masse L 2000. Characterization of wastewater. *Journal of agriculture and Engineering* **42**(3): 139-146.

Metcalf and Eddy Inc 2014. *Wastewater Engineering: Treatment and Resource Recovery*. 5th ed McGraw Hill, New York.

Prabhu P, Deepakraja TG and Keerthinarayana S 2017. Design of sequential anaerobic aerobic bio filter based reactor for the treatment of tannery waste water. *International Research Journal of Engineering and Technology* **4:** 1340-1342.

Preethi V, ParamaKalyani KS, Iyappan K, Srinivasakannan C, Balasubramaniam NN and Vedaraman N 2009. Ozonation of tannery effluent for removal of cod and color. *Journal of Hazard Mater* **166**:150-154.

Spellman FR 2009. *Handbook of Water and Wastewater Treatment Plant Perations* : CRC Taylor and Francis Group, London, pp 99-117.

Switzenbaum M 1983. A comparison of the anaerobic filter and the anaerobic expanded/fluidized bed processes. *Water Science and Technology* **15** (8-9): 345-358.

Tauseef SM, Abbasi T and Abbasi SA 2013. Energy recovery from wastewaters with high-rate anaerobic digesters. *Renewable Sustainable Energy Review* **19**: 704-741.

Yi jingchan, Mei Fong Chong and Chung Lim Law 2009. A review on anaerobic-aerobic treatment of industrial and municipal wastewater. *Chemical Engineering Journal* **155**: 1-18.

Yue Zhang, Sonia Heaven and Charles Banks 2009. Potential errors in the quantitative Evaluation of biogas production in anaerobic digestion processes. *Bioresource Technology* **100**: 6339-6346.

Economic Analysis and Constraints of Irrigation by Dry Season Rice Farmers in Ikwo Local Government Area of Ebonyi State, Nigeria

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Abstract: Imperfect markets or absence of markets for irrigation in developing countries such as Nigeria, particularly Ikwo Local Government Area of Ebonyi State has undermined the level of agricultural activities going on in the area especially during the dry season. Hence, estimating the economic value that farmers place on incremental changes in demand for irrigation has become vital in the process of deciding the economic viability of new irrigation projects. The study adopted both random and purposive sampling techniques in collecting primary data from 125 rice farmers with the aid of structured questionnaire guided by interview schedule in Ikwo Local Government Area of Ebonyi State, Nigeria. The findings indicated: socio-economic, geographic, and productive factors greatly influenced the farmer's willingness to pay for irrigation. The rice farmers are willing to pay for irrigation with an average of US $19 per 2.5 ha yr^{-1}. The 85.9% of the total variation observed in willingness to pay for irrigation was sufficiently explained by the independent variables included in the regression model. Educational qualification, farming experience, farm size, distance of farm to the nearest market, access to credit, attitude towards payment for the maintenance of supply irrigation and proximity to water sources were positively correlated with willingness of rice farmers to pay for irrigation. The weak irrigation policy, lack of access to credit, water source, non-inclusion of farmers in irrigation scheme among others as the constraints to rice farmers' willingness to pay for irrigation The study therefore recommends that rice farmers should be encouraged to form cooperative society so as to access credit for establishment of small irrigation scheme for dry season rice production, government should develop workable and feasible water scheme since the farmers are willing to pay for its sustainability.

Keywords: Economic value, Demand, Dry season farming, Irrigation, Willingness to pay

Over the years, rice production in Nigeria has on the increase with an average of 300,000 tonnes in the 1990s to over 4 million tonnes in the year 2013 (FAOSTAT 2015). Even with this increase, the domestic demand of the burgeoning population has not been met. The inability of local supply to meet up with rice consumption needs of the populace has resulted in high imports of rice. The phenomenal rise in imports of 300,000 tonnes annually in recent times has continued to drain the country of about N300 million annually in foreign reserves- on the average (Uduma et al 2016). To reduce the volume of rice imports and external shocks, and stimulate local production, the Nigerian government over the years has come up with various policy and programme interventions aimed at boosting local production. Notable among these interventions were: import restrictions, tariff restriction, and inauguration of presidential taskforce on rice in 1980, inputs subsidies and ban on imports 1986-1995 (Uduma et al 2016). In 2003 the Federal Government set up the presidential initiative on rice production with the aim to become self-sufficient in rice production. The objective was to eliminate imports, generate exportable surplus and enhance food security through the production of 6 million tonnes of milled rice by the year 2005. A tariff of 100% was imposed then on rice imports (Daramola 2005) and a levy of 10%. Effort to make the nation attain self-sufficient in rice production was again renewed in 2010, culminating in the formal launch of the rice transformation strategy under the agricultural transformation agenda (ATA). The strategy was to produce more paddy and industrial grade milled rice that could compete with imported rice in the market.

Considering that Nigeria is well endowed with water and land resources for irrigation farming, utilization of these resources can close the demand supply gap of rice in the country. A considerable increase in production is essential for Nigeria to meet up with the growing demand considering its fast growing population. However, the Nigerian rice irrigation production has been left underdeveloped. Rice production generally in Nigeria is rainfed, as only about 293,000 ha is equipped for irrigation and only about 218,800 ha is being actually irrigated with about 173,000 ha under private small scale while 29,000 ha is under public irrigation scheme (FAO 2005, Uduma et al 2016). Though Nigeria has not attained self-sufficiency as desired but a significant decrease has been made in rice imports (Uduma et al 2016). Therefore, achievement of this objective is dependent on adequate allocation of water to agriculture and the willingness of the

beneficiaries – farmers to pay for the resource. Kadigi (2006) argued that irrigated agriculture, which consumes about 50 to 70% of global water resources, constitutes a driving force for both food productivity and agricultural income. Water is an important input used in increasing rice productivity, with yields from irrigated rice being consistently higher than rainfed rice.

Ikwo Local Government Area of Ebonyi State is one the ecological areas well suitable for rice production in Nigeria. Currently, many of the people are engaged in rice production either at commercial or subsistence level although mostly at subsistence level. Very few farmers have long engaged in dry season farming mainly on the bank of rivers, streams and swamps using very small portions of the land. In this way, farmers have been able to produce dry season crops such as vegetable, yam, rice among others. Private individuals and cooperative groups have not really ventured in to irrigation farming because farmers' willingness to pay for irrigation in the study area has not been ascertained. This study therefore assessed the willingness of rice farmers to pay for irrigation for dry season rice production in Ikwo LGA of Ebonyi State. Specifically, the study identified the factors that influenced rice farmers' willingness to pay for irrigation in the area; estimated the cost values the rice farmers are willing to pay in the area; determined the effects of the socio-economic characteristics of the rice farmers on their willingness to pay for irrigation in the area; and analysed constraints to rice farmers' willingness to pay for irrigation water in the area.

MATERIAL AND METHODS

The study area was Ikwo Local Government Area of Ebonyi State, Nigeria located on the geographical coordinate of $3^0 01^'$ North and $3^0 03'$North latitude and 28.5' West and 28.7' West longitude (EBADEP Annual Report 2004. The study adopted both random and purposive sampling techniques. Out of the 1766 registered rice farmers in the study area (EBADP 2015), 10% was selected from each community, making a total of 125 rice farmers that were used for the study. Both descriptive and inferential statistics were employed for analysis of data generated from the field survey which included descriptive statistics, contingent valuation method (CVM), ordinary least square regression analysis and principal component factor analysis .

Decision rule for factor analysis: The analysis was done in line with the simple thumb rule developed by Kaiser (1958), that variable with coefficient of (0.40) and above have high loading and may be used in naming a factor.

Model specification: The model for CVM analysis on willingness to pay for irrigation by dry season rice farmers in Ikwo local government area of Ebonyi State, Nigeria was stated as:

$$V(y–WTP, p, q1, Z)= V(y, p, q0, Z) \dots\dots\dots\dots\dots\dots\dots\dots 1$$

Where, V denotes the indirect utility function, y is the income of the individual rice farmer, WTP is the willingness to pay of the individual rice farmer, p is a vector of prices faced by the individual, $q0$ and $q1$ are the alternative levels of provision of the irrigation water under baseline and improved conditions, respectively (with $q1 > q0$ indicating an improvement from $q0$ to $q1$), and Z is a vector of individual characteristics affecting the trade-off that the individual is prepared to make between income and the supply of irrigation water. This equation implies that willingness to pay depends on (i) the initial and final level of the good in question ($q0$ and $q1$); (ii) respondent income; (iii) prices faced by the respondent; and (iv)other respondent socio-economic characteristics.

$$Y_i = \beta_0 + \beta_i \ X_i + \mu_i \dots\dots\dots\dots\dots\dots\dots\dots\dots 2$$

Where: Y_i is the dependent variable, X_i is a vector of explanatory variables, β_0 and β_i are the parameters to be estimated, and μ_i is the random error term.

Thus, the estimated WTP model explaining variation in willingness to pay across sampled rice farmers in the study area is specified as: $WTP = \beta_0 + \beta_1 EDU + \beta_2 EXP + \beta_3 HHS + \beta_4 FSIZE + \beta_5 DMKT + \beta_6 EXT + \beta_7 CRE + \beta_8 ATT + \beta_9 PWSOURCE + \mu i \dots\dots\dots\dots\dots 3$

Where; WTP = Amount willing to pay (naira); EDU. = years of education (years); EXP. = farming experience (years); HHS = household size (number of individual); FSIZE = farm size (hectares); DMKT = distance from the farm to the nearest market (km); EXT = access to ext. agent (dummy: access= 1; 0 = otherwise); CRE = access to credit (dummy: access =1, 0 otherwise); ATT = attitude towards payment for irrigation (dummy: positive =1; 0=otherwise); PWSOURCE = proximity to water source (km); β1 – β10 = regression parameters; µi random error term.

RESULTS AND DISCUSSION

Factors that influence farmers' decision: The three major factors influence rice farmers' willingness to pay for irrigation in the study area were socio-economic (Factor I), geographic (Factor II) and productive (Factor III) (Table 1). Factor I included variables related to socio-economic issues. These variables are age (0.619), educational qualification (0.690), farming experience (0.967), household size (0.915), farm size (0.922) and attitude/perception towards irrigation (0.610). The geographic factors were proximate to water source (0.836) and to market (0.771). The productive variable were high performance of irrigation rice (.859), access to extension service (0.847) and credit (0.876), and ownership of rice swamp (0.856). This is in agreement with

the finding of Alemayehu (2014) who observed that the willingness to pay is likely to be influenced by various factors ranging from socio-demographic, farm-specific, market related, policy-institutional related factors as well as attitudes and perceptions. Alhassan et al (2013) identified location of farm, land ownership, and land lease prices as the significant and influencing factors that affect farmers' willingness to pay for the irrigation water in Bontanga Irrigation Scheme in Northern Ghana.

Cost value: All the rice farmers (100%) were willing to pay for irrigation water for dry season farming in the area (Table 2). Further probing indicates that 52% of the respondents were willing to pay between US $3.13-15.63 per 2.5 ha^{-1} with a mean of US $19 per 5ha. About 96% of the rice farmers were willing to pay if the cost of irrigation increases while 36% of them were willing to pay maximum amount of US $30.6 – 41.7/5ha/year. The mean willingness to pay amount was US $29.3/5ha/year. Alemayehu (2014) estimated the mean willingness to pay by small holder farmers for improved irrigation water in the case of the Koga irrigation project in Ethiopia and observed that households were willing to pay a mean value of US$6.78 hectare/year and with estimated total of US$ 92,951.34 per year. Alhassan et al (2013) estimated the mean farmers' willingness to pay for improved irrigation services in Bontanga Irrigation Scheme in Northern Ghana using the contingent valuation method to be US$ 8.50 per ha per year.

Socio-economic characteristics : The willingness to pay for irrigation showed that the coefficient of determination (R^2) was 0.859 or 85.9%, suggesting that 85.9% of total variation observed in the dependent variable – willingness to pay for irrigation was sufficiently explained by the independent variables included in the regression model (Table 3). The reliability of the model was confirmed by high value of the F-

Table 2. Cost values willing to be paid by rice farmers for dry season rice farming

Variable	Freq. (n=125)	Percentage
Willingness to pay for irrigation		
Yes	125	100
Amount willing to be paid per 2.5 ha		
1000 - 5000	65	52
6100 - 10000	45	36
Above 10000	15	12
Mean	US $19.0	
Willingness to pay if the cost of irrigation increases	120	96
Yes	5	4
No		
Maximum amount willing to be paid at increase in cost of irrigation:		
<6000	35	28
6000 – 10000	30	24
10100 – 15000	45	36
Above 15000	15	12
Mean	US$29.3	

statistics (77.601) and low value of standard error of the estimate (0.13053). Overall, the model was statistically significant meaning that the socio-economic characteristics of the rice farmers exert significant effect on their willingness to pay for irrigation. Educational qualification, farming experience, and farm size indicated positive correlation with willingness of rice farmers to pay for irrigation. Ogunniyi et al (2011), Mezgebo et al (2013) and Alemayehu (2014) also observed positive relationship between formal education and willingness to pay. The coefficient of household size was and statistically insignificant. This signifies that large household size decreases rice farmers' willingness to pay for irrigation in the study area.

The coefficients of distance of farm from the nearest market and access to credit were positive and statistically

Table 1. Factors influencing rice farmers' willingness to pay for irrigation water

Factor	Socio-economic	Geographic	Productive
Age	0.619	0.188	-0.271
Educational qualification	0.690	0.361	0.009
Farming experience	0.967	-0.084	-0.009
Household size	0.915	0.307	0.024
Farm size	0.922	0.295	-0.016
Proximate to water source	0.395	0.836	-0.078
Proximate to market	0.325	0.771	-0.066
Access to extension services	-0.173	0.306	0.847
Access to credit	-0.013	0.375	0.876
Attitude and perception toward irrigation	0.357	0.238	0.610
Ownership of rice swamp	0.334	-0.139	0.856
High performance of irrigation rice	0.336	0.047	0.859

significant. This suggests that farmers' willingness to pay for irrigation increases with increase in distance of farm from the market, distance to water and access to credit. The coefficients of 0.175, 0.153 and 0.292 implies that a unit increase in distance of farm from the nearest market, distance to water source and access to credit increases the willingness to pay for irrigation by 17.5, 15.3 and 29.2 percent, respectively. Ulimwengu and Sanyal (2011) observed negative impact of travel distance on the willingness to pay for agricultural services, but corroborates with the findings of Addis (2010) and Illukpitiya and Gopalakrishnan (2004) who observed that access to credit increases willingness to pay. The coefficient of access to extension services was negatively and significant. The coefficient of -0.112 means that any unit increases in access to extension services decreases farmers' willingness to pay for irrigation by 11.2%. This is however, contrary to a priori expectation because extension programmes was expected to facilitate the extension of innovations and novel ideas to farmers for improving their farming operations.

Attitudes toward payment for the maintenance of supply of irrigation had positive coefficient but statistically not significant. The coefficient of 0.030 means that as attitudes toward payment for maintenance of supply of irrigation increases, farmers' willingness to pay for irrigation water increases by 3.0% and this confirms to the a priori expectation. To justify the result, the test of hypothesis (Ho$_3$) which states that the socio-economic characteristics of the rice farmers have no significant effect on their willingness to pay for irrigation in the study area showed that f-cal (77.8) > f-tab at 5% (2.02) hence the null hypothesis was rejected while its alternative was accepted. This implies that the socio-economic characteristics of the rice farmers have significant effect on their willingness to pay for irrigation in the study area.

Constraints to rice farmers: The constraints were institutional, political and economic factors. Using varimax principal component analysis with Kaisers' normalization and rule of thumb, the identified institutional component factors were unfavourable or weak irrigation policy overlapping and duplication of institutional functions and mandate lack of access to credit, lack of access to water source, lack of access to improve seed, non-inclusion of farmers in irrigation scheme), interference from environmental authority and problem of pest and disease (Table 4). Weak stakeholders' ownership was identified as political component factor that constrain rice farmers' willingness to pay for irrigation water in the area. Similarly, high cost of labour poor financing of irrigation project high cost of irrigation water were identified as economic component factors that constrain rice farmers' willingness to pay for irrigation project. Meanwhile, Uduma et al (2016) observed that the challenges of irrigation water in Nigeria farming system ranges from institutional, policies, and climate change to low access to capital. However, owing to the unfavourable land use policy in Nigeria and other African countries, the future of private ownership of irrigation water which is believed to be an effective way of irrigation water management is bleak because no farmer would be willing to invest on a land which he owns no title or ownership (Valipour 2014). There is therefore, a need for good and concerted government polces to encourage farmers to use irrigation system and raise cropping intensity for irrigated areas.

CONCLUSION

The rice farmers in Ikwo Local Government Area (LGA) of Ebonyi State, Nigeria are willing to pay for irrigation for dry season rice even if the cost goes higher. The high willingness expressed by the rice farmers to pay for maintenance of supply of irrigation water makes the project economically

Table 3. Effects of Socio-economic characteristics of rice farmers on their willingness to pay for irrigation water

Variable name	Coefficient	Std. Error	t-value
Constant	3.062	0.118	25.954***
Educational qualification	0.051	0.003	16.554***
Farming experience	0.004	0.024	.174***
Household size	-0.032	0.051	-.626[NS]
Farm size	0.055	0.050	1.101***
Distance of the farm to the nearest market	0.175	0.036	4.838***
Access to extension services	-0.112	0.068	-1.662*
Access to credit	0.153	0.061	2.519**
Attitudes towards payment for the maintenance of supply of irrigation	0.030	0.044	.677[NS]
Proximity to water source	0.292	0.058	5.022***

*, ** and *** indicates significance at 10%, 5% and 1% levels respectively

Table 4. Constraints to rice farmers' willingness to pay for irrigation water

Variable name	Institutional	Political	Economic
Unfavourable/weak irrigation policy	0.836	0.172	0.247
Overlapping and duplication of institutional functions and mandates	0.716	0.312	-0.129
Lack of access to credit	0.565	0.370	0.210
Lack of access to water source	0.858	0.165	0.110
Lack of access to improve seed	0.862	0.275	0.230
High cost of labour	0.007	0.271	0.837
Limited autonomy for local people	0.525	0.538	-0.062
Non-inclusion of farmers in irrigation scheme	0.801	0.305	-0.196
Weak stakeholders ownership	0.083	0.877	-0.096
Poor financing of irrigation project	-0.412	-0.299	0.719
Interference from environmental authority	0.755	0.242	-0.171
High cost of irrigation water	-0.045	0.106	0.942
Problem of pest and disease	0.942	0.106	-0.045
Water interference by host community	0.267	0.140	0.171

viable and sustainable on the long term basis. The study advocates integration of the socio-economic attributes, geographic and productive variables that positively influence rice farmers' willingness to pay for irrigation water into irrigation project for promoting all year rounds rice production, thereby reducing food import bill and promoting food security. However, this cannot be attained if institutional, political and economic constraints hindering rice farmers' willingness to pay for irrigation water are not addressed headlong. It is suggested that government should come up with a workable and feasible water scheme since the farmers are willing to pay for its sustainability and should streamline and harmonize the overlapping and duplication mandates and functions agencies to be more effective in meeting the water need of the farmers. The farmers should be encouraged to form cooperative society so as to access credit for establishment of small irrigation scheme for dry season rice production. The government should make farm machinery available for farmers at subsidized price so as to enhance the use of modern production inputs for larger scale rice production and extension programme of Agricultural Development Programme (ADP) should incorporates irrigation scheme into their programmes and extend same to farmers.

REFERENCES

Adewumi JK, Olayanju TMA and Adewuyi SA 2007. *Support for Small Rice Threshers in Nigeria*, Monograph Series No. 23. Making Nigerian Agricultural Markets Work for the Poor. DFID/PrOpCom. SA II Associates LTD/GTE, 40, Mississippi Street, Maitama, Abuja.

Alemayehu T 2014. Farmers' small holder farmers' willingness to pay for improved irrigation water: A contigent valuation study in Koga irrigation project Ethiopia. *Journal of Economic and Sustainable Development* **5**(19): 5-15.

Alhassan M, Loomis J, Frasier M., Davies S and Andales A 2013. Estimating farmers' willingness to pay for improved irrigation: An economic study of the Bontanga irrigation scheme in Northern Ghana. *Journal of Agricultural Science* **5**(4):31-42.

Daramola B 2005. Government policies and competitiveness of Nigerian rice economy. Paper presented at the `*Workshop on Rice Policy & Food Security in Sub-Saharan Africa*' organized by WARDA, Cotonou, Republic of Benin, November 07-09. 12.

EBADEP 2004. EBADEP Annual 2004 Report. Abakaliki: EBADEP.

FAO 2005. AQUASTAT *Country Profile: Nigeria*. [Online] http://www.FAO.org/nr/water/aquastat/countries_regions/NGA/index.stm"

FAO 2015. FAOSTAT Country Selection. [Online] http://FAOstat3.FAO.org/home/index.html#DOWNLOAD Assessed 19 June, 2017

Illukpitiya P and Gopalakrishnan C 2004. Decision-making in soil conservation: Application of a behavioural model to potato farmers in Sri Lanka. *Land Use Policy* **21**(4): 321–331.

Kadigi RMJ 2006. *Evaluation of Livelihoods and Economic Benefits of Water Utilization: at Great Ruaha River Catchment*, Unpublished Thesis for Award of Ph.D. Degree at Sokoine University of Agriculture, Morogoro, Tanzania, pp. 59-134.

Mezgebo A, Tessema W and Asfaw Z 2013. Economic values of irrigation water in Wondo Genet District, Ethiopia: An application of contingent valuation method. *Journal of Economics and Sustainable Development* **4**(2): 23-36.

Ogunniyi LT, Sanusi WA and Ezekiel AA 2011. Determinants of rural household willingness to pay for safe water in Kwara State, Nigeria. *Aquaculture, Aquarium, Conservation and Legislation. International Journal of the Bioflux* **4**(5): 660-669.

Uduma BU, Adeoye SO and Agbonlahor MU 2016. Irrigation potentials and rice self-sufficiency in Nigeria: A review. *African Journal of Agricultural Research* **11**(5): 298-309.

Ulimwengu J and Sanyal P 2011. *Joint estimation of farmers' stated willingness to pay for agricultural services*, International Food Policy research Institute Discussion Paper, 1070.

Valipour M 2014. *Land use Policy and Agricultural Water Management of the Previous Half of Century in Africa. Applied Water Science*, DOI 10.1007/s13201-014-0199-1.

Assessment of Ground Water Quality Based on Socio Economical Activities in Cauvery River Bed of Tamil Nadu

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Abstract: The present research work is to evaluate the correlation between socio economical activities and water quality of Cauvery river bed, Tamil Nadu. Thirty samples were collected from different locations of Cauvery river bed based on industrial development and social activities. The groundwater quality was analysed in the study area. This study indicated that the characteristics of water quality deteriorate in Erode and Karur areas when compared with other sampling points and exceeds the WHO limit. Mainly fluoride exceeds the permissible limits of 0.2 mg l^{-1}. This research proves that the impact of social and economical activities (industrial development) plays a key role in deterioration of groundwater quality.

Keywords: Water quality index, Pollution, Urbanization and industrialization, Self purification capacity, Assimilation ground water, Surface runoff

River basin is important for the development of civilization and play a most imperative role in incorporate or bringing industrial and municipal wastewater, manure discharges and run off from agricultural fields, community and residential areas which are accountable for river pollution. The discharge of pollution load from various sources varies for all climatic conditions Due to increasing growth of urbanization and industrialization the pollution load increases in day to day life. The water quality of the river reflects on the groundwater quality of the river bed. The Cauvery river act as a main source of drinking water, fishing and other domestic uses for the inhabitants. It is an uppermost course of winding, with a rocky bed and high banks under abundant vegetation (Vidhya et al 2015). After passing through a slender ravine and dipping about 60 to 80 feet in the rapids of Chunchankatte. In Tamilnadu the Kaveri continues through a series of twisted wild gorges until it reaches Hogenakal Falls and flows through a straight, narrow gorge near Salem (Maria et al 2017). In Mettur Dam, 5,300 feet along and 176 feet high, impounds a lake of 60 square miles and then it flows into Erode and Karur, the industrial zone of Tamilnadu. In tiruchchirappalli, the Kaveri breaks at Srirangam (Salam et al 2018) in eastern Tamil Nadu state and extensively irrigated deltaic region of about 4,000 square miles and Kabani, Amaravati, Noyil, and Bhavani rivers are the main branch of Cauvery (Sehnaz et al 2017). In the entire stretch of Cauvery River the industrial and urbanization changes the water quality of the entire stretch of river bed. The main objective of this research work is to determine the water quality for pre monsoon, monsoon and post monsoon of the Cauvery stretch to investigate the inter relationship between socio economical activities and water quality of the locality and suggest the remediation process available for the pollution problem.

MATERIAL AND METHODS

Study area: The study carried out in the river basin of Cauvery in Tamil Nadu, These regions receive an average rainfall of 865 mm rainfall in the monsoon period. The temperature of these study area raises in the month of April and after it drops gradually. The mean monthly maximum and minimum temperature ranges from 27.3 to 34 and 12 to 24°c respectively. This geological condition of this region consists of crystalline limestone (Abul et al 2018). The study regions of Mettur and Salem contain magnesite and in Erode, Karur region having red sandy soil, the industrial activities are high when compare to other region of our study (Daiki et al 2016). The trichy region having black cotton soil and the agriculture activities are high in the river bed of trichy and thanjavur region consist of red sandy soil and black cotton soil (Alexandra et al 2017). The agricultural activities are the major work in this region. The samples were collected from Mettur (R1) (Latitude: 11°47' 16°66"N, Longitude: 77°48'E), Erode (R2) (Latitude: 11°14'60'00"N, Longitude: 77°18'60"E), Karur (R3) (Latitude: 10°56'60"N, Longitude: 78°04'48"E), Trichy(R4) (Latitude: 10°48'55"N, Longitude: 77°48'28"E) and Thanjavur (R5) (Latitude: 10°48'00"N, Longitude: 79°09'00"E) region (Fig.1).

Sample collection: During monsoon period of October 2017 the sample were collected and the water quality study proceeded to know the characteristics of water. For the entire study totally 1170 samples were collected and stored at 4°c for analysis. The 75 samples collecting bottle drenched in 1:1 HCl for 24 h and it's thoroughly washed with deionized water. The groundwater sample collected for pre monsoon, monsoon and post monsoons. The samples were characterized for various physicochemical parameters like pH, DO (dissolved oxygen), conductivity, BOD, nitrate, Fecal coliform, total coliform, turbidity, chloride, hardness, calcium, sulphate and fluoride (Georgia et al 2015). The entire data was incorporated to determine the pollution load and basis for pollution load.

RESULTS AND DISCUSSION

Water quality level in premonsoon period: In Mettur region the normal temperature in the premonsoon period was 28-30ºC, in Erode the normal temperature was 31-39ºC, in Karur the temperature was 28-36ºC, Trichy region the normal temperature in premonsoon period its slightly high the average range of temperature in this 35-42ºC, Thanjavur region is almost same when compare to Trichy the temperature in this place was 34-40ºC. The pH of the sampling points arewas alkali (7- 8.5) in Karur (PS13) the range of the pH exceed the permissible limit of WHO which 6.5-6.8. The Dissolved oxygen (DO) ranges from 3.0mg/l (Kulavilakkamman temple –PS10) to .6.6 mg/l (Alakkudi-PS30) and the minimum range of The minimum conductivity was213 Mhos/cm at Thiruvaikkavur (PS29) and the maximum range of 451 Mhos/cm atKulavilakkamman temple (PS10). The maximum range of Biochemical oxygen demand

(BOD at 20°C) recorded at 14 sampling points and the low BOD was recorded at Pallipalayam (PS12) in the range of 0.4 mg l^{-1}. The nitrate ranges was recorded minimum level of 0.20 mg l^{-1} at Kalvadangam (PS5) and the maximum level of 0.33 mg l^{-1} at Pallipalayam (PS12). The maximum level of fecal coliform ranges was 89 MPN/100 ml at Guruvadi (Kollidam) (PS28). The maximum total coliform recorded in the range of 330 MPN/100 at Koyampalli (PS16) and the minimum level 187 MPN/100 in Alakkudi (PS30).The turbidity ranges recorded in 3 – 5.6 NTU. The minimum chloride range 19 mg/l was recorded in Perupallam (PS2) and maximum range recorded 52 mg l^{-1} at Karur (PS13). The minimum hardness range of 9 mg l^{-1} recorded at Perumpallam (PS2) and the maximum level was 183 mg l^{-1} at Erode (PS7).The minimum range of sulphate 3 mg l^{-1} was recorded at Perupallam (PS2) and maximum range was 18 mg l^{-1} at Thirumanilayure (PS14). The fluoride at minimum level 0.2 mg l^{-1} in at Perumpallam (PS2) and the maximum range of 2.81 mg l^{-1} in Erode (PS7), it's slightly high in Pallipalayam (PS12), Nava brindavan Temple (PS8) and in Karur (PS13) when compared to the permissible limit of 1.5 mg l^{-1}.

Water quality level in monsoon period: The minimum pH range of 6 was observed in Perumpallam (MS2) and maximum range of 7.9 was Kottamangalam (MS11). The pH range of Erode and Karur region exceeds the permissible limit. The minimum DO was recorded as 2.4 mg l^{-1} in melapalayam (MS17) and the maximum level of 8.1 mg l^{-1} at Poolampatti (MS3) and Singampettai (MS4). The minimum conductivity range was observed as 196 Mhos cm^{-1} Thudaiyur (MS21) and maximum level of 401 Mhos cm^{-1} in Pallipalayam (MS12). The minimum BOD level at 20C was observed as 1 and the maximum level was 1.7 mg l^{-1} at

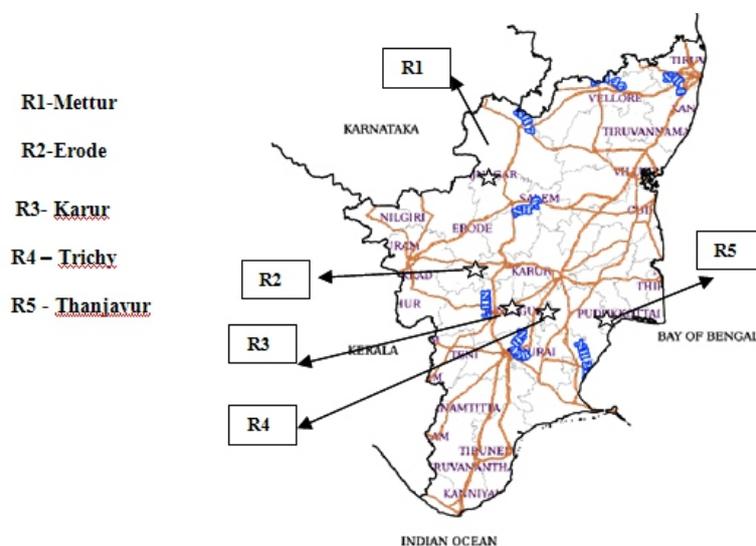R1-Mettur
R2-Erode
R3- Karur
R4 – Trichy
R5 - Thanjavur

Fig. 1. Cauvery river stretch in Tamil Nadu with sampling locations

Thiruvaikavur (MS29). The minimum nitrate level of 0.10 mg/L at Goundampalayam (MS9) was observed. The maximum level of nitrate 0.28 mg/l was observed at Ramanoor (MS15) and the minimum level of 0.11 mg/l was recorded in Thanjavur (MS25). The minimum level of fecal coliform 79 MPN/100 ml was observed and the maximum level of 186 MPN/100 ml at Thirumanilayure (MS14).The minimum total coliform range of 163 MPN/100 ml at Thanjavur (MS25) and the maximum range of 312 MPN/100 ml observed in Kottamangalam (MS11). The minimum range of turbidity recorded in Mettur (MS1) in the range of 2.5 NTU and the maximum range was observed in karur (MS13) in the range of 4.9 NTU. The minimum chloride range was observed as 14 mg/l in Alakkudi (MS30). The maximum range of chloride observed as 49 mg/l in Thirumanilayure (MS14). The minimum hardness level was observed as 8 mg/l at Perumpallam (MS2) and the maximum level of hardness recorded as 164 mg/l in Goundampalayam (MS9) and Kottamangalam (MS11).The minimum calcium ranges was observed as 9 mg/l in mettur (PS1) and the maximum level of 28 mg/l taken in Koyampalli (MS16). The minimum sulphate level recorded as 2 mg/l in the region of Perumpallam (MS2) and the maximum level observed as 15 mg/L at Ramanoor (MS15). The minimum fluoride was recorded as 0.10 mg/l at Payanakurichy (MS23). The maximum level of 1.64 mg/l was observed in Kaverypatti (MS6) and the minimum level at Nathanmangudi (MS26).

Water quality level in Post monsoon period: In Post monsoon period of April 2018 the sample were collected and the water quality study proceeded to know the characteristics of water. The minimum pH range of 6.5 was observed in Thiruvaikavur (POS29) and maximum range of 8.9 was observed at Melappalayam (POS17). The pH range of Erode and Karur region exceeds the permissible limit and it is in alkaline nature. The minimum DO was recorded as 3.1 mg/L in Erode (POS7) and the maximum level of 8.9 mg/L at Singampatti (POS4). The minimum conductivity range was observed as 204 Mhos/cm at Perumpallm (POS2) and maximum level of 435 Mhos/cm in Pallipalayam (POS12). The minimum BOD level at 20c was observed as 1 and the maximum level was 2 mg/L at Thiruvaikavur (POS29). The minimum nitrate level of 0.21 mg/l at Thanjavur (POS25) was observed. The maximum level of nitrate 0.41mg/l was observed at Melappalayam(POS17). The minimum level of fecal coliform 88 MPN/100 ml was observed and the maximum level of 164 MPN/100 ml at Erode (POS7). The minimum total coliform range of 189MPN/100 ml in Alakkudi (POS30) and the maximum range of 312MPN/100 ml observed in Kottamangalam (MS11). The minimum range of turbidity recorded in Mettur (POS1) in the range of 3.1 NTU

and the maximum range was observed inpallipalayam (POS12) in the range of 5.9 NTU. The minimum chloride range was observed as 18 mg/l in Alakkudi (POS30). The maximum range of chloride observed as 51mg/l in Thirumanilayure (POS14). The minimum hardness level was observed as 9 mg/l at Perumpallam (POS2) and the maximum level of hardness recorded as 173 mg/l in Nava brindavan Temple (POS8).The minimum calcium ranges was observed as 10 mg/l in mettur (POS1) and the maximum level of 38 mg/l taken in Pallipalayam (POS12). The minimum sulphate level recorded as 4 mg/L in the region of Mettur (POS2) and the maximum level observed as 38 mg/l at Pallipalayam (POS12). The minimum fluoride was recorded as 0.17mg/l at Nathamangudi (POS26).The maximum level of 3.91 mg/l was observed in Kottamangalam (POS11).

Comparison of Physico-Chemical Characteristics and Relativity Analysis of Water Quality Parameters in Pre-monsoon, Monsoon and Post monsoon period:

The graphical representation evidently compares the physicochemical characteristics of water in three different climatic conditions and this comparative study furnishes the reason for alteration in water quality. The main intend of this relativity analysis whether the socio economical activities implies in the changes in water quality. In pH range almost in all climatic condition it's in alkaline nature and 90% of sample exceeds the permissible level of 6-6.8 (WHO limit) (Fig. 2). Due industrial activity and vehicle consumption the pH level gets altered in all sampling points (Alexandra et al 2017). In all climatic condition the dissolved oxygen level was very low when compared to the (4-7 mg/l) WHO permissible limit; particularly in Erode and Karur region the Dissolved oxygen (DO) level was very poor due higher level of contamination (Fig. 3). The conductivity range gets altered in Erode and Karur zone (Fig. 4). The BOD level was not in a steady state in all climatic condition (Fig. 5). The loading of organic compound varies every day. In Pre monsoon and Post Monsoon the nitrate ranged almost same and it's slightly gets altered in monsoon period (Fig. 6). The fecal and total coliform ranges exceed the permissible limit of 90MPN100/ml and 110MPN100/ml in Erode and Karur region due to higher level of pollution load (Fig. 7 & 8).The turbidity level was not exceeding the permissible limit of 10 NTU because infiltration process (Fig. 9). At the same time the higher turbidity level was noticed in Erode and Karur region. The chloride and sulphate level was higher in Erode and Karur (Fig.10 &13) at the same time it is not exceeded the WHO limit of 250mg/l. The hardness level exceeds the permissible level in Erode and Karur zone (Fig. 11). Likewise calcium limit also follows the previous level because it is one of the important compounds to produce hardness in water
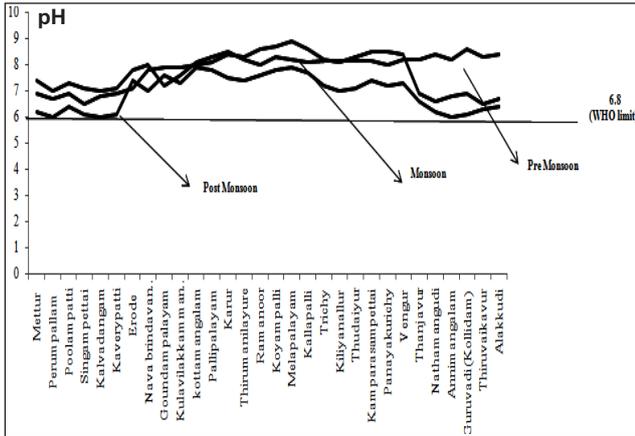
Fig. 2. pH in pre monsoon, monsoon and post monsoon
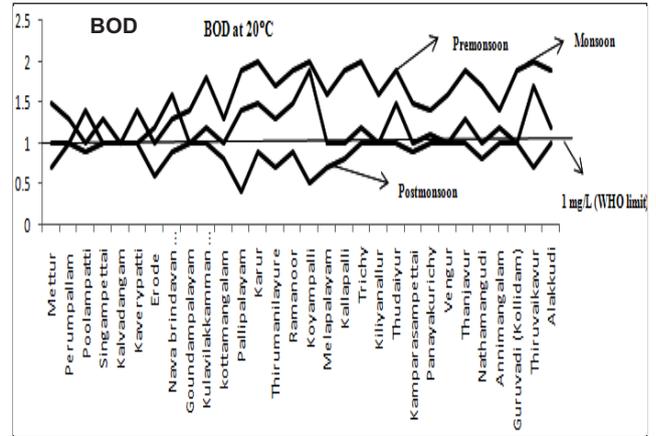
Fig. 5. BOD in pre monsoon, monsoon and post monsoon
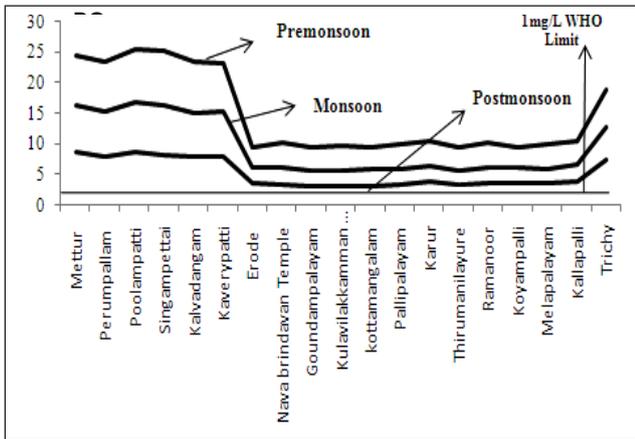
Fig. 3. Dissolved Oxygen in pre monsoon, monsoon and post monsoon

Fig. 6. Nitrate in pre monsoon, monsoon and post monsoon

Fig. 4. Conductivity in pre monsoon, monsoon and post monsoon
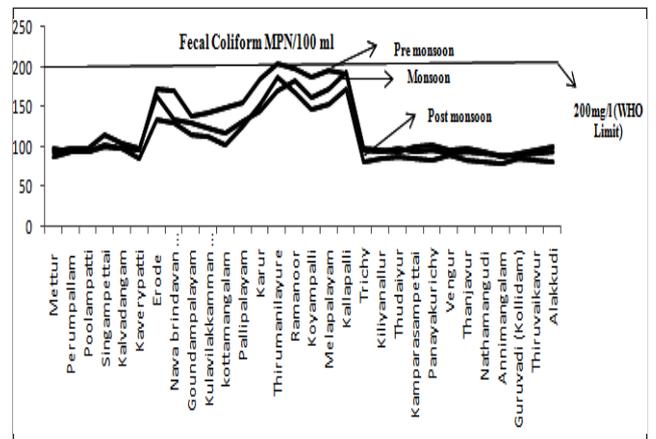
Fig. 7. Fecal coliform in pre monsoon, monsoon and post monsoon

Fig. 8. Total coliform in pre monsoon, monsoon and post monsoon

Fig. 11. Hardness in pre monsoon, monsoon and post monsoon

Fig. 9. Turbidity in pre monsoon, monsoon and post monsoon

Fig. 12. Calcium in pre monsoon, monsoon and post monsoon

Fig. 10. Chloride in pre monsoon, monsoon and post monsoon

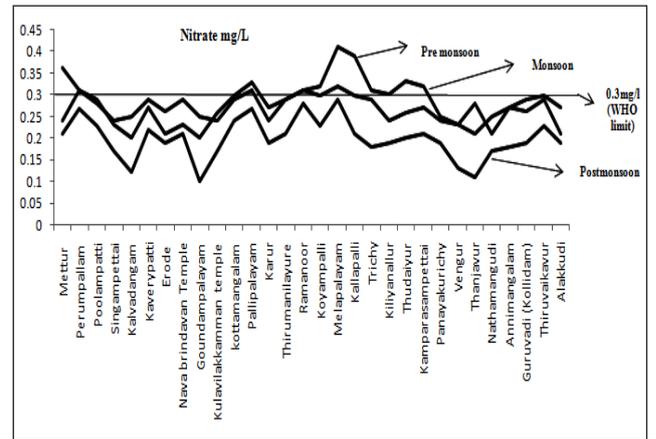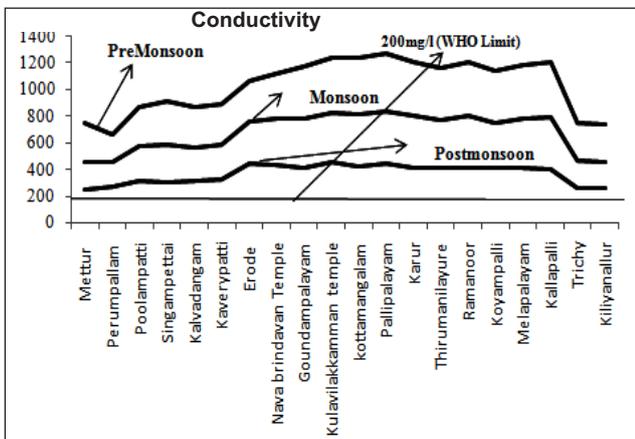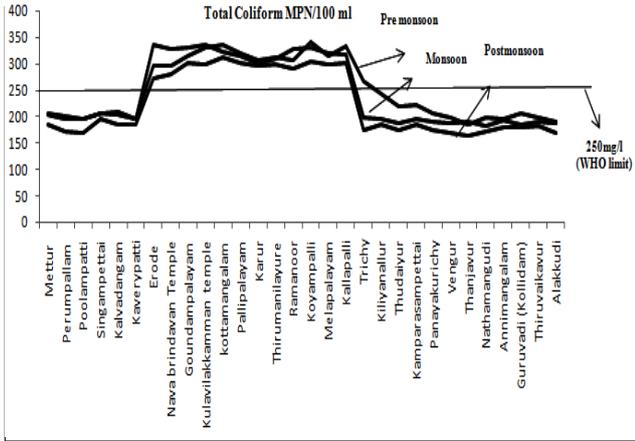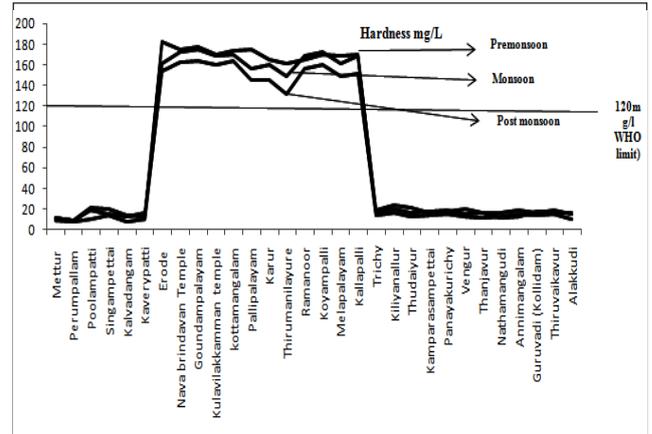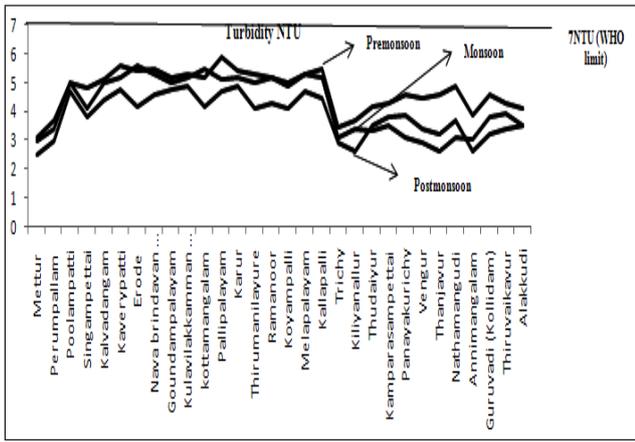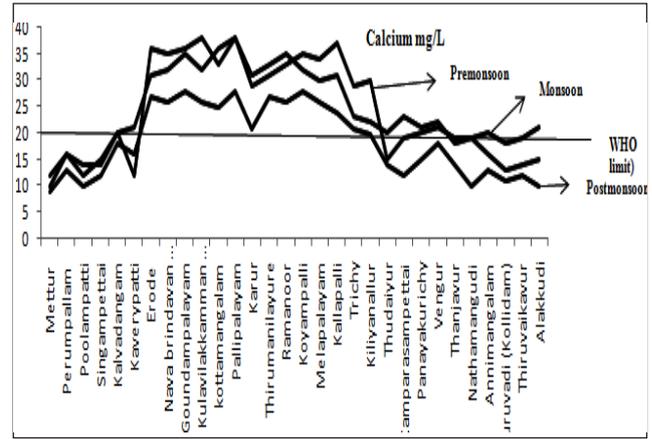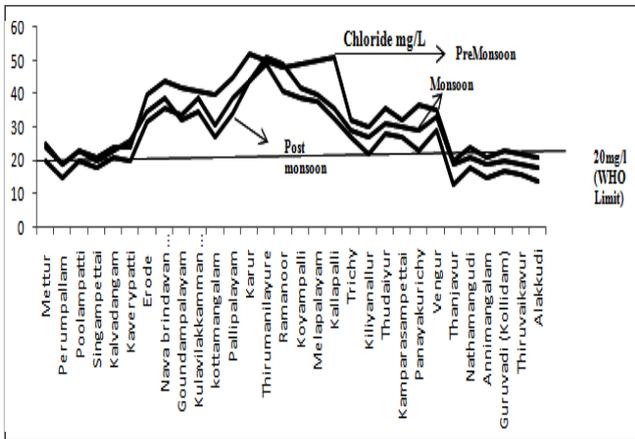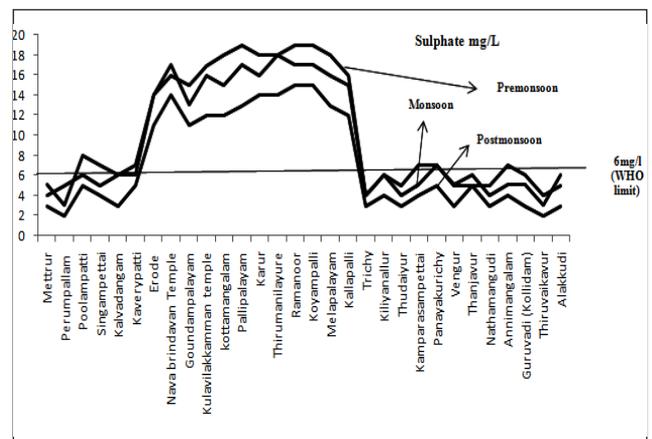**Fig. 13.** Sulphate in pre monsoon, monsoon and post monsoon

(Fig. 12). The discharge of dye effluent into the river bed gets leachate and enters into the groundwater table. The level of fluoride was in alarm condition which exceeds the permissible limit of 1-1.5mg/l in Erode and Karur zone (Fig. 14). Particularly These two regions Erode and Karur are having high industrial activity particularly dyeing units are high in this region and vehicular emission also pollutes the atmosphere, the river bed is the main resource for discharging waste water from dying units. It pollutes the surface and groundwater bodies through leachate of polluting agent through industrial and other economical activities into the groundwater bodies.

CONCLUSION

In this research the entire water quality was analyzed for pre monsoon, post monsoon and monsoon period of Cauvery river bed Tamil Nadu. The groundwater deterioration of two sampling points of Erode and Karur zone. The main aspire of this study to conceive that there is a relationship between Industrial and urbanization activity with water quality of the locality. During Pre Monsoon and Post monsoon period the pollution load was high when compared to the monsoon period because of the higher moment of groundwater table and self purification capacity. The hardness level gets increased in all regions due to several economical activities. From this river stretch analysis and graphical relative analysis we revealed that Erode and Karur regions are in alarm level of water pollution. These regions are the higher industrial zone which is having lot of dying and textile industries. The proper treatment and disposal of effluent was lacking in this region. The effluent was discharged in the river bed unauthorized condition so the pollution load gets infiltrate into the groundwater of the river bed. This heavy discharge causes higher level of fluoride contamination in this region, which produces serious health effects of the local peoples living in Erode and Karur region. The study suggested the necessity for uninterrupted monitoring of the river water to recognize the pollution basis to defend this large river from auxiliary contamination. Appropriate treatment of ground water requires to be foreseeing for its drinking and other intentions. Proper drainage arrangement could also prevent the diverse polluting sources including anthropogenic activities.

REFERENCES

Abul Hasan Md Badiul Alam, Koichi Unami and Masayuki Fujihara 2018. Holistic water quality dynamics in rural artificial shallow water bodies. *Journal of Environmental Management* **223**: 676-684.

Alexandra 2017. Physicochemical parameters affecting the perception of borehole water quality in Ghana. *International Journal of Hygiene and Environmental Health* **220**: 990-997.

Amaal M 2017. Indices of water quality and metal pollution of Nile River, Egypt. *The Egyptian Journal of Aquatic Research* **43**: 21-29.

Dilip Kumar Jha 2015. Water quality assessment using water quality index and geographical information system methods in the coastal waters of Andaman Sea, India. *Marine Pollution Bulletin* **1:** 555-556.

Daiki Kinuma 2016. A Fundamental Study in the Characteristics of Water Quality for Improvement in the Urban Closed Water Body. *Procedia Engineering* **154**: 565-573.

Elijah MM 2016. Determination of the water quality index ratings of water in the Mpumalanga and North West provinces, South Africa. *Physics and Chemistry of Earth, Parts A/B/C* **92**: 70-78.

Georgia L Kayser 2015. Drinking water quality governance: A comparative case study of Brazil, Ecuador, and Malawi. *Environmental Science & Police* **48**: 186-195.

Hamed Soleimani 2018. Data on drinking water quality using water quality index (WQI) and assessment of groundwater quality for irrigation purposes in Qorveh & Dehgolan, Kurdistan, Iran. *Data in Brief* **20**: 375-386.

Ian Thornhill 2017. Prioritising local action for water quality improvement using citizen science; A study across three major metropolitan areas of China. *Science of the total Environment* **585**: 1268-1281.

John Curtis and Brian Stanley 2016. Water quality and recreational angling demand in Ireland. *Journal of Outdoor Recreation and Tourism* **14**: 27-34.

Kinda Constantine 2017. The role of the water tankers market in water stressed semi-arid urban areas: Implications on water quality and economic burden. *Journal of Environmental Management* **188**: 85-94.

Linda Fernandez and Dan MC Garvey 2018. Water quality decisions and policy for an interstate watershed. *Water Resources and Economics* Article in press.

Lewis Stetson Rowles 2018. Perceived versus actual water quality: Community studies in rural Oaxaca, Mexico. *Science of the Total Environment* **13**: 622-623.

Mohsen Dehghani Darmian 2018. Assessment of tools for protection of quality of water: Uncontrollable discharges of pollutants. *Ecotoxicology and Environmental Safety* **15**: 190-197.

Maria Rusca 2017. An interdisciplinary political ecology of drinking water quality. Exploring socio-ecological inequalities in Lilongwe's water supply network. *Geoforum* **84**: 138-146.

Salam 2018. Predicting the Tigris River water quality within Baghdad, Iraq by using water quality index and regression analysis. *Environmental Technology & Innovation* **11**: 390-398.

Sehnaz Sener 2017. Evaluation of water quality using water quality index (WQI) method and GIS in Aksu River (SW-Turkey). *Science of the Total Environment* **585**: 131-144.

Lobato TC 2015. Construction of a novel water quality index and quality indicator for reservoir water quality evaluation: A case study in the Amazon region. *Journal of Hydrology* **522**: 674-683.

Wei Hou 2016. Assessing water quality of five typical reservoirs in lower reaches of Yellow River, China: Using a water quality index method. *Ecological Indicators* **61**: 309-316.

Vidhya Chittoor Viswanathan 2015. Does river restoration affect diurnal and seasonal changes to surface water quality? A study along the Thur River, Switzerland. *Science of the Total Environment* **532:** 91-102.

Impact of Check Dam in Groundwater Level and Water Quality of Vaigai River Madurai District, Tamil Nadu, India

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Abstract: The main objective of this research work is to analyse the impact of check dams constructed athwart the Vaigai river in Madurai. The contrivance of check dam resolves the issues of water scarcity and advances both the quality and quantity of groundwater. According to the world health organisation standards the quality of water and groundwater level is analysed and concluded that the check dam is measured as the preeminent practice to fulfil the requirement.

Keywords: Aquifer, Groundwater recharge, Groundwater Quality, Mechanism, Recharge structure

The precipitation is the main source for groundwater, because to infiltration capacity and the porosity of the soil the surface water converts into groundwater (Mailhot et al 2018). This groundwater flows downwards into the soil and supplying water to the spring and aquifer. Most of the groundwater contaminated by seepage through pores of soil surface, bore holes was used to that tap the water in the fractures and aquifer (Ali Reza et al 2017). The major problem in recent year is groundwater depletion (HuaizhiSu et al 2018). The exploitation of the groundwater is major problem for reduction in groundwater level (Guillaume Piton et al 2017). The climate change, industrialization and urbanization are the main reason for unauthorized exploitation (Nwokwu et al 2017). This is the main reason for drastic depletion groundwater (Senthil Kumar et al 2017). Usually ground water level in river bed area was higher when compared to land region (Gonzalez et al 2018). To improve the groundwater, the different types of recharging method followed. In river area check dam is one of the efficient methods of recharging groundwater (Maciej et al 2017). The increase in groundwater table level depends upon the characteristics and pore ranges of the soil region (Mohammed et al 2018).The present study was carried out to assess the improvements over quantity and quality of sub surface water and the impacts comparing the quantity and quality aspects of sub surface water before and after the construction of Check dam across Vaigai River at Kochadai, Madurai Tamil Nadu.

MATERIAL AND METHODS

Study area: The study was carried out in Vaigai river basin in Madurai District, Tamil Nadu which lies between 9°30' to 10°00' latitude and 78°00' to 78°30'longitude (Pratibha et al 2018). The Vaigai river up stream bed level Melakal to Manalur comprises of normal slope facing towards west to east direction with an average slope of 1 in 870 from with mean sea level 101.50 to 152.810 meter. In this region the water spread area was 157,608 square meters due to extended back up water holding. The crest level of Kochadai check dam is 132.40 mean sea level (Bouregaya et al 2018). The depth of aquifer varies from 7.00 to 22.00 meters and fluctuation varies from 2.00 to 15.00 meters (Pradeep et al 2018). The study area is characterized by fissile hornblende biotite gneiss, charnockite, granite, quartzite and flood plain alluvium along the patches of the river alluvial deposits such as sand, silt, stiff clay, gravel are transported sediments by the river on either side of Vaigai in Madurai (Huaizhi et al 2018). The pore space enlarged in the weathered mantle acts as shallow granular aquifers and forms the impending water deportment and acquiescent zones (Suneet et al 2018). In major parts of the study area shallow fractures yield good groundwater prospective. In shallow aquifers, the permeability rate is $>1–70$ m day^{-1} with $1–2$ % of specific yield (Tomas et al 2018). The water table level depth varies from 3.13 to 7.66 m below ground level. The yield of open wells varies from 10 to 256 m^3 day^{-1} and the yield of bore wells vary from13 to 363 m^{3}day^{-1} (Xuanmei et al 2018). The study area is covered by hard rock aquifer except along the flood plain of the Vaigai River.

Climate: The climate is dry and hot, with the relative humidity varies from 45 to 85% and is high during north east monsoon. The study area is mainly dependent on agriculture with an

average rainfall of 827.1 mm per annum. As this basin is situated in the rain shadow area of the western ghats, it receives very little rainfall during south-west monsoon in the hilly region. This basin is subject to a tropical climate and as such the temperature varies with the region. The mean temperature is around 25° C in January and 27.5° C to 35^0 C in May.

Existing ground water scenario before construction of Kochadai check dam: The study area predominantly by crystalline formations and alluvium along the courses of the river. Ground water occurs under heretic conditions in weathered residum and interconnected shallow fractures and under semi-confined to confined conditions in deeper fractures. The depth of weathering varies from 20-40 m. In the exploration programme of Central Ground Water Board, 29% of the wells yielded less than 60 lpm while 30% of the wells yielded between 60 to180 lpm. In general there are about 2 to 3 fracture zones less than 50 m and about 2 to 3 fracture forms beyond 100 m also. The variation in the yield of bore wells is very high in this study area before construction of check dam. The depth to water level in study area varies from 3.13 to 7.66 m below ground level during pre monsoon (May 2006) and 1.86 to 5.74 m below ground level during post monsoon. The long term water height vacillation for the phase 1998-2007 indicates rise in the water level in the order of 0.05 to 0.74 m yr^{-1} while the fall in the water level is in the range of 0.07 to 0.93 m yr^{-1}. Categorization for future ground water development for this east and west block are in safe category.

Project Implementation-Kochadai check dam: The check dam construction in Kochadai across the river Vaigai was sanctioned to augment water supply from existing decommissioned water supply head works from the Ministry of Urban Development, and it was completed in February, 2010 .

Sample collection: Samples were collected from Kochadai check dam latitude: 999' 11.98"N, longitude 783 2'7.11"E and Infiltration well, before construction of check dam (2010) in May (pre monsoon) and January (2011) and the samples were collected and tested continuously up to January 2018. A check dam across Vaigai River in Kochadai chainage L.S: 68.000 K.M -9.9455 N78.0823 E were collected as per standard test procedures from a check dam across Vaigai river in Kochadai chainage L.S: 68.000 K.M at universal co-ordinates 9.94550 N 78.0823^0 E were collected at 11.30 am to 12.30 pm in order to maintain uniformity. The water samples water are filtered in the field using 0.45 µ filter paper using vacuum hand pump. Electrical conductivity EC and pH was measured in situ using multi parameter probe, carbonate (CO_3) and bicarbonate (HCO_3) were estimated using an alkalinity test kit in the field, which is based on the volumetric titration method. TDS, TSS, EC, DO and Mg parameters were analyzed by using standard procedures (APHA 2005).

RESULTS AND DISCUSSION

The pH of Vaigai river surface water at Kochadai and the groundwater in the study area was slightly alkaline the same level was maintained before and after construction of check

Table 1. Water quality of Vaigai Kochadai

Parameter	Level of water quality parameters	Before construction of Check Dam in the year 2011-2014		After construction of Check Dam average value 2015-2018	
		Vaigai River surface water	Infiltration well Vaigai River Kochadai	Vaigai River surface water	Infiltration well Vaigai River Kochadai
pH	8.5	7.5	7.5	7.7	7.7
Specific conductance (µmhos cm^{-1})	2250	900	980	1060	1200
Turbidity (NTU)	5	8	3	6	0
Total dissolved solids (mg l^{-1})	2000	920	300	790	140
Dissolved oxygen (mg l^{-1})	5	4.2	2	4	1
Total alkalinity as CaCO$_3$ (mg l^{-1})	600	870	342	690	210
Total Hardness as CaCO$_3$ (mg l^{-1})	600	1200	240	716	177
Calcium as Ca (mg l^{-1})	200	220	190	195	60
Magnesium hardness (mg l^{-1})	100	70	45	44.3	31
Sulphate (mg l^{-1})	400	28	14	24	11
Chloride as Cl (mg l^{-1})	1000	355	300	340	71
Sodium (mg l^{-1})	100	142	93	140	30
Phosphate as PO$_4$	0.5	0.2	0	0.2	0
Fluoride as F	1	1	0.31	0.8	0.29

dam and it is in the permissible limit of 6-6.8 (WHO). EC of groundwater was comparatively high after the check dam construction. The desirable limit for TDS in drinking water is 500 mg/l as per WHO, the sample at Kochadai of the river having higher TDS range of 140-1060 mg l^{-1}. The TDS of groundwater were within the desirable limit due to shorter residence time. The turbidity level was maintained between 0- 8 and it was in the permissible limit of 10NTU of WHO. The dissolved solid range was in permissible limit of WHO range 2500 mg l^{-1}. The dissolved oxygen level was higher when compared with WHO standard of 1 mg l^{-1}. It shows the high purity of water. The hardness level was slightly high when compared to WHO limit of 120 mg l^{-1}. The calcium hardness level was also high when compared with the permissible level. The chemical component like magnesium, sulphate, sodium, chloride, phosphate and fluoride are in the range of

WHO. The commercial activities increases the chemical contamination but due to self-purification process and large quantity of water dilute the contamination level during monsoon period in post monsoon the contamination little bit high.

The average monthly groundwater table level was observed to determine the efficiency of check dam after construction from 2010 to 2018. The average low groundwater level was observed 5.30m in the year 2012 due to low level of rainfall. The highest groundwater level was observed in the year 2017 with a average of 9.00m. This study shows that during the entire month of 2010 to 2018 the groundwater level was maintained due to the activity progression of check dam showed in the Table 3. Same time the water level of infiltration well was checked in the particular period (2010 to 2018) in nearby six wells for this study and the

Table 2. Monthly ground water table level before and after construction of Kochadai check dam Madurai district

Year	Ground water table average Madurai district BGL in meters								
	2010	2011	2012	2013	2014	2015	2016	2017	2018
period	1	2	3	4	5	6	7	8	9
January	6.10	2.74	3.05	6.88	7.64	6.27	5.41	8.83	7.76
February	4.32	2.82	3.29	7.46	7.82	6.37	5.65	9.14	8.16
March	6.24	3.21	3.81	7.88	8.24	7.06	6.25	10.34	6.39
April	6.52	4.01	4.77	8.08	8.83	7.52	6.99	8.95	7.12
May	6.16	4.12	4.75	8.4	9.22	7.15	7.38	9.36	7.43
June	6.26	4.12	4.75	8.67	8.96	6.30	7.50	9.34	7.26
July	6.37	5.17	6.16	9.07	9.45	6.61	7.44	10.09	8.13
August	6.61	5.48	6.61	9.07	9.85	6.99	7.66	9.41	8.46
September	6.71	5.67	7.02	8.36	9.77	7.18	7.9	8.6	6.91
October	7.55	5.35	6.77	8.51	9.41	7.23	8.28	8.41	6.84
November	4.70	4.15	6.14	7.25	6.47	6.71	7.72	7.82	5.64
December	2.79	3.35	6.48	7.37	6.21	5.63	8.42	7.76	5.83
Average	5.99	4.18	5.30	8.08	8.49	6.75	7.22	9.00	7.96

Table 3. Vaigai river surface water level in upstream of check dam and ground water level in infiltration and observation wells (below ground level in meters)

Year	Surface water Kochadai Check Dam	Raw water from infiltration well	Well 1	Well 2	Well 3	Well 4	Well 5	Well 6
Before construction of CD (2009)	4.00	5.00	5.10	5.80	5.70	5.40	5.70	6.00
After Construction of CD (2010)	3.80	3.90	4.20	4.70	4.30	4.50	4.70	4.30
2011	3.70	3.80	5.30	5.00	4.80	5.10	5.00	5.10
2012	3.80	3.90	8.00	7.60	6.30	7.60	7.60	7.80
2013	4.00	4.10	8.30	7.80	6.00	7.50	7.70	8.10
2014	3.90	4.00	7.50	7.40	6.20	7.20	7.00	7.40
2015	4.00	4.10	7.10	6.70	6.00	6.50	6.90	7.20
2016	4.10	4.20	7.90	6.90	6.00	6.60	7.90	7.70
2017	3.70	3.90	7.50	6.30	6.20	6.10	7.30	7.40
2018	3.50	3.70	6.80	5.20	4.70	5.00	5.20	6.00
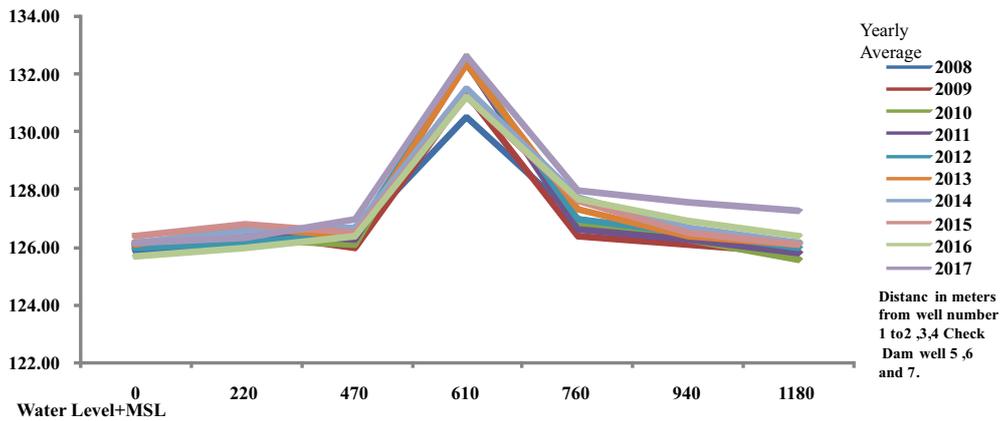
Fig. 1. Below ground water level with reference to mean sea level

water level was checked before and after construction of check dam. It is observed that after construction of check dam, the infiltration rate increased the groundwater level in well. Ground-water levels are controlled by the balance among recharge to, storage in, and discharge from an aquifer. Physical properties such as the porosity, permeability, and thickness of the rocks or sediments that compose the aquifer affect this balance. So, too, do climatic and hydrologic factors, such as the timing and amount of recharge provided by precipitation, discharge from the subsurface to surface-water bodies, and evapo transpiration. When the rate of recharge to an aquifer exceeds the rate of discharge, water levels or hydraulic heads will rise. Conversely, when the rate of ground-water withdrawal or discharge is greater than the rate of ground water recharge, the water stored in the aquifer becomes depleted and water levels or hydraulic heads will decline. Using a pulsed recharge to create dry and wet cycles and maintaining low standing water heads in the basins appeared to reduce microbial growth, and therefore enhanced infiltration. The considerable rise in water table was observed due the construction of check dam in this area. The necessity of
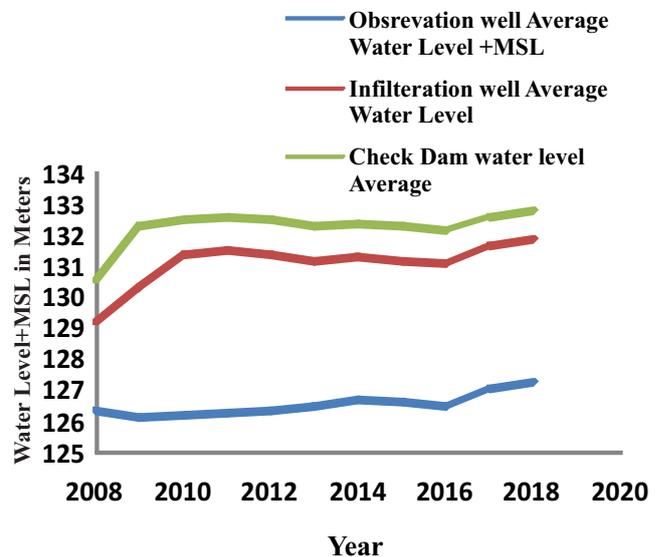
Fig. 3. Average water level in Kochadai Check dam and wells

artificial recharge of aquifers is increasing day by day due to excessive demand of water by the ever-growing population and also because of the scarcity of good dam sites available for construction. Artificial recharge of aquifer is the process of adding water to an aquifer through human effort. The main purpose of artificial aquifer recharge is to store water for later use while improving upon the quality of water.

In this study, the groundwater level of Kochadai Check Dam increased significantly even though continuous withdrawal of average daily 3.375 million liters and totally 1231.80 million liters. From this study, the continuous yield of 3.375 million liters and good quality of raw ground water from decommissioned Kochadai Water supply head works. The total water extracted or withdrawal from Ground water aquifer in Vaigai river in Kochadai Check Dam water spread works out to Equivalence to the Check dam capacity as number of fillings equals to 1231875/86684=14.21times. This detailed

Fig. 2. Ground water level B.G.L in meters

study confirmed that the groundwater level increased into 0.30 to 0.85 meter.

CONCLUSIONS

In Kochadai Check Dam the ground water levels increased in the range of 7.8m. Even though continuous withdrawal of average daily 3.375 million liters and totally 1231.80 million liters annually. The continuous yield of 3.375 MLD and good quality of raw ground water from decommissioned Kochadai water supply head works proves the efficiency of the constructed check dam to augment ground water through artificial recharge from the Vaigai river surface, water spread and stored due to Kochadai check dam water throughout the year. The total water extracted or withdrawal from ground water aquifer in Kochadai check dam water spread works out to Equivalence to the check dam capacity as number of fillings equals to nearly 14 time capacity. This study proves that check dam is one of the best efficient method to improve the ground water quality and water head. The quality of surface water of Vaigai improved substantially due to extended filtration available since the sandy aquifer Vaigai River at Kochadai check dam. The upstream act as a sand filter. The water held by the check dam due to infiltration process resulted in maintaining the ground water level.

REFERENCES

Ali Reza Vaezi, Mohammad Abbasi, Saskia Keesstra and Artemicerda 2017. Assessment of soil particle erodibility and sediment trapping using check dams in small semi-arid catchments. *Catena* **157**: 227-240.

Guillaume Piton and Alain Recking 2017. Effects of check dams on bed-load transport and steep-slope stream morphodynamics. *Geomorphology* **291**: 94-105.

HuaizhiSu, Jinyou, Zhiping, wen, ZhiunGuo and Ranilian Zhou 2018. Integrated certainty and uncertainty evaluation approach for seepage control effectiveness of a gravity dam. *Applied Mathematical Modeling* **65**: 1-22.

Hao Sun, Yong You and Jinfeng Liu 2018. Experimental study on blocking and self cleaning behaviors of beam dam in debris flow hazard mitigation. *International Journal of Sediment Research* **33**: 395-405.

Identiciamarwein and Susmita Gupta 2018. Aquatic Insects as Indicator of Water Quality: A Study on a Small Stream of Shillong, Meghalaya, North-east India. *Indian Journal of Ecology* **45**: 511-517.

Julian Kirchherr, Mats Philip Ahrenshop and Katrina Charles 2018. Resettlement lies Suggestive evidence from 29 large dam projects. *World Development* **114**: 208-219.

Gonzalez-Romero J, Lucas Borja ME, Plaza Álvarez PA, Moya D and De Las Heras J 2018. Temporal effects of post-fire check dam construction on soil functionality in SE Spain. *Science of the Total Environment* **642**: 117-124.

Senthil Kumar M, Sivasankar V and Gopalakrishna GVT 2017. Quantification of benzene in groundwater sources and risk analysis in a popular South Indian Pilgrimage City A GIS based approach. *Arabian Journal of Chemistry* **10**: 523-533.

Maciej 2018. Dam reservoir backwater as a field-scale laboratory of human-induced changes in river bio geomorphology: A review focused on gravel-bed rivers. *Science of the total Environment* **651**: 2899-2912.

Mohammed Falah Allawi, Othman Jaafar, Firdaus Mohamad Hamzah and Ahmedei Shafie 2018. Novel reservoir system simulation procedure for gap minimization between water supply and demand. *Journal of Cleaner Production* **206**: 928-943.

Mohammad Ebrahim Banihabib and Ali Forghani 2017. An assessment framework for the mitigation effects of check dams on debris flow. *Catena* **152**: 277-284.

Mailhot A, Talbot G, Richard S, Turcotte R and Guinard K 2018. Assessing the potential impacts of dam operation on daily flow at ungauged river reaches. *Journal of Hydrology Regional Studies* **18**: 156-167.

Nwokwu GN, Ekwu LG and Utobo EB 2018. Performance of groundnut Arachishypogaea L varieties as affected by weeding frequencies. *Indian Journal of Ecology* **45**: 325-329.

Sathyamoorthy NK, Ramaraj AP, Senthilraja K, Swaminathan C and Jagannathan R 2018. Exploring rainfall scenario of PeriyarVaigai command area for crop planning. *Indian Journal of Ecology* **45**: 11-18.

Pratibha Kumari, Pravendra Kumar and Singh PV 2018. Rainfall runoff modelling using artificial neural network and adaptive Neuro-Fuzzy inference system. *Indian Journal of Ecology* **45**: 281-285.

Roger L Burritt and Katherine Christ L 2018. Water risk in mining: Analysis of the Samarco dam failure. *Journal of Cleaner Production* **178**: 196-205.

Su Huaizhi, Jinyou Li, Zhiping Wen and Fengfeng Zhou 2018. A bi-criteria combined evaluation approach for reinforcement effect of gravity dam with cracks. *International Journal of Solids and Structures* **147**: 238-253.

Bouregaya S, Kacimi L, Patapy C and Clastres P 2018. Synthesis of alite cement with low environmental impact by using sludge from a dam reservoir and zinc sulphate as a mineralizer. *Construction and Building Materials* **190**: 752-764.

Suneet Naithani, Ashutosh Singh and Akshaya Verma 2018. Mapping of natural hazards and expected incidences in Great Himalayan national park. Himachal Pradesh. *Indian Journal of Ecology* **45**(3): 483- 488.

Tomas Galia, Radek Tichavsky, Vaclav Skarpich and Karel Silhan 2018. Characteristics of large wood in a headwater channel after an extraordinary event the roles of transport agents and check dams. *Catena* **165**: 537-550.

Pradeep T and Ananda Kumar 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.

Xuanmei Fan, Weiwei Zhan, Xiujun Dong, Ceesvan Westen and Hans-Balder Havenith 2018. Analyzing successive landslide dam formation by different triggering mechanisms The case of the Tangjiawan landslide, Sichuan, China. *Engineering Geology* **243**: 128-144.

Socio-Economic Vulnerability of Riverbank Erosion of Displacees: Case Study of Coastal Villages in Bangladesh

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Abstract: Bangladesh is a riverine country and the geography and culture of this country is influenced by the riverine delta system. The country is suffering from acquit riverbank erosion and which forced to the people to be displaced from their native place. This prevalent river bank erosion of Barisal District has led to numerous socio-economic vulnerability and consequences like loss of housing and other essential infrastructure, loss of agricultural land, other important resources, distrust and political instability, ethnic tensions and civil conflict. The aim of the study was to examine the socio-economic vulnerability and coping strategies of riverbank erosion displacees in the district of Barisal, Bangladesh. The study was conducted with 253 displacees and face-to-face interview used a semi-structured questionnaire. Result shows that displacees suffer from severe poverty (35.17%), unemployment (41.89%), lose of land (95.26%), houses (98.42%), agricultural firm (90.91%) and livestock (86.56%). The social destruction and degradation of quality of life makes them more vulnerable in the society. The exposure to this natural hazards was assessed and analyzed to see their effects on socio-economic sector.

Keywords: Bangladesh, Disaster, Riverbank erosion, People, Vulnerability

Bangladesh has been victim is edseverely by various sporadic natural disasters- flood, cyclone and storm surge, flash flood, drought, tornado, riverbank erosion, and landslide etc. Family and societal lives of people are being seriously disturbed and unsecured by these every year natural calamities. They also bring deadly damages for economy and general environment of the country (Ali, Hatta and Azman 2014). Disaster impacts include loss of life, injury, disease and other negative effects on human physical, mental and social well-being, together with damage to property, destruction of assets, loss of services, social and economic disruption and environmental degradation (Zimmermann, Glombitza and Rothenberger 2010). Among the above highlighted natural hazards, riverbank erosion is one of the most important hazard in Bangladesh. A study estimated that riverbank erosion displacees 50,000 to 200,000 people every year in Bangladesh (Kniveton et al 2013). The major rivers, Brahmaputra, Padma, Jamuna, and Meghna, erode several thousand hectares of flood plain making millions of people landless and homeless every year in Bangladesh (Islam and Rashid 2011). In 2017, severe floods have affected at least 8 million people, causing deaths, loss of livestock and food supplies, and damage to housing and infrastructure. The floods caused severe damage to the agriculture sector, including crop losses of the main staple food rice, mostly in the northern district. It also destroys their employment and social network and forces the coastal people to leave their place of origin and compels them to find out safer places for resettlement. The farmers of Bangladesh at large and of coastal areas in particular are depended on nature for agricultural production that is destroyed by erosion. The onslaught of erosion on agriculture has an adverse impact on food security of the region as well as the whole country (Islam and Rashid 2011).

Riverbank erosion causes socio-economic and environmental problems in Bangladesh. Climate change has contributed to rapid siltation of the river in recent years, which is intensifying bank erosion during the monsoon. The flow of the Brahmaputra is influenced strongly by the melting of snow and ice upstream, mainly in the eastern Himalaya mountains. Every year, the river carries silt from the Himalayas and deposits it downstream in Bangladesh, creating myriad islands known as chars. When floods occur upstream on the Brahmaputra, amid more intense bursts of heavy rainfall linked to climate change, the silted-up river has less capacity to carry the huge volume of water, accelerating bank erosion. The, objectives of this study were to identify the socio-economic vulnerability of displaces people due to

riverbank erosion that makes them more helpless in the society in Bangladesh.

MATERIAL AND METHODS

The study was conducted from June-December in 2017 in two villages Lohalia and Rajguru at the Upazila (sub-division) of Babuganj in the district of Barisal (Fig. 1). The study was conducted with 253 displacees and face-to-face interview used a semi-structured questionnaire by random sampling. Data was analysed by descriptive statistics and findings were presented by tables, figures and graphs.

RESULTS AND DISCUSSION

Among the participants, 58.49 per cent were male and 41.51 percent were female. In term of marital status 80.63 percent were married, 11.06 per cent widow, 5.13 percent widower and rest of 3.16 per cent were divorced. It was proved that the rate of divorce was very low in the study areas. A similar finding on employment status indicate that 41.89 percent were unemployment, 24.50 and 15.81 per cent depend on fishing and agriculture. There is a great concern that majority of the respondents were unemployed. The displaces are engaged in fishing activities and day-labour in agricultural activities. Moreover, the people considered for the survey represent the main workforce at the study area, they have been facing all the negative impacts of riverbank erosion and to take steps for their own survival. The people are more vulnerable to natural and other hazards currently than ever before, due to increases in population, but more so to their location in dangerous areas (Barman et al

2012, Ali, Hatta and Azman 2014). The majority of the (35.17 percent) respondents' income were 5-10 US$, which is below in the poverty line and only 7.50 per cent were with annual income of 41-50.US$. Majority of 48.61 per cent were with family size of 4-5 persons followed by 16.21 per cent with 6-7 persons (Table 1). Therefore, most of the family was in joint family structured and depended on each other's.

Age of marriage and literacy rate of the displacees: The male are married typically around the age of fifteen and less than 20 years and female age between 15−20 years. The report also shown the majority (59.72 per cent) of the respondents were 20 years old, followed by 29.63 per cent 20−30 years old and 10.65 per cent 30−40 years old. The riverbank erosion affected area of Lohalia and Rajguru revealed that most of the displacees (64.19 per cent) are illiterate and work as unskilled labourer with low income. The displacees are very poor, so they could not ensure primary or other education category system for themselves and their children because of financial problems. The majority respondents of displaces, education qualification is bellow secondary school. Almost every respondents of the study area reported that priority for income for living but no need for education indicating that education not priority. Among the riverbank erosion affected area of Lohalia and Rajgurua very low attainment in education among the respondents and head of the household. The higher the education level, the greater one's capacity to understand flood forecasting and to reduce one's vulnerability to flooding is essential (Islam et al 2012). According to the constitution of Bangladesh and Millennium Development Goals (MDGs) it is responsibility to
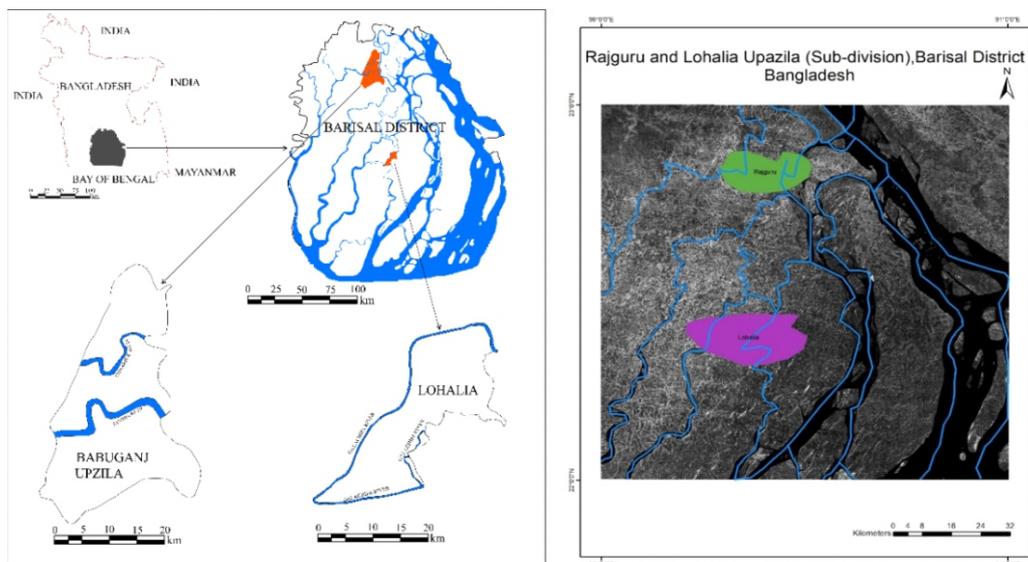
Fig. 1. Geographic information system (GIS) map of study areas

Table 1. Demographic profile of the respondents

Indicators	N (253)	Percentage (%)
Sex of the respondents		
Male	148	58.49
Female	105	41.51
Marital Status		
Married	204	80.63
Widow	28	11.06
Widower	13	5.13
Divorced	08	3.16
Employment status of the respondents		
Unemployment	106	41.89
Fishing	62	24.50
Agriculture	40	15.81
Day labour	07	2.77
Shoop keeper	06	2.37
Hawkers	05	1.97
Rickshaw Puller	10	3.96
Service	07	2.77
Business	10	3.96
Monthly income (USD) of the respondents		
05−10	89	35.17
11−20	66	26.06
21−30	40	15.81
31−40	24	9.48
41−50	15	5.92
51−60	19	7.50
Family size of the respondents		
2−3 persons	89	35.18
4−5 persons	123	48.61
6−7 persons	41	16.21

ensure primary education for all of her citizens.

Residential pattern of the displacees: The most of the displacees are very poor that makes them more vulnerable in the society. The displacees had lost their houses due to riverbank erosion. Temporary housing structure are made of bamboo, straw, wood, and mud, semi-permanent structure made of tin, bamboo, and brick, permanent structure made of brick, concrete etc. The majority (79.41%) of the displacees made their house by CI sheet with woods, 7.1 per cent thatched house, 6.72 per cent straw with woods and 6.32 per cent semi-building. Governmental responses to face natural disaster have been slow, unresponsive or insufficient. Top-down intervention alone in disaster management was becaus such intervention often paid little attention to addressing community dynamics, perceptions and needs, ignored the potential of local resources and capacities that in some cases increased people's vulnerability (Chamlee-

Wright and Storr 2011). The national and local voluntary agencies lack adequate financial resources to operate community-based program for disaster management. Moreover, the government could not repair the damaged embankments even after several years (Begum 2014). The majority (54.54%) houses were 3-4 years, 24.51 per cent 1-2 years, 13.83 per cent 5-6 years, 7.11 per cent more than seven years old.

Frequency of displaces by displacees: The majority (68.77%) of the respondents were displaced more than three (>3) times, 18.58 per cent three (3) times, 7.51 per cent two (2) times and rests of 5.14 per cent once from their original homestead. Most of the people are living with natural calamities and due to the natural disaster i.e. riverbank erosion hit and eroded their lands and homestead every year. The displaced usually move to nearby areas and sometimes far way. In erosion-prone areas, most families have witnessed a displacement in their lifetime (Rahman 2010). The river bank erosion and flood disaster are dominant reasons of extensive damage of infrastructures, crops, livestock, rural livelihoods and increased social insecurity, economic loss, temporary migration and displacements (Paul and Routray 2011, Islam and Walkerden 2014 and Saha 2015). Their living places and cultivable lands submerged into riverbed. Therefore, the displaced people have to leave their living place several times. Erosion causes destruction of land and force people to migrate from their native place (Barman et al 2012).They are living in the bellow of poverty line because they had lost their all kinds of assets. More than 95.65 percent displacees were forced to leave their original homesteads and migrated to another places of same village On the other hand, only 5.14 percent of the displacees migrated to another place and later came back and rebuilt their house. The earlier study show that 50 percent of the total homeless people are victims of riverbank erosion and they cannot rebuild their home due to poverty and scarcity of resources (Islam and Rashid 2011).

Nature of losses of displacees: The 98.42 per cent of the respondents lost houses, 95.26 per cent displaced people has lost their land and households, 90.91 per cent crops, 86.56 per cent livestock, 74.70 per cent loses their income and 55.35 per cent loses their neighbours (Fig. 2). Estimation shows that, 50 percent of the total homeless people are victims of riverbank erosion and they cannot rebuild their home due to poverty and scarcity of daily life resources (Table 1). Four million of such homeless people in Bangladesh are compelled to lead a floating life (Islam et al 2012 and Ali et al 2016). Most of the displacees did not have access to safe drinking water and faced food scarcity and pure drinking water is scarce and cost in that affected area.
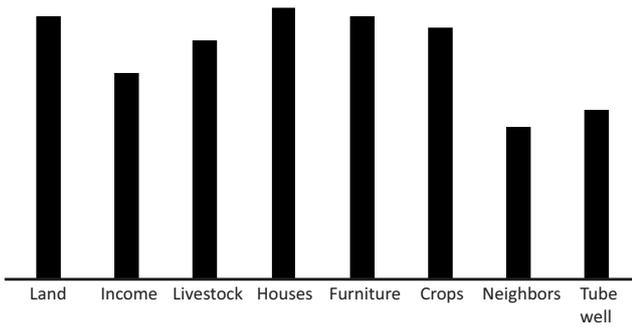
Fig. 2. Losses due to riverbank erosion induced displacement (note: multiple responses considered)
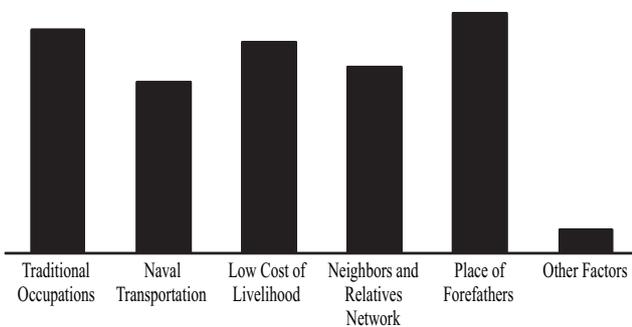
Fig. 3. Factors behind choosing present location for the settlement

The losses of riverbank erosion it had actively impact on their socio-economic situation and the enormous loss is quite impossible to recover.

Factors behind choosing present location for the settlement: The villages of Lohalia and Rajguru are very much vulnerable to riverbank erosion displacement and mostly disastrous areas in southern Bangladesh. Most of the displacees reported that they feel no comfort with their low socio-economic profile to leave their place of origin and to go for resettlement in new places (Haque and Uddin 2013) and feel very much ease in resettling themselves in the present villages after displacement. Majority of the displacees (98.81%) stayed for resettlement, as it is their fore fathers' land. More that 92.09 percent displaces stayed and resettled in their present villages for continuing their livelihood within a network of traditional occupations. About 86.96 percent indicated that they are capable of continuing their subsistence need. After displacement, their cost of livelihood is comparatively low. About 76.68 per cent respondent also indicated they don`t want lose of their neighbors and relatives and naval transportation (70.36%). They are committed to stay in their original village and very much reluctant to leave though they recurrently displaced due to riverbank erosion

attacks. Moreover, they are optimistic for the accretion of their dislocated homestead plot in near future and they will be able to resettle on that accreted land.

Perception for assistance and cooperation and coping mechanism of displacees: Social bonding between the displacees is strong. The 57.31 per cent of the respondents of Lohalia and Rajguru were satisfied with their local neighbours in cooperation for the emergency and 42.69 per cent not satisfied. They shared their labour force and worked physically also for other households to shift household goods and family members. They responded quickly and shared all other facilities in that crucial time. That was so many years, they were living side by side, shared their joy and sorrow and asserted security for each other. The majority (34.59%) of the displacees sold their cattle and households properties, 28.10 percent taking loan form NGOs, 11.08 per cent getting help from their relatives, 10.56 per cent changing their profession, 8.65 per cent received assistance from government and rest of 7.02 per cent received assistance from local leaders. Uddin (2012) also mentioned self-coping strategies were decreasing the number and size of daily meals, consumption of wild food, selling labour at very low rate, selling fixed and movable household assets, contracting new loan at a high interest rate and cultivation of short duration crop. On the other hand, assisted coping strategies include relief food, social network and begging.

Policy recommendations: Every year, areas on the bank line are getting affected by riverbank erosion. Therefore, a comprehensive riverbank erosion management policy should be made nationally like the rights and security of the victims should be ensured, proper steps for relief and rehabilitation for the displacees should be taken and development program for resettlement of erosion-induced displacees can be introduced. In addition, emergency fund' for the erosion-induced can be created by the government, National Coordination Council can be formed to coordinate bank-protection worksand victims, Government should provide accommodation in *Adarshya Gram (*refugee camps) and *Abashon (housing)* projects on priority basis, Allotte minimum amount of *Khasland* (government land) to them for shelter The steps are required for creation of employment opportunities.

CONCLUSION

The displacees are in under poverty with lose of land and houses, agricultural firm, livestock firm. Moreover they are displaced socially and degradation of quality of life that makes them more vulnerable in the society. There is need to introduce the Community-Based Disaster Management (CBDM) strategy, which will reduce vulnerabilities and the

strengthen people's capacity to deal with hazards and cope with disasters. The exposure to this naturel hazards should be assessed and analyzed for effects on socio-economic sector. The findings will be helpful for the academicians, national planners, development workers, and the policy implementers to formulate a proper policy for displacees in Bangladesh.

REFERENCES

Adam MR 2010. Upgrading homestead to flood shelters in Char Kochkhali, Gaibandha. Postgraduate Programs in Disaster Management (PPDM), *BRAC University, Dhaka*: Bangladesh. Retrieved 12 October, 2018,

Ali I, Hatta Z and Azman A 2014. Transforming the local capacity on natural disaster risk reduction in Bangladeshi communities: A social work perspective. *Asian Social Work and Policy Review* **8**(1): 34-42.

Ali I, Hatta Z, Azman A, Islam S, Mazumder AH and Hossain K 2016. Community participation in disaster management: A case study of Bangladesh. *Indian Journal of Ecology* **43**(2): 463–472.

Barman SD, Majumder SC, Rahaman M Z and Sarker S 2102. Foundations of migration from the disaster consequences coastal area of Bangladesh. *Developing Country Studies* **2**(4): 22-30.

Begum M 2014. Politics in disaster management in Bangladesh. *Scholars Journal of Arts, Humanities and Social Sciences* **2**(4A): 522-530.

Chamlee-Wright E and Storr VH 2011. Social capital as collective narratives and post disaster community recovery. *The Sociological Review* **59**(2): 266-282.

Emmanuel Mavhura, Bernard Manyena and Andrew E. Collins 2017. An approach for measuring social vulnerability in context: The case of flood hazards in Muzarabani district, Zimbabwe. Geoforum **86:** 103-117.

Hossain AM 2013. Community participation in disaster management: Role of social work to enhance participation. *Antrocom Online Journal of Anthropology* **9**(1): 159-171.

Hossain K and Rama RA 2014. Environmental change and it's affect. *European Journal of Sustainable Development* **3**(2): 89-96.

Islam MF and Rashid ANMB 2011. Riverbank erosion displaces in Bangladesh: Need for institutional response and policy intervention. *Bangladesh Journal of Bioethics* **2**(2): 4-19.

Islam MR 2012. Vulnerability and coping strategies of women in disaster: A study on coastal areas of Bangladesh. *The Arts Faculty Journal* **2**(2): 147-167.

Islam R and Walkerden G 2014. How bonding and bridging networks contribute to disaster resilience and recovery on the Bangladeshi coast. *International Journal of Disaster Risk Reduction* **10**(part A): 281-291.

Islam MS, Hasan TM, Chowdhury SIR, Rahaman MH and Tusher TR 2012. Coping techniques of local people to flood and river erosion in char areas of Bangladesh. *Journal of Environmental Sciences and Natural Resources* **5**(2): 251-261.

Kniveton D, Martin M and Rowhani P 2013. *Sensitivity testing current migration patterns to climate change and variability in Bangladesh.* Working paper 5. Refugee and Migratory Movements Research Unit (RMMRU), University of Dhaka, Bangladesh and Sussex Centre for Migration Research (SCMR), University of Sussex: London.

Mallick B and Vogt J 2014. Population displacement after cyclone and its consequences: Empirical evidence from coastal Bangladesh. *Natural Hazards* **73**(2):191-212.

Paul SK and Routray JK 2011. Household response to cyclone and induced surge in coastal Bangladesh: Coping strategies and explanatory variables. *Natural Hazards* **57**(2): 477-799.

Rahman MR 2010. Impact of riverbank erosion hazard in the Jamuna flood plain areas in Bangladesh. *Journal of Sciences Foundation* **8**(1 and 2): 55-65.

Saha CK 2015. Dynamics of disaster-induced risk in South Western coastal Bangladesh: An analysis on tropical cyclone aila 2009. *Natural Hazards* **75**(1): 727-754.

Shajahan A and Raja MY 2012. Riverbank erosion and sustainable planning guidelines for Bangladesh with emphasis on Padma River. *Journal of Habitat Engineering and Designing* **4**(2): 145-156.

Uddin ME 2012. Household food security status of marginal farmers in selected storm surge prone coastal area of Bangladesh. *The Agriculturists* **10**(1): 98-103.

Haque C E and Uddin M S 2013. Disaster management discourse in Bangladesh: A shift from post-event response to the preparedness and mitigation approach through institutional partnerships. In Tiefenbacher (Eds.), *Approaches to disaster management-examining the implications of hazards, emergencies and disasters* (p.34-54). INTECH: Rijeka: Croatia- European Union.

Zimmermann M, Glombitz KF and Rothenberger B 2010. *Disaster risk reduction programme for Bangladesh 2010-2012.* Swiss Agency for Development and Cooperation (SDC). Switzerland.

Hydrochemical Analysis of Groundwater Quality in Virudhunagar district, Tamil Nadu, India

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Abstract: Groundwater quality varies with time and hence it is necessary to continuously monitor the groundwater quality. This study was aimed to identify the groundwater quality for various uses in Virudhunagar district, Tamil Nadu, India. Groundwater samples were collected from fifty-three locations in two seasons, pre-monsoon and post monsoon. Thickness of weathered zone ranges from 4 to 15 m. Depth of dug wells range from 10 to 15 m bgl and bore wells extend from 60 to 90 m bgl. Groundwater level ranges from 5.6 to 41.2 m bgl in pre-monsoon and from 1.2 to 28.4 in post-monsoon.Dominant groundwater types were Ca-Mg-Cl and Na-Cl. Dominance of major cations in pre-monsoon was sodium> magnesium> calcium> potassium and post-monsoon was sodium> calcium> magnesium >potassium. The order of dominance of major anions was same for both seasons-chloride> bicarbonate>sulphate> carbonate. Groundwater is fresh in 55% of samples in both seasons and brackish in 45% of the samples based on total dissolved solids. Based on total dissolved solids, it was permissible in 13% of the samples in pre-monsoon and 8% of the samples in post-monsoon. Water was hard based on total hardness. For irrigation use, groundwater was unsuitable mainly based on magnesium hazard. Nearly 70% of groundwater samples were unsuitable for industrial use. Groundwater quality have to be assessed in this area before using it for any intended purpose.

Keywords: Groundwater quality, Fluoride, Spatial interpolation, Geostatistics

Groundwater is exploited more than surface water as it is available throughout the year and comparatively less polluted than surface water. But this condition is decline in these days as several cases of groundwater pollution are reported frequently (Muhammad et al 2011 and Brindha & Elango 2014). Source and composition of recharge water i.e. rainfall, infiltration from river flow, treated wastewater etc. determine the groundwater quality. Influence of temperature in dissolution of minerals from rocks, interaction between the dissolved salts and residence time of groundwater determines its regional chemical composition and characteristics (Rajesh et al 2012 and Brindha et al 2014). These are the natural processes contributing to groundwater chemical composition. Additional complexity arises from human-induced pollution such as industrial wastewater disposal, landfills, mining operations, use of chemical fertilizers.

The water use for domestic, industrial and irrigation is determined by its chemical composition. Assessment of groundwater quality is important not only in the spatial scale but also at temporal scale. Even when there is no risk posed to groundwater quality, it is necessary to monitor them regularly to understand the dynamics. Major water quality issues in India are due to fluoride (Brindha et al 2016, Jagadeshan et al 2015), nitrate (Buvaneshwari et al 2017,

Singh et al 2017), arsenic (Sankar et al 2014 and Chakraborti et al 2016), other heavy metals (Kanagaraj and Elango 2016) and salinity (Kumar et al 2015 and Surinaidu 2016).

The present study was carried out in a water quality deteriorated district of Tamil Nadu, India. Several industries manufacturing textiles, cement, fireworks and printing industries are located inthis area (Kumar et al 2015 and Surinaidu 2016). So far, very few studies are available on the water quality of this area. Manimegalai and Muthulakshmi (2006) reported on the fluoride content in groundwater of few areas within the district. Magesh and Chandrasekar (2011) developed a water quality index (WQI) map (for samples collected in the year 2008) indicating good quality water in most parts of the district. This study was carried out with the aim to identify the recent groundwater chemistry and its use for various purposes in Virudhunagar district, Tamil Nadu, India.

MATERIAL AND METHODS

Study area: Virudhunagar (4510sq km) is an administrative district in the southern part of Tamil Nadu state, India (Fig. 1). Hot summers and mild winters are experienced in this sub-tropical climatic region with temperature ranging between 22°C to 38°C (Virudhunagar Statistical handbook, undated). Arjuna, Deviar, Gundar and Vaippar are the non-perennial

rivers draining this area. Anddrainage pattern is dendritic. Geology of this area comprises of recent alluvium, sandstones, gneisses andcharnockites (CGWB 2009 and Magesh & Chandrasekar 2011). Major aquifer systems are the unconsolidated andsemi-consolidated formations with weathered, fissured and fractured crystalline rocks. Due to the variations in lithology, texture and structural features, these aquifers exhibit high heterogenicity even at short distances. Groundwater occurs under phreatic conditions in the weathered zones and semi-confined conditions in the fissured and fractured zones. Alluvial formations of this area have a maximum thickness of 25 m (CGWB 2009).Thickness of weathered zone ranges from 4 to 15 m. Depth of dug wells range from 10 to 15 m bgl and bore wells extend from 60 to 90 mbgl.

Presence of black loamy soil affects irrigation productivity in this region. Surface irrigation is through water from rivers, canals and tanks. Since surface water availability through rivers is only during monsoon period, groundwater is extracted through open wells, tube wells and bore wells for irrigation use. Major crops grown are paddy, millets, maize, pulses, oilseeds, cotton and sugarcane (Loganathan et al 2017). Groundwater samples were collected from 53 locations (35 open wells, 18 bore wells) spread throughout the Virudhunagar district (Fig. 1 and Table 1) in November 2015 and February 2016 to represent post-monsoon and pre-monsoon conditions. Electrical conductivity (EC) and pH was measured at the sampling site with digital portable meters. These digital portable meters were calibrated in the laboratory before the sampling using 84 µS cm^{-1} and 1413 µS cm^{-1} conductivity solutions for EC and 4.01, 7 and 10.1 for pH. 500 ml of groundwater sample was collected in pre-cleaned sampling bottles, properly labelled, stored away from sunlight and brought to the laboratory. Calcium, magnesium, sodium, potassium, carbonate, bicarbonate, chloride, sulphate, fluoride, nitrate and phosphate were analysed in the laboratory following standard titrimetric methods (APHA, 1998). Samples were analysed in triplicate for concordant results and ion balance error (±10%) was calculated for determining the accuracy of the analysis.

RESULTS AND DISCUSSION

Groundwater level: Groundwater occurs under phreatic conditions in the weathered zones and semi-confined conditions in the fissured and fractured zones (CGWB 2009). Alluvial formations of this area have a maximum thickness of 25 m (CGWB 2009). Average groundwater level for pre-monsoon was 13.5 m bgl and post-monsoon 9.5 m bgl. Recharge due to rainfall has led to increase in groundwater level from 0.2 m to 20m (Fig. 2). This range is larger than the

Table 1. GPS location of the sampling station

Sample ID	Location	Latitude	Longitude
1	Khansahibpuram	77.633	9.517
2	Kodikulam	77.858	9.564
3	S.Pudhupatti	77.7681	9.477
4	ZaminSalvarpatti	77.768	9.451
5	Maraneri	77.7563	9.429
6	South Sattur	77.913	9.3678
7	Ramalingapuram	77.932	9.381
8	N.Mettupatti	77.909	9.383
9	Melapattamakurisalkulam	77.569	9.484
10	Mansapuram	77.589	9.498
11	Sundaranaciapuram	77.501	9.424
12	Thulukankulam	77.622	9.463
13	North Karisalkulam	77.62	9.483
14	Padikkasuvaithanpatti	77.613	9.487
15	Kothankulam	77.604	9.47
16	Koiloor	77.63	9.504
17	Kollankondan	77.78	9.372
18	Kovilankulam	77.757	9.571
19	Kovilur	77.633	9.504
20	Malaipatti	77.867	9.55
21	Mandapasalai	77.767	9.333
22	Mararikulam	77.625	9.339
23	Muthuramalingapuram	77.653	9.412
24	Udhaiyanendal	78.09	9.564
25	Uppathur	78.1	9.631
26	Vadakarai	77.95	9.608
27	Vadugapatti	78.163	9.597
28	Vakkanangundu	78.2	9.533
29	Valayapatti	78.011	9.619
30	Vembakottai	78.25	9.517
31	Vidthakulam	78.003	9.567
32	Virudunagar	78.254	9.619
33	Virudunagar Main	78.192	9.667
34	A.Salapuram	77.7	9.564
35	Alankulam	77.475	9.508
36	Amathur	77.558	9.469
37	Asalapuram	77.483	9.4
38	Aviyur	77.45	9.517
39	Chattirareddipatti	77.496	9.497
40	Chekkiahpuram	77.608	9.633
41	Duraisamypuram	77.742	9.603
42	Ettunaikenpatti	77.658	9.55
43	Gananjampatty	77.875	9.617
44	Naduvapatti	77.633	9.462
45	Nathampatti	77.726	9.475
46	P.Pudupatti	77.786	9.481
47	Palavanatham	77.837	9.478
48	Panaiyur	77.794	9.344
49	Pandalkudi	77.835	9.382
50	Pattampudur	77.917	9.353
51	Perumalthevanpatti	77.931	9.281
52	Pulvaykarai	77.939	9.494
53	Rajapalayam	77.869	9.303

reported increase from 0.7 to 12 m bgl (May 2006) and 0.5 to 8.8 m bgl (January 2007) by CGWB (2009) and reported long-term (1998-2007) rise and fall in water level upto 0.4 m and 0.3 m respectively. Pre-monsoon water level in open wells is 5.6 to 19.2 with average of 10.8 m bgl. Post-monsoon open wells 1.2 m to 17.5 with average of 6.9 m. Post-monsoon water level in bore wells is 10.2 to 41.2 with

average of 18.8 m bgl. Post-monsoon bore wells 5.6 m to 28.4 with average of 14.6 m. Water level is shallow in the central and southern parts of the district while deeper water levels are found in other parts (Fig. 3).

Hydrochemical characteristics: The groundwater characteristics of this area was diverse (Fig. 4). The Ca-Mg-Cl and Na-Cl were the dominant types. Order of dominance of major cations and anions in pre-monsoon was sodium> magnesium > calcium> potassium and chloride>

bicarbonate>sulphate> carbonate. The order for anions remained same in post-monsoon, but for cations it was sodium> calcium> magnesium >potassium.

Drinking water quality: The pH exceeded the limits in 25 and 30% of the samples in pre-monsoon and post-monsoon respectively. TDS (calculated from EC) was high in the study area. The maximum permissible limit for TDS is 500 mg l^{-1} and the maximum concentration was 9984 mg l^{-1} and 8056 mg l^{-1} in pre-monsoon and post-monsoon, respectively. Only

Table 2. Minimum, maximum and mean of hydrochemical parameters in pre-monsoon and post-monsoon

Parameter	Unit	Pre-monsoon			Post-monsoon		
		Min	Max	Average	Min	Max	Average
Water table	m bgl	5.6	41.2	13.5	1.2	28.4	9.5
pH	No unit	6.8	9.1	8.3	7.5	8.9	8.3
EC	µS/cm	550.0	15600.0	2255.8	423.0	12587.0	2444.0
TDS	mg/l	352.0	9984.0	1443.7	270.7	8055.7	1564.2
TH	mg/l	144.3	4493.4	614.8	154.1	2361.6	573.2
Ca	mg/l	13.0	350.0	80.7	12.0	568.0	98.3
Mg	mg/l	4.0	899.0	100.8	12.0	458.0	79.9
Na	mg/l	23.0	1986.0	285.8	15.0	1789.0	260.1
K	mg/l	1.0	99.0	12.0	2.0	123.0	14.3
CO_3	mg/l	0.1	9.0	3.3	0.8	6.3	2.6
HCO_3	mg/l	101.0	1986.0	370.4	15.0	1562.0	363.2
Cl	mg/l	25.0	4232.0	445.4	25.0	2147.0	387.2
SO_4	mg/l	20.0	2968.0	253.3	12.0	1984.0	233.3
NO_3	mg/l	2.0	101.0	24.5	2.0	65.0	27.7
PO_4	mg/l	0.3	6.0	1.7	0.5	4.5	1.8
F	mg/l	0.3	1.9	1.0	0.5	2.5	1.3

Table 3. Permissible limit of various parameters in drinking water

Parameter	Unit	Requirement (acceptable limit)	Permissible limit in the absence of alternate source	Number of samples exceeding the limits		Reference
				Pre	Post	
pH	No unit	6.5 to 8.5	No relaxation	13	16	BIS (2012)
TDS	mg/l	500	2000	8	12	BIS (2012)
TH	mg/l	200	600	12	14	BIS (2012)
Calcium	mg/l	75	200	4	3	BIS (2012)
Magnesium	mg/l	30	100	11	13	BIS (2012)
Sodium	mg/l	Not available	200	17	17	WHO (1993)
Potassium	mg/l	Not available	12	12	15	WHO (1993)
Carbonate	mg/l	Not available	Not available	-	-	-
Bicarbonate	mg/l	200	600	4	7	BIS (2012)
Chloride	mg/l	250	1000	4	5	BIS (2012)
Sulphate	mg/l	200	400	6	8	BIS (2012)
Phosphate	mg/l	Not available	Not available	-	-	-
Nitrate	mg/l	45	No relaxation	4	13	BIS (2012)
Fluoride	mg/l	1	1.5	7	15	BIS (2012)

55% of the groundwater samples were suitable for drinking use at both seasons considering the 2000 mg l^{-1} limit. Classification of TDS (Freeze and Cherry 1979) and TH (Sawyer and McCarty 1978) indicate the groundwater of this area is hard and fresh/ brackish (Fig. 5). Though the groundwater has high hardness, calcium was above permissible limits only in few samples (Table 4). However, calcium was above acceptable limits in 38 and 49% in pre-monsoon and post-monsoon respectively. Magnesium exceeded acceptable limits in more than 75% of the groundwater samples and above 20% in prescribed limit. Compared to the other hydrochemical parameters, groundwater quality was worse with respect to magnesium. This has led to the hardness of water and poor water quality due to hardness. Sodium does not have a health-based guideline, but sodium above 200 mg l^{-1} it imparts a displeasing taste to water. Groundwater was above this limit in 32% of the samples at both seasons. Potassium was above the WHO limits in 23% and 28% of the groundwater in pre-monsoon and post-monsoon respectively.

Bicarbonates contribute to the alkalinity of groundwater. Among the anions, bicarbonate exceeds the acceptable limits in most samples- 87% in pre and 62% in post-monsoon. Less than 15% of the groundwater samples exceed permissible limits for bicarbonate. Chloride and sulphate do not pose a threat to groundwater quality in most locations . However, very high concentration of all major ions in few samples raise a public health concern.

High concentration of nitrate in groundwater is a major health concern as it causes methemoglobinemia (Padmanaban et al 2018). Hence, there is no relaxation in the acceptable limits for nitrate. During pre-monsoon and post-monsoon, 8 and 25% of the groundwater samples were above the 45 mg l^{-1} limit. Fluoride, another important ion in view of the health perspective was above permissible limits in 13and 28% of the samples in pre- and post-monsoon, respectively. Consumption of water with fluoride above 1.5 mg l^{-1} for a long period is known to cause dental and skeletal fluorosis. Samples were above acceptable limit for fluoride in 47and 60% in pre- and post-monsoon respectively. The number of samples exceeding the limits for most ions is higher in post-monsoon than pre-monsoon.

Irrigation water quality: Suitability of groundwater for irrigation was assessed based on seven indices. Magnesium hazard (MH) ranges from 10.5 to 90.7 with an average of 64.2 in pre-monsoon and from 15.9 to 88.8 with an average of 54.5 in post-monsoon. MH less than 50 is suitable and above 50 is unsuitable. Majority of the groundwater samples (83%) were unsuitable for MH in pre-monsoon and 68% in post-monsoon (Table 5). Kelly's ratio range from 0.1 to 9.3 in pre-monsoon and 0.1 to 7.6 in post-monsoon. Average of Kelly's ratio was 1.2 and 1.3, respectively. This ratio above 1 is unsuitable and below 1 is suitable. Kelly's ratio based on calcium, magnesium and sodium content of groundwater was unsuitable in 36 and 40% of the samples in pre-monsoon and post-monsoon, respectively.

Residual sodium carbonate (RSC) is based on the hardness and carbonates in groundwater. Average RSC was 6.1 meq l^{-1} and 5.1 meq l^{-1} in pre-monsoon and post-monsoon, respectively. RSC less than 1.25 meq l^{-1} is safe for irrigation, between 1.25 and 2.5 meq l^{-1}is moderately suitable and above 2.5 meq l^{-1} is unsuitable for irrigation. Groundwater is unsuitable in 9% (pre-monsoon) and 15% (post-monsoon) of the samples based on RSC. PI indicated no harm from

Table 4. Suitability as drinking water

| Parameter	Range	Classification	Number of samples		Percentage of samples	
			Pre-monsoon	Post-monsoon	Pre-monsoon	Post-monsoon
TDS (mg/l)	<1000	Fresh	29	29	55	55
	1000-10000	Brackish	24	24	45	45
	10000-100000	Saline	0	0	0	0
	>100000	Brine	0	0	0	0
TDS (mg/l)	<500	Desirable for drinking	7	4	13	8
	500-1000	Permissible for drinking	22	25	42	47
	1000-3000	Useful for agriculture	20	17	38	32
	>3000	Unfit for drinking and agriculture	4	7	8	13
TH (mg/l)	<75	Soft	0	0	0	0
	75-150	Slightly hard	1	0	2	0
	150-300	Moderately hard	15	14	28	26
	>300	Very hard	37	39	70	74
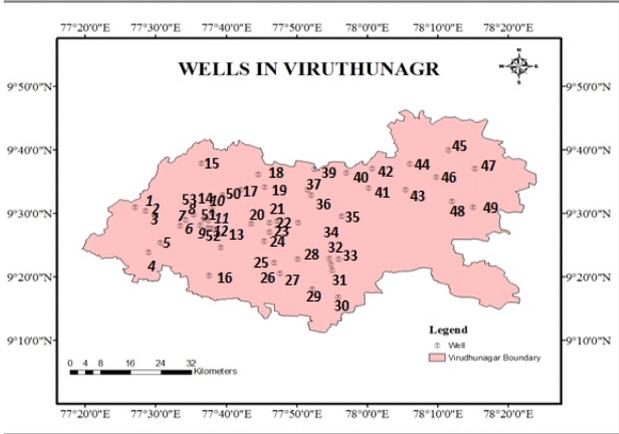
Fig. 1. Location of sampling wells
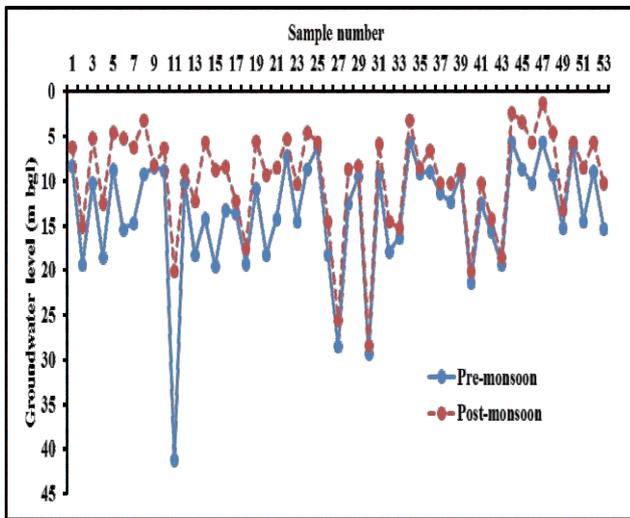
Fig. 2. Groundwater level in pre-monsoon and post-monsoon
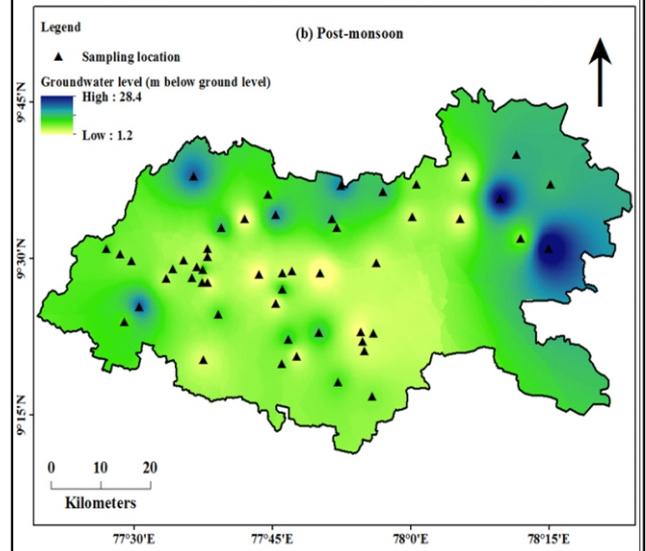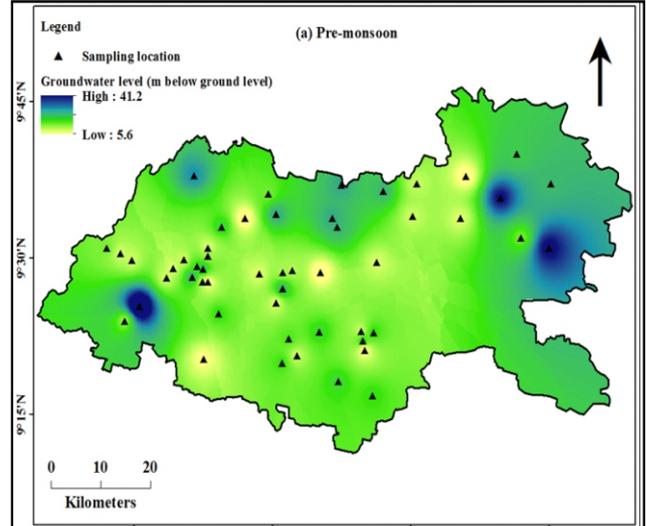
Fig. 3. Spatial variation in groundwater level in pre-monsoon and post-monsoon
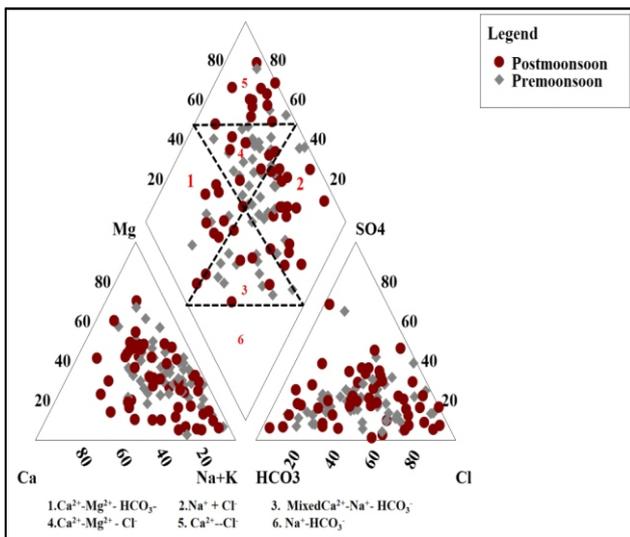
Fig. 4. Piper diagram
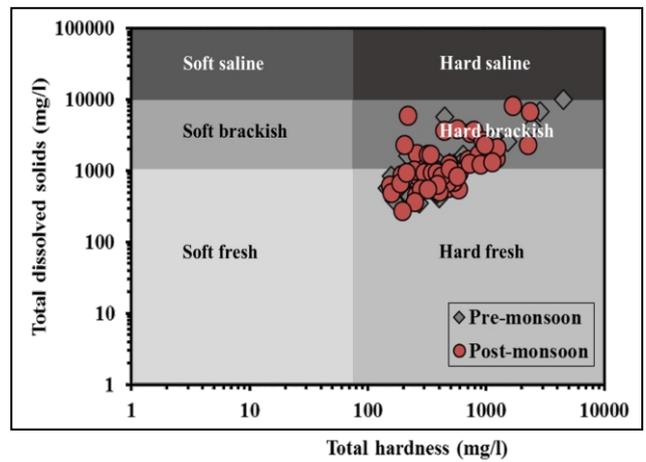
Fig. 5. Hardness and water quality

groundwater use for irrigation (Fig. 6). Sodium based indices classify most samples (>85%) as excellent quality based on sodium absorption ratio (SAR) (Fig. 7) while sodium percent (Na%) (Fig. 8) and salinity hazard classify more than 15% of samples as unsuitable for irrigation (Table 5). All these indices produce independent classification for the same samples. Percentage of samples in the unsuitable range has increased post-monsoon for most indices except for MH Compared to other chemical ions, calcium and magnesium are the major parameters that affect groundwater suitability for irrigation.

Industrial use: LSI indicates the degree of saturation of water with respect to calcium carbonate. It is based on pH as the main parameter and is measured as the difference between the pH measured in water to the pH required to bring the water to its equilibrium state. Positive LSI indicates water is supersaturated with calcium carbonate leading to scale formation and precipitation of calcium carbonate may occur. Negative LSI indicates water is under-saturated with calcium carbonate causing calcium carbonate to dissolve and thus there is no scale formation. Neutral LSI specify that an equilibrium is achieved with neither precipitation of calcium carbonate not dissolution of the compound. Based on LSI index 79-85 samles were not suiable for industrial use. RSI can be classified as the tendency of water for heavy scaling (<5.5), moderate scaling (5.5- 6.2), neutral (6.2-6.8), aggressive water likely to cause corrosion (6.8-8.5) and very aggressive water with high tendency for corrosion (>8.5)and 72-74 % sample fall in this category. For simplicity, this study follows a classification into three simple types as given in Table 6. The modification in calcium carbonate leads scaling and corrosion. Scaling is formed by the deposition/

Table 5. Suitability of groundwater for irrigation

Parameter	Range	Classification	Number of samples		Percentage of samples	
			Pre-monsoon	Post-monsoon	Pre-monsoon	Post-monsoon
Na (%)	<20	Excellent	2	3	4	6
	20-40	Good	16	20	30	38
	40-60	Permissible	25	14	47	26
	60-80	Doubtful	8	13	15	25
	>80	Unsuitable	2	3	4	6
PI	Class I	Suitable	40	42	75	79
	Class II	Permissible	13	11	25	21
	Class III	Unsuitable	0	0	0	0
SAR	<10	Excellent (S1)	48	47	91	89
	10-18	Good (S2)	4	4	8	8
	18-26	Doubtful (S3)	0	0	0	0
	>26	Unsuitable (S4)	1	2	2	4
Salinity hazard (EC in	<250	Excellent or low (C1)	0	0	0	0
	250-750	Good or medium (C2)	5	4	9	8
	750-2250	Permissible or high	37	32	70	60
	>2250	Unsuitable or very	11	17	21	32

Table 6. Industrial water use

Parameter	Range	Classification	Number of samples		Percentage of samples	
			Pre-monsoon	Post-monsoon	Pre-monsoon	Post-monsoon
LSI	Negative	Suitable	7	7	13	13
	Neutral	Suitable	4	1	8	2
	Positive	Unsuitable	42	45	79	85
L-SI	<0.8	Suitable	14	14	26	26
	0.8 to 1.2	Moderate	2	3	4	6
	>1.2	Unsuitable	37	36	70	68
RSI	<6.2	Unsuitable due to scaling	8	7	15	13
	6.2 to 6.8	Suitable	6	8	11	15
	>6.8	Unsuitable due to corrosion	39	38	74	72

precipitation of a coating or layer of calcium or magnesium carbonate inside the pipelines. It prevents corrosion of the pipes to some extent, but instead can cause clogging of the pipes. Corrosion is caused by redox reactions that reduce the processed metals to their natural stable state. Primary concern with corrosion is that it leads to release of toxic metals such as lead through the water it carries. So, the suitability of groundwater for industrial use is assessed against these factors. Calcium carbonate and pH of water have the major influences on these processes (scale formation and corrosivity).

Larson-Skold index is based on the total alkaline earths present in groundwater to its alkalinity (Larson and Skold 1958). An index <0.8 indicates non-interference of alkaline earths in the natural film formation. Index between 0.8 and 1.2 indicates that there is minor interference by these ions which can cause corrosion. With increase in the index above 1.2, corrosion rates also increase. Corrosion affects the hydraulic capacity of pipes (Srinivas et al 2013). Based on LSI index 68-70 % samples were not suitable for industrial use.

Identified polluted area associated with hydrochemical parameters

pH: During pre-monsoon, pH showed 90% of groundwater in Virudhunagar district varied between 6.8-8.5 and were within permissible limit. The pH level from the Vadugapatti, Vembakottai, Uppathur, Valayapatti, Pattampudur, Alankulam, Amathur and Malaipatti has exceeded the safest limit and ranged between 8.5-9.1. The safest level was observed only in the Kovilankulam during pre-monsoon. The pH level of post-monsoon indicate that 84% of groundwater in Virudhunagar district were within safest limit. The pH level in the Virudhunagar, Vidthakulam, Vakkanangundu, Vadakarai, Valayapatti, Aviyur, Asalapuram, Pandalkudi, Mettupatti and Pattampudur exceeded the safest limit (8.5-8.9).

Flouride (mg l^{-1})*:* Fluoride analysis of pre-monsoon showed that 30% of groundwater in Virudhunagar district affected by fluoride content. Particularly the fluoride substance in 90% of groundwater from the west and center region of Virudhunagar district reached unsafe level (0.3-6). The fluoride level in Virudhunagar, Vadugapatti, Mandapasalai and Chekkiahpuram was in unsafe level and varied from 1.5 to 6. Fluoride level during post-monsoon indicate 86% of groundwater in Virudhunagar district affected by fluorine content. The fluoride in 90% of groundwater from the west and center region of Virudhunagar district reached unsafe level (1.2-6). The fluoride level from Virudhunagar and Mararikulam also exceeded limit .

Biocarbonate (mg l^{-1})*:* Biocarbonate level of pre-monsoon

showed that 65% of groundwater in the Virudhunagar district exceedied safe limit and rangesd between 600-1200. The biocarbonate in groundwater from Gananjampathy, Vadakarai, Virudhunagar, Kodikulam, Duraisamypuram and Perumalthevanpatti was in unsafe limit (700-800). Among Virudhunagar the unsafe limit of Sulphate varies between 1100-1200. Biocarbonate level of Post-monsoon shows 96% of groundwater in the Virudhunagar district exceeded safe limit and ranged between 600-780. The biocarbonate in groundwater from Asalapuram, Mararikulam, Vembakottai, Palavanatham, Gananjampathy, Vadugapatti, Pandalkudi, Amathur, and Malaipatti was in unsafe limit and varied between 700-1100.

Chloride (mg l^{-1})*:* Chloride level in 90% of groundwater in the Virudhunagar district was above permissible limit and ranged between 25-4230. The chloride in the groundwater from the west region of Virudhunagar district reached maximum safe limit (25-250). The chloride level of Vadakarai and Virudhunagar main area was between 3179-423). Almost 90% of groundwater from the Kodikulam Vadugapatti affected by high chloride limit which ranged from 2127 to 3179. Chloride level for post-monsoon showed 85% of groundwater in the Virudhunagar district has the safest limit, values ranges between 250-1000. The nitrate in the groundwater from the west region of Virudhunagar district reached safe limit. The chloride level of Vadakarai area has was 1900-2546. Almost 90% of groundwater from the Virudhunagar main, Kodikulam, Pandalkudi and Vadugapatti affected by high chloride limit and was between 100 0and 1900.

Calcium (mg l^{-1})*:* Calcium level for pre-monsoon showed 48% of groundwater in the Virudhunagar district has retained the permissible limit, values ranges between 75-200. The calcium in groundwater from the west and east region of Virudhunagar district was in unsafe level. Almost 98% of groundwater in the west region increased with calcium level varies between 14-75. The Calcium level in the east region reached 250-323 which showed that water from the Virudhunagar main, Kodikulam, Vadakarai, Gananjampathy and Vembakottai are toxic. Calcium level for post-monsoon showed 58% of groundwater in the Virudhunagar districts retained the permissible limit, ranged between 75-200. The calcium in groundwater from the west and east region of Virudhunagar district reached an unsafe level. Almost 98% of groundwater in the west region calcium level varied between 12-75. The calcium level in the east region was 428 shows in Virudhunagar main and Vembakottai and classified as toxic.

Sulphate (mg l^{-1})*:* Sulphate level of pre-monsoon showed that 80% of groundwater in the Virudhunagar district reached the safe limit, ranged between 20-200. The sulphate in
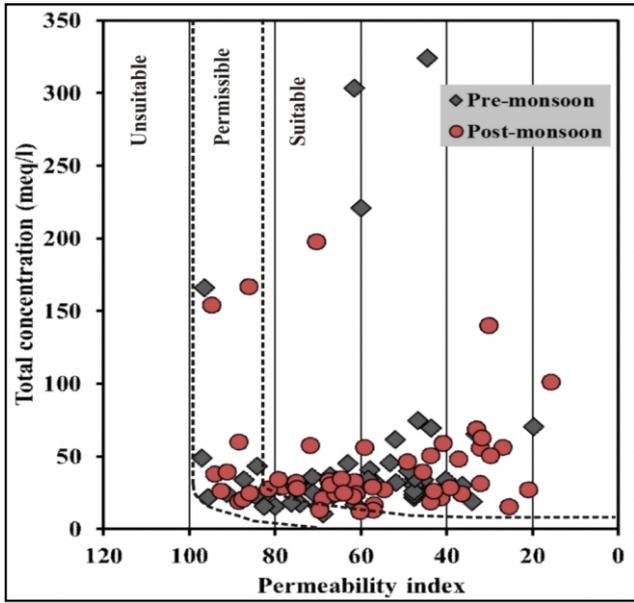
Fig. 6. Suitability of groundwater for irrigation based on permeability index
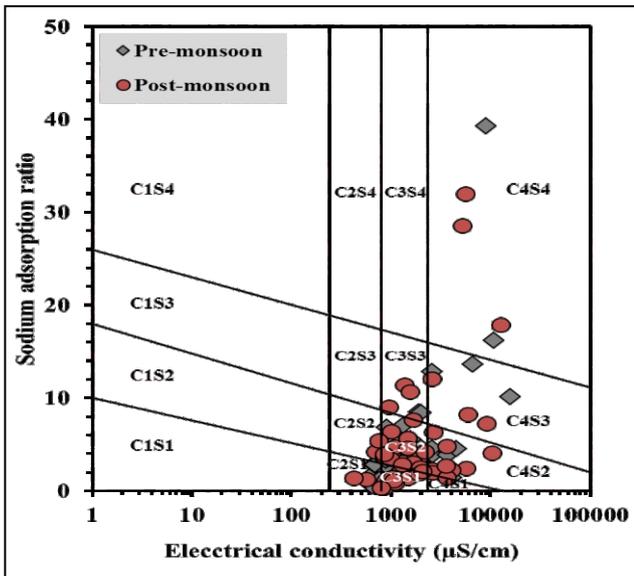
Fig. 7. Suitability of groundwater for irrigation based on sodium adsorption ratio

groundwater from Gananjampathy, Vadakarai, Virudhunagar, Kodikulam, Duraisamypuram and Perumalthevanpatti was in unsafe limit varied between 400-1500. Virudhunagar sulphate varied between 1500-2967 and was unsafe . Sulphate map of post-monsoon shows 96% of groundwater in the Virudhunagar district crossed safe limit and ranged between 2-64. The sulphate in groundwater from Asalapuram, Mararikulam, Vembakottai, Palavanatham, Gananjampathy, Vadugapatti, Pandalkudi, Amathur and
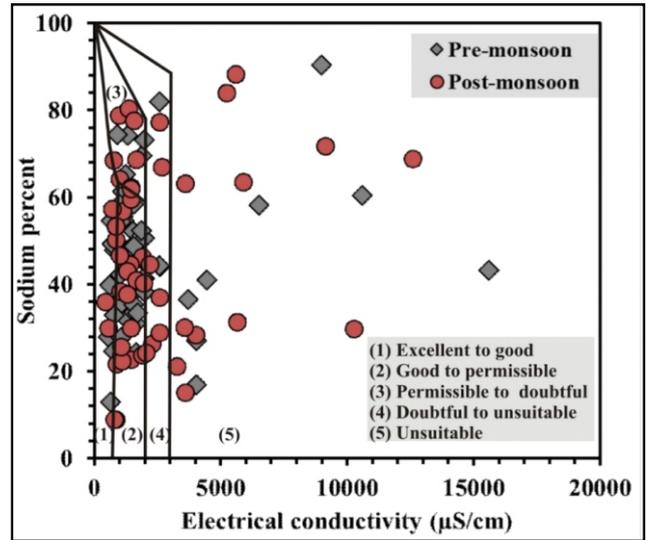
Fig. 8. Suitability of groundwater for irrigation based on sodium percent

Malaipatti was in unsafe limit and varied between 49-64.

TH: TH level from pre-monsoon, observed from the analysis shows, 65% of groundwater in Virudhunagar district has permissible limit varies between 200-600. The TH level from the Vadugapatti, Vembakottai, Uppathur, Valayapatti, Pattampudur, Alankulam, Amathur and Malaipatti has exceeded the safest limit (600-750). The safest level 200 found only in the Kovilankulam during pre-monsoon. TH level from post-monsoon, observed from the analysis shows, 84% of groundwater in Virudhunagar district has permissible limit varies between 200-600. The TH level from the Virudhunagar, Vidthakulam, Vakkanangundu, Vadakarai, Valayapatti, Aviyur, Asalapuram, Pandalkudi, Mettupatti and Pattampudur has exceeded the safest limit (600-750).

Total dissolved oxygen (mg l^{-1}): The TDS level of Virudhunagar district showed that 90% of groundwater in the Virudhunagar district during pre-monsoon ranged between 89-2000and was in safe limit. The TDS substance in groundwater from Alankulam, Amathur, A. Salapuram, N. Metupatti and Vadakarai was also in safest limit between 86-500. The TDS level in groundwater from Vadakarai, Virudhunagar main, Vembakottai and Gananjampathy region has exceeded safe limit and ranged between 2000-7863.

The TDS level of Virudhunagar district shows 85% of groundwater in the Virudhunagar district during post-monsoon has not reached the exceeding limit i.e., values ranges between 89-2000. The TDS substance in groundwater from Pandalkudi, Vadakarai, Pudupatti, Virudunagar main, Vembakottai and Gananjampathy reached to exceeding limit between 2000-10454. The

magnesium level in groundwater from Aviyur, Alankulam, Chattirareddipatti, salapuram, Kovilankulam, Pulvaykarai, Virudhunagar, Mettupatti and Mandapasalai region has very safe level ranges between 89-500.

Magnesium (mg l⁻¹): Magnesium level shows 85% of groundwater in the Virudhunagar district were with in prescribed limit. The magnesium content in groundwater from Panaiyur, Pandalkudi. N. Mettupatti, Palavantham, Pulvaykarai, Malaipatti, Kodikulam, Gananjampathy, Virudunagar main, Virudunagar and Vembakottai exceeded the limit and was between 100-344. The magnesium content in Vadugapatti and Nathampatti reached to safe limit (100-200), meanwhile magnesium in Aviyur, Alankum and Sundaranaciapuram range between 4-30 and was above safe limit. Magnesium level shows 90% of groundwater in the Virudhunagar district has not reached the safe limit and values ranged between 30-100. The magnesium content in groundwater from Aviyur, Kovilankulam, Salapuram, Kodikulam, Vadakarai, Pudupatti, Asalapuram, Palavanatham, Virudunagar, Uppathur, Vakkanangundu, Vembakottai, Mandapasalai, and Gananjampathy crossed the safe limit and was between 6-344.

Nitrate (mg l⁻¹): Pre-monsoon nitrate level showed that 95% of groundwater in the Virudhunagar district the exceeded limit (2-45) during post-monsoon. The nitrate in groundwater from Vembakottai, Pandalkudi, Vadugapatti, and Gananjampathy reached 45.9 - 64, which was highest and concentrated in the inner villages and town when compared to the outskirt. Post monsoon nitrate level shows 95% of groundwater in the Virudhunagar district exceeded limit and values ranged between 2-45 during post-monsoon. The nitrate in groundwater from Asalapuram, Mararikulam, Vembakottai, Palavanatham, Gananjampathy, Vadugapatti, Pandalkudi, Amathur and Malaipatti ranged between 45.9 - 64, which was higher than safe limit and concentrated in the inner villages and town when compared to the outskirt.

CONCLUSION

The groundwater quality in six stations was identified as a vulnerability zone. The highest vulnerability was in Aviyur, Vembakottai and the lowest in center region of Virudhunagar district. Nearly 90% of groundwater location is non-suitable for drinking purposes. Mainly magnesium was above the limits in many places. Hence, the groundwater should properly have treated with bioremediation process. The process use of naturally transpiring microorganisms to consume and break down environmental pollutants, in order to clean a polluted water and land. Magnesium hazard was above the limits in many locations, so the ground water was not suitable for irrigation. The contaminated land and ground

water should appropriately have treated with bioremediation and introduce more runoff and infiltration in the affected area by constructing artificial ponds, channels and tanks.

REFERENCES

Aravindan S, Manivel M and Chandra Sekar SVN 2004. Groundwater quality in the Hard rock area of the Gadilam river basin, Tamil Nadu. *Journal of Geological Society of India* **63:** 625-635.

Brindha K and Elango L 2014. Polycyclic aromatic in groundwater from a part of metropolitan city, India: A study based on sampling over a ten-year period. *Environmental Earth Sciences* **71**: 5113-5120.

Brindha K, Jagadeshan G, Kalpana L and Elango L 2016. Fluoride in weathered rock aquifers of southern India: Managed Aquifer recharge for mitigation. *Environmental Science and Pollution Research* **23:** 8302-8316.

Brindha K, NeenaVaman KV, Srinivasan K, SathisBabu M and Elango L 2014. Identification of surface water - groundwater interaction by hydrogeochemical indicators and assessing the suitability for drinking and irrigational purposes in Chennai, southern India. *Applied Water Science* **4**(2): 159-174.

Buvaneshwari S, Riotte J, Sekhar M, Kumar MSM, Sharma AK, Duprey JL, Audry S, Giriraja PR and Praveenkumar Reddy Y 2017. Groundwater resource vulnerability and spatial variability of nitrate contamination: Insights from high density tube well monitoring in a hard rock aquifer. *Science of the Total Environment* **579:** 838–847.

CGWB 2009. *District groundwater brochure, Virudhunagar district, Tamil Nadu.*

Chakraborti D, Rahman MM, Ahamed S, Dutta RN, Pati S and Mukherjee SC 2016. Arsenic groundwater contamination and its health effects in Patna district (capital of Bihar) in the middle Ganga plain, India. *Chemosphere* **152:** 520–529.

Freeze RA and Cherry JA 1979. *Groundwater,* Printice-Hall, New Jersey.

Jagadeshan G, Kalpana L and Elango L 2015. Major ion signatures for identification of geochemical reactions responsible for release of fluoride from geogenic sources to groundwater and associated risk in Vaniyar River basin, Dharmapuri district, Tamil Nadu, India. *Environmental Earth Sciences* **74**: 2439-2450.

Kanagaraj G and Elango L 2016. Hydrogeochemical processes and impact of tanning industries on groundwater quality in Ambur, Vellore district, Tamil Nadu, India, *Environmental Science and Pollution Research* DOI: 10.1007/s11356-016-7639-4.

Kumar M, Rao MS, Deka JP, Ramanathan AL and Kumar B 2015. Integrated hydrogeochemical, isotopic and geomorphological depiction of the groundwater salinization in the aquifer system of Delhi, India. *Journal of Asian Earth Sciences* **111**: 936-947.

Larson TE and Skold RV 1958. Laboratory Studies Relating Mineral Quality of Water to Corrosion of Steel and Cast Iron. *Illinois State Water Survey, Champaign, IL.* pp. 43-46, ISWS C71

Loganathan R 2017. Economics of production and utilisation of Jatropha and competing crops in Tamil Nadu: A discounted net return analysis. *Journal of Innovative Agriculture* **43**: 16-20.

Magesh NS and Chandrasekar N 2011. Evaluation of spatial variations in groundwater quality by WQI and GIS technique: a case study of Virudunagar District, Tamil Nadu, India. *Arab Journal Geoscience* DOI 10.1007/s12517-011-0496-z

Manimegalai S and Muthulakshmi L 2006. A study on the levels of fluoride in groundwater and prevalence of dental fluorosis in certain areas of Virudhunagar district, *Indian Journal of Environmental Protection* **26**(6)**:** 546-549.

Muhammad S, Shah MT and Khan S 2011. Health risk assessment of heavy metals and their source apportionment in drinking

water of Kohistan region, northern Pakistan. *Microchemical Journal* **98**: 334-343.

NADP (National Agricultural Development Programme) 2008. Virudhunagar district agriculture plan, Prepared by the Centre for Agricultural and Rural Development Studies (CARDS), *Tamil Nadu Agricultural University, Coimbatore, India.*

Parimalarenganayaki S and Elango L 2013. Impact of recharge from a check dam on groundwater quality and assessment of suitability for drinking and irrigation purposes, *Arabian Journal of Geosciences*, DOI 10.1007/s12517-013-0989-z.

Padmanaban R, Karuppasamy S and Narayanan R 2018. Assessment of pollutant level and forecasting water pollution of Chennai Coastal, Tamilnadu using R. *Indian Journal of Geo-Marine Sciences* **47**(7)**:** 1420-1429.

Rajesh R, Brindha K, Murugan R and Elango L 2012. Influence of hydrogeochemical processes on temporal changes in groundwater quality in a part of Nalgonda district, Andhra Pradesh, India. *Environmental Earth Sciences* **65:** 1203-1213.

Sankar MS, Vega MA, Defoe PP, Kibria MG, Ford S, Telfeyan K, Neal A, Mohajerin TJ, Hettiarachchi GM, Barua S, Hobson C, Johannesson K and Datta S 2014. Elevated arsenic and manganese in groundwaters of Murshidabad, West Bengal, India. *Science of The Total Environment*: 488–489, 570–579.

Sappa G, Ergul S and Ferranti F 2014. Water quality assessment of carbonate aquifers in southern Latium region, Central Italy: a case study for irrigation and drinking purposes. *Application of Water Science* **4:** 15-128.

Sawyer GN and Mcartly DL 1967. *Chemistry of sanitary engineers*, 2[nd]edition, McGraw Hill, New York, 518.

Singh CK, Kumar A, Shashtri S, Kumar A, Kumar P and Mallick J 2017. Multivariate statistical analysis and geochemical modeling for geochemical assessment of groundwater of Delhi, India. *Journal of Geochemical Exploration* **175:** 59-71.

Srinivas Y, Oliver DH, Raj AS and Chandrasekar N 2013. Evaluation of groundwater quality in and around Nagercoil town, Tamilnadu, India: *An integrated geochemical and GIS approach. Application of Water Science* **3:** 631-651.

Surinaidu L 2016. Role of hydrogeochemical process in increasing groundwater salinity in the central Godavari delta. *Hydrology Research* **47**(2): 373-389.

Assessment of Water Quality of Surface Water in Kalingarayan Canal for Heavy Metal Pollution, Tamil Nadu

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Abstract: Kalingarayan canal is one of the leading oldest canal in Erode district. Many industries are located along stretch of the canal and dumping most of the solids waste into the canal water. For the investigation, samples were collected from the above canal for analysing parameters like pH, EC, Fe, Cu, Mn, Cr, Zn, Cd, Pb and Ni for two years 2015 and 2016. The pH of the samples were in the alkaline state (7.2 to 7.89), whereas conductance was in the range of 529 - 2687 µs/cm. The average concentration of heavy metals in the surface water range from 0.045-8.530, 0.040-0.710, 0.023-0.723, 0.002-1.557, 0.001-0.009, 0.002-0.053, 0.009-0.097 and 0.140-2.698 mg/L for the metals Fe, Mn, Zn, Cu, Cd, Ni, Pb and Cr respectively. Heavy metal concentrations except Cd and Zn exceeds limit in all analysed samples in accordance with two standards, Bureau of Indian Standards and WHO. The dominance of various heavy metals in the surface water is follows the sequence: Fe > Cr > Cu > Zn > Mn > Pb > Ni> Cd. The results revealed that there was negatively correlation of Cd with all the variables. Mn is positively and significantly correlated (at 0.05 level) in summer season with all the other studied parameters. This study revealed that quality of water in the canal is affected by anthropogenic activities and industrialization.

Keywords: Surface water, Water quality, WHO, BIS, Correlation, Solid waste

Many rivers in India are unsuitable for use because of the entry of industrial and domestic waste water (Govindaraju 2003, Tariq et al 2006). In US also many watersheds like Kentucky is polluted by anthropogenic activities (James 2007). Olowu et al (2010) observed concentration of heavy metals in surface water of Oke Afa Canal Lagos, Nigeria and except lead all the detected parameters were within limits. In Bahirdar, Ethiopia ground water surrounding Tana lake is also polluted by stream water runoff and domestic waste water entry (Tenagne Addisu Wondie 2009). The untreated and partially treated industrial effluents and sewage cause the severe pollution.

The present study was conducted to assess the impact on the Kalingarayan canal by the surrounding environmental activities. The Kalingarayan Anaicut is located just above the confluence of the rivers Bhavani and Cauvery: This Anaicut was constructed in fourteenth century and was reorganized before several centuries. This canal is 90 km length and having an irrigated area of 6,300 hectare. This canal was useful for irrigation throughout the year and farmers were able to get harvest three cropping in a year and resulted in higher yield of crops. At present, productivity in canal area is facing severe problem and it is impossible to obtain 50% of yield, which was attained 10 years back. Many sluices in this canal are closed and has become a drain for public sewers and industrial effluents. The pollution to this canal starts from the

9th km downstream to the Kalingarayan Anaicut. Major cluster of dyeing, bleaching units, tanneries and sewage streams are located within 50 meters from the canal. They used to let out their sludge in to the canal in the weekends or in the night time. These cause severe pollution over the Kalingarayan canal. The public and other research workers are planning for integrated approach and plan towards the management of the canal water for a better usage in future. Therefore, monitoring these heavy metals is helpful for the health aspects and environment in this region. The objective of this study includes experimental part to indentify the pollutant levels in the surface water of the Kalingarayan canal. Samples of surface water are assessed for variation in heavy metals and correlation matrix and the status of water sample at various location of the canal for different seasons. The study leads to suitability of water for irrigation (IS 2296: 1982) and drinking water purpose (IS 10500: 1991 and WHO).

MATERIAL AND METHODS

Study area: The construction work of Kalingarayan canal was carried out during the period 1271AD-1283AD. The canal starts with Kalingarayan dam on River Bhavani, near Bhavani and flows through Erode before terminating near Kodumudi. It is designed in a circuitous way with as many twists and turns as possible. The canal is in the curvilinear path to cover more land area for irrigation. The length of the

canal is 92 km passing entirely through Erode district, Tamilnadu as per the survey conducted. The mean sea level (MSL) where the canal begins is 534 ft and ends at 412.48 ft. The Kalingarayan canal is situated on the western bank of the river Cauvery in an area of 7621 sq kms (Fig. 1). The area is characterised by tropical climate and the area around the canal is heavily populated and industrialised (Table 1).

Sample collection: Every month during Jan 2015 to Dec 2016 the water samples were collected from 8 stations on the canal (Fig. 1). The locations for samples were chosen according to the industrials, agricultural and domestic activities. The polythene bottles were used to collect the samples in eight different locations in Kalingarayan canal (Table 1), after measurement of pH on spot in the field. Atomic Absorption Spectrophotometer was used for heavy metal analysis of water while other analysis was carried out by procedure adopted in standard methods.

RESULTS AND DISCUSSION

Water samples collected were in alkaline pH in the range of 7.29 to 7.89 with an overall mean of 7.79. Mean values in various seasons varies from 7.64 in monsoon to 7.89 during summer (Table 2). In monsoon pH was lowest at all the eight locations due to the dilution effect of rain water. During the summer and winter significant difference was not observed in pH. The variation in pH in sampling location was also not significant when comparing observed values for pH with drinking water quality standards (WHO 1973) and were well within the safe limit (Kumar et al 2018). The values of EC varied from 529 to 2687 µs cm^{-1}. According to IS: 2296 water used for irrigation should not exceed EC value 2250 µs cm^{-1}. Its presence above the permissible limit is unacceptable in water used for irrigation purpose (Sacchidananda and Prakash 2006).

Iron (Fe): The high value of iron in summer season (8.53

Table 1. Location of surface water samples in Kalingarayan canal

| Latitude	Longitude	Sample code	Sampling locations
11°26'26.69"N	77°40'36.27"E	SW1	KalingarayanAnicut (Agricultural Activities)
11°23'13.92"N	77°41'43.78"E	SW2	Chunnambuoodai (Tanneries)
11°21'49.29"N	77°42'43.45"E	SW3	Convent School(Domestic area)
11°21'44.96"N	77°43'16.18"E	SW4	Vairapalayam (Dyeing units)
11°21'27.98"N	77°44'12.87"E	SW5	Pallipalayam (Paper mills)
11°19'37.77"N	77°45'9.56"E	SW6	Vendipalayam (Domestic area)
11°18'39.08"N	77°46'13.97"E	SW7	Lakkapuram (Domestic area)
11°17'37.41"N	77°46'39.02"E	SW8	Colony Pudur (Domestic area)
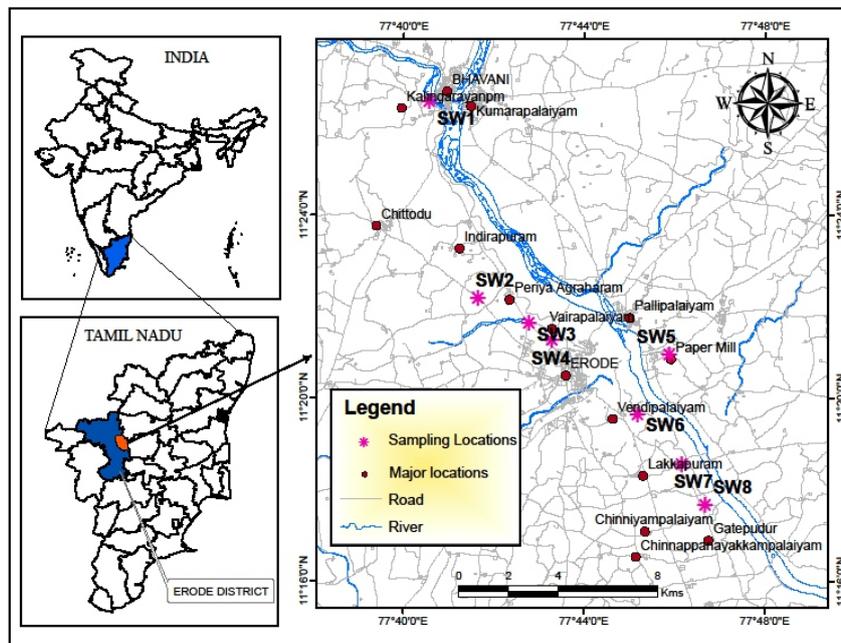
Fig. 1. Locations of the monitoring stations on Kalingarayan canal in Erode

mg l^{-1}) was at site SW2 and low in post monsoon (0.045 mg l^{-1}) at SW7 and SW8. The maximum permissible limit is 0.3 mg l^{-1}. The high value in summer may be due to the industrial waste water exposed to the water system and high concentration of industrial effluent and domestic sewages (Muhammad et al 2017)

Manganese (Mn): The high value of manganese in pre monsoon season (0.71 mg l^{-1}) was at SW1 and low (0.04 mg l^{-1}) in post monsoon at SW7 and SW8. The maximum permissible limit is 0.1 mg l^{-1}. High values of manganese were in monsoon compared to summer. This may be due to flushing action of the rain (Kaushik et al 1999). The high value of manganese may be due to the influence of industrial effects and domestic sewage entering into the canal system.

Copper (Cu): The high value of copper in pre monsoon season (1.557 mg l^{-1}) was at SW6 and low (0.002 mg l^{-1}) in post monsoon at SW7 and SW8. The maximum permissible limit is 1.0 mg l^{-1}. The high value of copper in pre monsoon may be due to the agricultural and sewage inputs (Mullick and Konar 1996).

Chromium (Cr): The high value of chromium (2.698 mg l^{-1}) in summer season was at SW2 and low (0.14 mg l^{-1}) in post monsoon at SW1 and SW3. The maximum permissible limit is 0.05 mg l^{-1}. Chromium is mainly from industrial and sewage flushes. It is not suitable for domestic purpose (Khurshid and Zaheeruddin 2000). The highest value of chromium in summer at SW2 may be due to untreated sewage water.

Zinc (Zn): The high value of zinc (0.723 mg l^{-1}) in pre monsoon season was at SW4 and low (0.023 mg l^{-1}) in summer season at SW7 and SW8. The drinking water limit for zinc ranges from 5 to 15 mg l^{-1}. The high value to zinc in SW4 may be due to the domestic waste discharge and the agricultural runoff. Zinc is toxic and may cause vomiting, renal damage and cramps. Its presence above the permissible limit is unacceptable in water used for drinking purpose (Harikumar and Ramani 1998).

Cadmium (Cd): The maximum value of cadmium (0.009 mg l^{-1}) in pre monsoon season was at SW4 and low (0.001 mg l^{-1}) in post monsoon at SW3 to and SW8. The maximum permissible limit is 0.01 mg l^{-1}. High concentration of

cadmium in pre monsoon is considered a potential carcinogen (Singh et al 2005). It also has been shown to cause toxic effects on the kidneys, bone defects, high blood pressure and reproductive organs.

Nickel (Ni): The high value of nickel 0.053 mg l^{-1} in summer season was at SW2 and low (0.002 mg l^{-1}) in post monsoon at SW6 to SW8. The maximum permissible limit is 0.1 mg l^{-1}. The low value of nickel may be result of adsorption process by the soil reduces the concentration of the heavy metals in water (Asheesh Shrivastava et al 2015).

Lead (Pb): The high value of lead (0.097 mg l^{-1}) in summer season was at SW4 and low (0.006 mg l^{-1}) in post monsoon at SW1. The maximum permissible limit is 0.1 mg l^{-1}. The lead pollution on the surface water may be the results of discharge of old plumbing, effluents, house hold sewages, agricultural runoff containing phosphatic fertilizers and human and animal excreta (Prem et al 2017). Low values may be due to the complex formation with organic materials during the passage through the soil (Wang et al 2016). The dilution effect of rain water may be the reason for variation. The amount of heavy metals present in the water is negligible during the monsoon season. While comparing with these three seasons in post monsoon season the heavy metal concentration is low. This is due to the dilution of canal water in that season. The average concentration of heavy metals in the surface water range from 0.045-8.530, 0.040-0.710, 0.023-0.723, 0.002-1.557, 0.001-0.009, 0.002-0.053, 0.006-0.097 and 0.140-2.698 mg l^{-1} for the metals Fe, Mn, Zn, Cu, Cd, Ni, Pb and Cr, respectively (Table 3). Heavy metal concentrations except Cd, Ni and Zn exceeds limit in all analysed samples in accordance with two standards, Bureau of Indian Standards and WHO. The dominance of various heavy metals in the surface water follows the sequence: Fe > Cr > Cu > Zn > Mn > Pb > Ni > Cd.

Correlation matrix: Correlation coefficient is the relationship between the variables and the measure of one variable depends or not depending on other variables. A correlation matrix was developed for 10 variables for three different seasons summer, pre monsoon and post monsoon (Table 4, 5 and 6). In summer season, copper has negative

Table 2. Average values of pH and EC of surface water of the Kalingarayan canal in Tamilnadu

Parameter	Season	SW$_1$	SW$_2$	SW$_3$	SW$_4$	SW$_5$	SW$_6$	SW$_7$	SW$_8$
pH	Summer	7.33	7.89	7.87	7.89	7.67	7.64	7.55	7.57
	Pre monsoon	7.29	7.37	7.32	7.39	7.36	7.43	7.41	7.64
	Post monsoon	7.56	7.53	7.49	7.49	7.48	7.34	7.32	7.42
EC	Summer	817	2083	1611	2687	1723	1512	998	795
	Pre monsoon	647	1243	779	806	579	549	529	550
	Post monsoon	574	1504	1040	1367	1177	946	768	686

correlation with manganese and cadmium. Lead has negative correlation with iron, manganese, zinc, cadmium and nickel. All the remaining elements have positive correlation with each other. Among these, chromium is strongly correlated to pH and EC. In pre- monsoon season, iron is strongly correlated with EC and copper is positively correlated with only pH (Table 5). Cadmium is strongly

correlated with zinc. Chromium is positively correlated with EC, iron, manganese and zinc. In post- monsoon season also iron has a strong correlation with EC (Table 6). Apart from iron, manganese, zinc, copper, lead and chromium also have positive correlation with EC. Chromium is strongly correlated with lead and lead is strongly correlated with zinc. Nickel has a strong correlation with cadmium. The quality of

Table 3. Average concentrations of pollutant parameters in surface water of the Kalingarayan canal in Tamil Nadu

Metal	Season	Average concentration of metal (mg mg l⁻¹)							
		SW_1	SW_2	SW_3	SW_4	SW_5	SW_6	SW_7	SW_8
Fe	Summer	1.58	8.53	4.19	3.25	5.27	1.23	1.15	1.15
	Pre monsoon	1.25	2.34	1.74	1.3	0.65	1.00	0.79	0.79
	Post monsoon	0.091	1.421	0.121	0.11	0.32	0.091	0.045	0.045
Mn	Summer	0.41	0.43	0.4	0.26	0.28	0.36	0.25	0.24
	Pre monsoon	0.71	0.64	0.42	0.13	0.18	0.24	0.18	0.18
	Post monsoon	0.08	0.06	0.07	0.08	0.05	0.06	0.04	0.04
Zn	Summer	0.065	0.084	0.053	0.082	0.071	0.064	0.023	0.023
	Pre monsoon	0.35	0.66	0.512	0.723	0.642	0.524	0.326	0.326
	Post monsoon	0.024	0.095	0.111	0.083	0.058	0.084	0.062	0.062
Cu	Summer	0.017	0.283	0.347	0.426	0.585	0.427	0.302	0.302
	Pre monsoon	0.804	0.885	0.748	0.645	0.682	1.557	1.424	1.424
	Post monsoon	0.003	0.007	0.095	0.012	0.086	0.004	0.002	0.002
Cd	Summer	0.008	0.006	0.006	0.007	0.005	0.004	0.003	0.003
	Pre monsoon	0.001	0.008	0.008	0.009	0.004	0.003	0.003	0.003
	Post monsoon	0.003	0.002	0.001	0.001	0.001	0.001	0.001	0.001
Ni	Summer	0.045	0.053	0.044	0.052	0.052	0.031	0.025	0.025
	Pre monsoon	0.035	0.041	0.038	0.035	0.032	0.026	0.02	0.02
	Post monsoon	0.021	0.005	0.005	0.006	0.005	0.002	0.002	0.002
Pb	Summer	0.015	0.015	0.091	0.097	0.092	0.09	0.09	0.09
	Pre monsoon	0.015	0.015	0.012	0.012	0.009	0.009	0.009	0.009
	Post monsoon	0.006	0.008	0.01	0.01	0.009	0.009	0.009	0.009
Cr	Summer	0.804	2.698	2.28	2.424	1.56	1.424	0.84	0.84
	Pre monsoon	0.283	1.56	1.54	1.14	1.17	0.302	0.302	0.302
	Post monsoon	0.14	0.94	0.14	0.685	0.585	0.28	0.28	0.28

Table 4. Correlation of different pollutant parameters in summer season

	pH	EC	Fe	Mn	Zn	Cu	Cd	Ni	Pb	Cr
pH	1.000									
EC	0.844	1.000								
Fe	0.665	0.601	1.000							
Mn	0.096	0.020	0.360	1.000						
Zn	0.455	0.761	0.642	0.429	1.000					
Cu	0.545	0.525	0.242	-0.424	0.171	1.000				
Cd	0.117	0.399	0.342	0.572	0.732	-0.371	1.000			
Ni	0.482	0.708	0.759	0.381	0.888	0.147	0.795	1.000		
Pb	0.234	0.124	-0.396	-0.603	-0.382	0.717	-0.548	-0.371	1.000	
Cr	0.924	0.830	0.662	0.378	0.606	0.375	0.428	0.658	0.087	1.000

Table 5. Correlation of different pollutant parameters in Pre- monsoon season

	pH	EC	Fe	Mn	Zn	Cu	Cd	Ni	Pb	Cr
pH	1.000									
EC	0.309	1.000								
Fe	-0.401	0.935	1.000							
Mn	-0.596	0.291	0.540	1.000						
Zn	-0.335	0.573	0.410	-0.216	1.000					
Cu	0.649	-0.459	-0.398	-0.367	-0.593	1.000				
Cd	-0.200	0.710	0.658	-0.039	0.752	-0.528	1.000			
Ni	-0.715	0.771	0.791	0.579	0.651	-0.824	0.618	1.000		
Pb	-0.570	0.741	0.799	0.721	0.210	-0.576	0.309	0.800	1.000	
Cr	-0.421	0.734	0.675	0.189	0.756	-0.718	0.863	0.792	0.390	1.000

Table 6. Correlation of different pollutant parameters in Post- monsoon season

	pH	EC	Fe	Mn	Zn	Cu	Cd	Ni	Pb	Cr
pH	1.000									
EC	0.303	1.000								
Fe	0.412	0.678	1.000							
Mn	0.649	0.227	0.004	1.000						
Zn	-0.098	0.648	0.331	0.063	1.000					
Cu	0.257	0.248	-0.062	0.069	0.346	1.000				
Cd	0.641	-0.217	0.312	0.479	-0.532	-0.319	1.000			
Ni	0.679	-0.326	-0.059	0.653	-0.626	-0.100	0.887	1.000		
Pb	-0.415	0.405	-0.214	-0.209	0.715	0.403	-0.936	-0.799	1.000	
Cr	0.120	0.315	-0.312	0.273	0.537	0.792	-0.551	-0.231	0.733	1.000

the surface water quality is highly affected at the sampling stations SW2 and SW4. The heavy metal concentration is high during summer and pre-monsoon season. The heavy metals like lead, chromium, manganese and iron exceeded that of the limit of the drinking water at the sampling station SW2. This indicates that the discharge of industrial effluents at these locations is heavy and the water available in this location cannot be used without prior treatment. The concentration of Zn, Cd, Ni and Pb are within the permissible limit of drinking as well as crop production but the concentrations of Fe, Mn, Cu and Cr exceeded the BIS, (1991) standard for drinking of the analyzed samples during summer, pre and post monsoon period, respectively (Table 3). But, during rainy season the concentration of these parameters like Fe, Mn, and Cu are within the limits of Indian standards. Cr is not below the allowable limits because more tanneries are discharging their waste water into the canal.

concentration of toxic heavy metals Pb, Fe, Mn, Cu and Cr, in wastewater is a severe threat for human health and the environment. This indicates that the discharge of industrial effluents is heavy and the water available in the canal cannot be used without prior treatment. Heavy metal concentrations except Cd, Ni and Zn exceeds limit in all analysed samples which proves the discharge of industrial effluents including tanneries into the canal. The rise of the inflow of waste is clearly due to the rapid growth of residential and commercial activities in the study area. Due to the discharge of sewage, domestic waste water and human activities all parameters exceeds the permissible limit of WHO and Bureau of Indian standards in summer season. The canal water cannot be used for drinking and agriculture purposes before further treatment. The long-term usage of canal for irrigation also causes adverse effects in the soil as well as in the yield of crops.

CONCLUSION

The heavy metal concentration was high during summer and pre-monsoon season. The heavy metals like lead, chromium, manganese, copper and iron exceeded the limit of the drinking water at all sampling station. Increasing

REFERENCES

Asheesh S, Shalini AT and Rakesh K 2015. Water quality management plan for Patalganga river for drinking purpose and human health safety. *International Journal of Scientific Research in Environmental Sciences* **3**(2): 71-87.

BIS 1982. Indian standards surface water quality standards, *Bureau*

of Indian Standard, Indian Standard IS 10500-1991.

BIS 1991. Indian standards drinking water specification, *Bureau of Indian Standard, Indian Standard* IS 2296-1982.

Friberg L and Vahter M 1983. Assessment of exposure to lead and cadmium through biological monitoring: results of a UNEP/WHO global study. *Environmental Research* **30**: 95-128.

Govingarajalu K 2003. Industrial effluent and health status- A case study of Noyyal river basin, Proceedings of 3rd *International Conference on Environment and Health, Chennai, India* 150-57.

Harikumar PS and Ramani KN 1998. Water quality problems of Tamilnadu. Water scenario of Tamilnadu. The state committee of Science, Technology and Environment, Thiruvananthapuram.

James AW 2007. *Determining factors that contribute to nonpoint source pollution in the Lower Kentucky Watershed.* Masters Theses, University of Kentucky, Lexington, USA.

Kar D, Sur P, Mandal SK, Saha T and Kole RK 2008. Assessment of heavy metal pollution in surface water. *International Journal Environment Science Technology* **5** (1): 119-124.

Kaushik S, Sahu BK, Lawania RK and Tiwari RK 1999. Occurrence of heavy metals in lentic water of Gwalior region. *Pollution Research* **18**(2): 89-100.

Khurshid S and Zaheeruddin 2000. Heavy metal pollution and its toxic effect on water quality in parts of Hindon River Basin. *Indian Journal of Environmental Protection* **20**: 401-406.

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

Muhammed AE, Hoda AE and Yasser AE 2017. Assessment of heavy metal contamination in surface water of Burullus Lagoon, Egypt. *Journal of Scientific Agriculture* **1**: 233-243.

Mullick S and Konar SK 1996. Disposal of heavy metals and petroleum products in water. *Pollution Research* **15**: 223-225.

Prem NM, Raja MS, Ayeshamariam A and Mohamed RK Assessment of heavy metals in surface water of Adirampattinam Seashore, Thanjavur District, Tamil Nadu, India. *Fluid Mechanics* **4**(1):1-6.

Sacchidananda M and Prakash N 2006. *Ground Water Pollution and Emerging Environmental Challenges of Industrial Effluent Irrigation: A Case Study of Mettupalayam Taluk, Tamilnadu,* Madras School of Economics, Chennai. **7:** 52 pages.

Singh O, Kumar V and Raj SP 2005. Water quality aspects of some wells, rivers and springs in part of the Udhempur District (U&K). *Journal of Environmental and Engineering* **47**: 25-32.

Tariq M, Ali M and Shah Z 2006. Characteristics of industrial effluents and their possible impacts on quality of underground water. *Journal of Soil and Environmental Sciences* **25**(1): 64-69.

Tenagne AW 2009. *The impact of urban storm water runoff and domestic waste effluent on water quality of Lake Tana and local groundwater near the city of Bahir Dar, Ethiopia.* Masters Theses, Faculty of the Graduate School of Cornell University.

Wang C, Chen Z and Yang S 2015. Application of grapheme oxides for the removal of Pb(ll) ions from aqueous solutions: Experimental and DFT calculation. *Journal of Molecular Liquids* **211**: 957-964.

WHO 1973. World Health Organization technical report series No. 532, Geneva.

Physico-chemical Characteristics of Groundwater in and Around Tirunelveli Corporate Dumpsite

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Abstract: Groundwater samples were collected from 40 locations near Tirunelveli corporation dumpsite, Tamilnadu and water quality assessment was carried out for various parameters. From this study, it is evident that there is a considerable amount of variation in water quality parameters among the locations by leachate and rocky aquifer below the dumpsite. The high concentration of dissolved solids (above 3000 mg/l) in groundwater is making it unsuitable for domestic and agricultural purpose. The systematic calculation of correlation coefficient between water quality parameters and regression analysis provides an easy and rapid monitoring of water quality of the dumpsite region.

Keywords: Groundwater quality, physicochemical parameter, Dumpsite, Regression equation

Groundwater is severely assaulted with many sources of contamination such as waste dumps, sanitary landfills septic tank system municipal and industrial wastes, pesticides and fertilizers applied during irrigation etc. The seriousness of groundwater is placed after air and surface water pollution and society is totally unaware this fact.   If groundwater once gets polluted its purification is very difficult, costly and groundwater pollution causes irreparable damage to soil, plants, humans and animals. The leachate from the open dumps contains much substance that can contaminate the groundwater and hence make the groundwater unsuitable for domestic and agricultural purpose. The impact of such sites on groundwater quality can be assessed by monitoring the concentration of potential contaminants at a number of specific monitoring points. The strong correlation always exists among the water quality parameters, a systematic calculation and interpretation of correlation and coefficient give an idea of rapid water quality monitoring methods. The developed regression equations for the parameters having significant correlation coefficient can be successfully used to estimate the concentration of other constituents. Systematic study of correlation and regression coefficients of the water quality parameter not only helps to assess the overall water quality but also to quantify relative concentration of various pollutants in groundwater and provide necessary input for implementation of rapid water quality management programmes. The present study was conducted with these objectives.

MATERIAL AND METHODS

In Tirunelveli municipal corporation, the collected solid wastes are dumped at the disposal site in Ramaiyan Patty, which is located in the north-western side of the Tirunelveli city at distance of 6 km. The total area available for the disposal of solid wastes is 47 ha among which 18 ha were used for disposal. The weather condition of the dumping site is always hot. The open dumping site is surrounded by road in the eastern side and Megamudaiayarkulam tank bund in the western side. The terrain of the disposal site is sloping towards the east and is the region of Megamudaiayarkulam anaicut. Adjacent to this dump site, agricultural field (paddy field) and residential area are situated .In addition to this, a sewage treatment plant for Tirunelveli city of capacity 24 MLD is also situated at southwest corner of this dumpsite. In this study, the open wells bore wells and hand pumps around the solid wastes dumping site in Ramaiyan Patty were identified. Groundwater samples were collected from these sources periodically and were analysed for its quality (Table 1).

Table 1. Methods used for analysis of quality parameters for water samples

Quality parameters studied	Method used
pH	Recorded by pH meter
Electrical Conductivity, EC	Measured by conductivity meters
Total Dissolved solids, TDS	Evaporation method
Total Alkalinity, TA	Neturalising with standard HCl
Total Acidity, AC	Neturalising with standard NaOH
Total Hardness, TH	EDTA Titration
Chloride, Cl⁻	Mohr's method
Iron, Fe	Colorimetric method

Table 2. Physicochemical parameters of domestic water at studied wells

Station	Latitude	Longitude	pH	Conductivity μs cm^{-1}	TDS mg l^{-1}	Hardness mg l^{-1} as CaCo$_3$	Chloride mg l^{-1}	Alkalinity mg l^{-1} as CaCo$_3$	Acidity mg l^{-1} as CaCo$_3$	Iron mg l^{-1}
S1	8º45'40.975"N	77º41'09.124"E	7.25	2510	2000	800	620	784	10	0.2
S2	8º45'51.816"N	77º40'35.399"E	7.48	690	540	296	80	548	16	0.15
S3	8º45'53.958"N	77º41'01.286"E	7.3	2040	1500	688	495	648	14	0.15
S4	8º45'50.744"N	77º41'01.558"E	7.58	3380	2880	1280	920	776	15	0.2
S5	8º46'01.627"N	77º41'01.768"E	7.83	980	770	336	210	548	10	0.05
S6	8º46'01.753"N	77º41'02.878"E	7.5	940	730	264	200	508	11	0.7
S7	8º46'03.153"N	77º41'01.887"E	7.85	910	720	356	220	484	12	0.55
S8	8º46'00.356"N	77º41'05.679"E	7.41	1670	1220	572	440	504	5	0.4
S9	8º45'58.238"N	77º41'05.460"E	6.9	3980	3150	1200	1310	536	10	0.1
S10	8º46'01.469"N	77º41'07.368"E	7.54	1020	810	376	205	432	7	0.05
S11	8º46'04.952"N	77º41'04.732"E	7.15	1010	800	284	170	552	10	0.05
S12	8º46'03.707"N	77º41'13.484"E	7.12	2670	2020	724	740	528	20	0.05
S13	8º46'01.037"N	77º41'16.188"E	7.18	2320	1840	588	590	544	20	0.05
S14	8º45'55.064"N	77º41'14.326"E	7.36	1220	930	460	255	496	10	0.05
S15	8º46'11.129"N	77º40'56.211"E	7.72	860	670	316	145	520	8	0.05
S16	8º46'11.063"N	77º40'42.620"E	7.76	850	690	312	170	440	17	0.05
S17	8º45'50.693"N	77º41'08.248"E	6.97	3180	2580	968	800	664	19	0.05
S18	8º45'50.378"N	77º41'06.475"E	7.24	3920	3050	1368	895	696	16	0.1
S19	8º45'52.185"N	77º41'05.383"E	6.86	3270	2540	1276	880	660	18	0.05
S20	8º45'33.018"N	77º41'05.343"E	7.51	2420	1560	820	610	704	12	0.05
S21	8º45'34.679"N	77º41'03.939"E	7.34	1930	1500	456	470	816	18	0.05
S22	8º45'29.231"N	77º41'08.302"E	7.68	1870	1380	572	490	716	10	0.05
S23	8º45'31.463"N	77º41'06.288"E	7.04	3210	2300	1068	770	776	16	0.05
S24	8º45'32.926"N	77º41'06.991"E	7.46	2480	1880	784	610	774	11	0.05
S25	8º45'47.718"N	77º41'07.930"E	7.16	2700	2220	896	594	848	10	0.05
S26	8º45'25.500"N	77º41'14.319"E	7.48	2020	1520	620	460	908	11	0.05
S27	8º45'24.067"N	77º41'16.151"E	7.89	1620	1220	536	344	820	4	0.15
S28	8º45'24.968"N	77º41'15.582"E	7.6	2220	1560	644	540	800	10	0.1
S29	8º45'25.444"N	77º41'17.056"E	7.5	2760	1720	772	665	908	10	0.15
S30	8º45'24.602"N	77º41'19.406"E	7.25	2630	1960	692	645	956	8	0.15
S31	8º45'19.028"N	77º41'20.821"E	7.2	3020	2440	1180	720	856	20	0.2
S32	8º45'18.060"N	77º41'22.989"E	7.26	3260	2240	844	680	1108	15	0.1
S33	8º45'16.204"N	77º41'21.038"E	7.71	1430	1090	500	285	904	13	0.2
S34	8º45'21.520"N	77º41'10.398"E	7.52	860	690	372	120	556	15	0.2
S35	8º45'18.609"N	77º41'16.200"E	7.34	2770	1900	1232	735	892	24	0.1
S36	8º45'19.154"N	77º41'12.891"E	7.17	2400	1720	704	540	936	11	0.05
S37	8º45'14.398"N	77º41'25.568"E	7.3	3730	3000	1084	770	1116	16	0.05
S38	8º45'16.048"N	77º41'26.392"E	8.11	670	590	312	165	404	10	0.05
S39	8º45'14.117"N	77º41'17.114"E	7.53	2070	1580	728	485	496	13	0.05
S40	8º45'11.920"N	77º41'18.368"E	7.97	4160	3175	1456	1030	564	11	0.05
permissible limit			6.5 -8.5	–	500	300	250	200	200	0.3

Table 3. Classification of irrigation water based on electrical conductivity for the sampling location

Type of water	Classification	Electrical conductivity (µs/cm)	Sampling station point
Low saline	Excellent	100-250	–
Medium	Good	250-750	S2,S38
Saline	Permissible	750-2000	S5,S6,S7,S8,S10,S11,S14,S15,S16,S21,S22,S27,S33,S34
Highly	Doubtful	2000-3000	S1,S3,S12,S13,S20,S24,S25,S26,S28,S29,S30,S35,S36,S39
Very Highly	Unsuitable	Over 3000	S4,S9,S17,S18,S19,S23,S31,S32,S37,S40

Table 4. Correlation matrices for water quality parameters

Parameter	pH	Conductivity	TDS	Hardness	Chloride	Alkalinity	Acidity	Iron
pH	1	−0.518 **	−0.519 **	−0.431 **	−0.524 **	−0.265	−0.408 **	0.168
Conductivity		1	0.987 **	0.943 **	0.969 **	0.512 **	0.325 *	−0.267
TDS			1	0.941 **	0.961 **	0.462 **	0.335 *	−0.256
Hardness				1	0.922 *	0.411 **	0.379 *	−0.229
Chloride					1	0.382 **	0.303	−0.231
Alkalinity						1	0.136	−0.157
Acidity							1	−0.164
Iron								1

Solid waste collection: In Tirunelveli city, the collection of solid waste is done by the sanitary workers of the Tirunelveli Corporation. The stationary container system is used in most of the places. The contents of the containers emptied into corporation vehicles. In some places, especially in the marketplaces, bigger size steel containers are used to collect the solid wastes. In some places, the hoist container system is also practiced. In Tirunelveli city, the solid wastes are collected by the corporation crew during study periods once in 3 days. During the rainy season, the solid waste is collected, once in 2 days. Usually, the solid wastes are collected from 6 to 11 am.

RESULTS AND DISCUSSION

The lowest and highest pH values were in station S19 and S38 as 6.86 and 8.11. The lowest and highest conductivity were 670 and 4160 µs cm^{-1} in station S38 and S40. The lowest and highest TDS were in station S2 and S40 as 540 mg l^{-1} and 3175 mg l^{-1} respectively. The hardness was minimum and maximum in S6 and S40 (264 mg l^{-1} and 1465 mg l^{-1}). The chloride varied between 80and 1310 mg/l in S2 and S9 respectively. The lowest and highest alkalinity were in station S38 and S37 as 404 and 1116 mg l^{-1} respectively. The acidity was minimum (4 mg l^{-1}) and maximum (24 mg l^{-1})in station S27 and S35. The lowest concentration of iron was 0.05 mg l^{-1} in 22 sampling stations out of 40 and the highest concentration 0.7 mg l^{-1} in S6. The rocky aquifer is present below open dumpsite and all around. The large variation in groundwater quality of various locations around dumpsite is due to pollutants spread through cracks and fissures present

in the rock. The most of highly saline and very highly saline sampling locations are situated in Sivaji Nagar and Velankanni Nagar. The sampling location in Sivaji Nagar is polluted by cemetery yard leachate in addition to open dump leachate. The sampling location in Velankanni Nagar is polluted by percolation of wastewater from sewage treatment plant of capacity 24 MLD in addition to dumpsite leachate.

The pH has a positive and negative correlation with conductivity, TDS, hardness, chloride, alkalinity, acidity and weak correlation with iron. Conductivity has a positive and significant correlation with TDS, hardness, chloride, alkalinity and weak correlation with acidity and negative correlation with iron. TDS has a positive and significant correlation with hardness, chloride, alkalinity and weak correlation with acidity and negative correlation with iron. Hardness has a positive and significant correlation with chloride, alkalinity and weak correlation with acidity and negative correlation with iron. Chloride has positive and significant correlation with alkalinity and weak correlation with acidity and negative correlation with iron. Alkalinity has a positive and significant weak correlation with acidity and negative correlation with iron. Acidity has a weak negative correlation with iron. Finally, it can be concluded that the correlation studies of the water quality parameters have good significance in the study of groundwater resources.

CONCLUSIONS

The improper practices of solid waste management and inappropriateness of the leachate collection impact on the groundwater quality. Considerable variation in water quality

Table 5. Least square of the relation (y=ax+b) among significantly correlated parameters

y (Dependent)	X (Independent)	Correlation	Regression coefficient		Regression equation (y=ax+b)
			a	b	
pH	Conductivity	0.518	−0.149	−7.752	y = 0.149x +7.752
pH	TDS	0.519	0.0001	−7.746	y = 0.0001x–7.746
pH	Hardness	0.431	0.0001	−7.690	y = 0.0001x–7.690
pH	Chloride	0.524	−0.001	−7.708	y = 0.001x+7.708
pH	Alkalinity	0.265	0.0001	−7.710	y = 0.0001x–7.710
pH	Acidity	0.408	−0.027	−7.773	y = 0.027x+7.773
pH	Iron	0.168	0.356	−7.381	y = 0.356x–7.381
Conductivity	Iron	0.267	−1.962	−2.437	y = 1.962x+2.437
Conductivity	Acidity	0.325	0.075	−1.228	y = 0.075x–1.228
Conductivity	Alkalinity	0.512	0.003	−0.283	y = 0.003x–0.283
Conductivity	Chloride	0.969	0.003	−0.375	y = 0.003x–0.375
Conductivity	Hardness	0.943	0.003	−0.180	y = 0.003 x–0.180
Conductivity	TDS	0.987	0.001	−0.070	y = 0.001x–0.070
TDS	Hardness	0.941	2.166	−110.981	y = 2.166x–110.981
TDS	Chloride	0.961	2.651	−270.343	y = 2.651x–270.343
TDS	Alkalinity	0.462	1.926	−331.786	y = 1.926x–331.786
TDS	Acidity	0.335	59.688	897.148	y = 59.688x+897.148
TDS	Iron	0.256	−1457.55	1849.319	y = 1457.550x+1849.319
Hardness	Iron	0.229	−567.517	789.340	y = 567.517x+789.340
Hardness	Acidity	0.379	29.356	339.706	y = 29.356x+339.706
Hardness	Alkalinity	0.411	0.744	202.607	y = 0.744x+202.607
Hardness	Chloride	0.992	1.106	135.940	y = 1.106x+135.940
Chloride	Alkalinity	0.382	0.577	126.789	y = 0.577x+126.789
Chloride	Acidity	0.303	19.550	274.630	y = 19.550x+274.630
Chloride	Iron	0.231	−477.617	586.527	y = 477.617x–586.527
Alkalinity	Iron	0.157	−214.564	−719.970	y = 214.564x+719.970
Alkalinity	Acidity	0.136	5.794	618.409	y = 5.794x+618.409
Acidity	Iron	0.164	−5.235	13.554	y = 5.235x–13.554

parameters among the locations by leachate and rocky aquifer below the dumpsite was observed. Study finding revealed that the groundwater is unacceptable for drinking and agricultural purposes in some locations. TDS finds a high correlation with the conductivity, chloride and hardness. TDS has low correlation with alkalinity, acidity and iron. Regression equations relating water quality parameters were formulated. On the basis of the finding of the present study, it is recommended that borewell water in the study area should be treated before it is used for drinking purpose.

REFERENCES

Joji VS 2017. Characterization, classification and evaluation of groundwater in and around the open cast mining of clay deposits of Thonnakkal, South India. *International Journal of Environmental Sciences and Natural Resources* Ms. ID: 555630.

Jothivenkatachalam K, Nithya A and Chandra Mohan S 2010. Correlation analysis of drinking water quality in and around perur block of Coimbatore District, Tamilnadu, India. *Rasayan Journal of Chemistry* **3**(4): 649-654.

Kumar N and Sinha DK 2010. drinking water quality management through correlation studies among various physico chemical parameters; A case study. *International Journal of Environmental Sciences* **1**(2): 253-259.

Muthulakshmi L, Ramu A, Kannan N and Murugan A 2013. Application of correlation and regression analysis in assessing groundwater quality. *International Journal of Chemical Technology Research* **5**(1): 353-361.

Muthulakshmi L, Ramu, A and Kannan N 2008. Physico-chemical characteristics of ground water in and around Sivakasi Region. *Indian Journal of Environmental Protection* **29**(5): 435-438.

Nikunj Ashiyani, Falguni Parek and Suryanarayana TMV 2015. Analysis of Physicochemical properties of groundwater. *International Journals of Innovative Research in Science, Engineering and Technology* **4**(3): 1094-1098.

Patil VT and Patil PR 2010. Physico chemical analysis of selected groundwater samples of Amalner town in Jalgaon district, Maharashtra, India. *E-Journal of Chemistry* **7**(1): 111-116.

Priyanka Tiwari 2017. Water quality assessment for drinking and irrigation purpose. *Indian Journal of Scientific Research* **13**(2): 140-142.

Sami G. Daraigan, Ahamed S. Wahdain, Ahmed S. Ba-Mosa and Manak H. Obid 2011. Linear correlation analysis of drinking water quality for Al-Mukalla City, Hadhramout, Yemen. *International Journal of Environmental Sciences* **1**(7): 1692-1701.

Sudhakar Gummadi, Swarnalatha G, Vishnuvardhan Z and Harika D

2014. Statistical analysis of groundwater samples from bapatla model Guntur District in Andhra Pradesh, India. *IOSR – Journal of Environmental Science, Toxicology and Food Technology* **8**(1): 27-32.

Venkatramanan S, Chung SY and Ram Kumar T 2013. A multivariate statistical approaches on physico chemical characteristics of groundwater in and around Nagapattinam District, Cauvery Deltaic Region of Tamilnadu, India. *Earth Science Research Journal* **17**(2): 97-103.

Effect of Manure on Physico-Chemical Properties of Soil and the Yield of Cucumber (*Cucumis sativus*) in Abakaliki

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Abstract: The application of manure significantly ($p < 0.05$) improved soil pH, organic carbon, total nitrogen, available phosphorus, exchangeable bases, exchangeable acidity, effective cation exchange capacity, base saturation, bulk density, total porosity, gravimetric moisture content and hydraulic conductivity. The improvement in these parameters increased with an increase in the quantity of manure applied. Therefore, manure is recommended to use to improve soil productivity.

The problem of soil fertility and how to manage it for a suitable crop production has been a serious concern to many tropical farmers. In order to manage soil fertility, many tropical farmers abandon their piece of land after cultivating it for a few years due to decreased in soil productivity. This practice cannot sustain the rapid rising population since the land availability is scarce. It is imperative that manure that is easily available and cheap to get is adopted as soil amendments by the tropical farmers to ensure continuous usage of soil and low nutrient loss. Adding manure to soil may produce immediate effects on properties such as soil organic matter, nutrition, water retention or microbial activities (Atkinson et al 2010 and Lahmann et al 2011). Soils in Abakaliki southern Nigeria are poor in basic nutrients for optimal crop production (Nwite et al 2008). Njoku et al (2017a) and Njoku and Mbah (2012) showed that organic amendments increased soil organic matter. Manure is a valuable fertilizer for crop production and has been used for centuries to supply needed nutrients for crop growth. Compost is organic materials that has been decomposed and recycled as a fertilizer and soil amendment. Using manure as soil amendments is environmental friendly and help in waste disposal and nutrients recycle.

The test crop cucumber grows well in soils with moderate to high nutrient. Infertile soils result in bitter and misshapen fruit which are often rejected by consumers (Eifefiyi and Remision 2009). Inspite of the economic and health importance of cucumber crop, its optimum yield has not been attained in Abakaliki partially because of the poor germination of seeds sown directly, poor nursery establishment practices and climatic vagaries but the problem is further compounded because there is decreasing

soil fertility arising from continuous cultivation on the same piece of land yearly without organic fertilizer application. The drastic rise in price of inorganic fertilizer and inability of inorganic fertilizer to supply organic matter to soil has resulted to low production of cucumber in the study area. Almost all households produce organic wastes which can be easily composted to manure and use as organic fertilizer. Therefore, this study aimed at determining the effect of manure on soil physico-chemical properties and yield of cucumber in Abakaliki Southeastern Nigeria.

MATERIAL AND METHODS

The research was conducted at Ebonyi State University, Abakaliki and lies on a longitude 6.3367°N-6.01177°N and latitude 8.11267°E-8.14136°E at elevation of 447m above the sea level. Abakaliki is a derived savannah agroecological zone of southeastern Nigeria. The site is characterized with a daily temperature range of 27°C-32°C. The rainfall regime is bimodal (April-July) and (September-November), with peaks in July and September. The annual rainfall in the area ranges between 1500-2000 mm with mean annual rainfall of 1,800mm. Humidity is high (80%) with lowest (60%) occurring during the dry season in April before raining season begins. The soil is hydromorphic and belongs to the order Ultisol within Ezzamgbo soil association, derived from shale and classified as typic Hapludult (Federal Department of Agriculture and Land Resources 1987), which is largely sandy loam and ranging from low to medium fertility, indicating the need for the application of organic or inorganic amendment to its fertility status for crop production.

Land preparation and experimental design: Cutlass was used in clearing the vegetation and debris. The distance

between each bed was 0.5 m and between each block was 1 m. The size of each bed was 3 x 3 m. The experiment was in randomized complete blocks design with four treatments and five replicates. Broadcasting method was used to spread the manure in the plot for each treatment and immediately after cultivation. The spread manure was incorporated into the plots using hoes. A day after the treatment application, cucumber was planted at 25 x 75cm between plants and rows, respectively. The treatments were control, manure application at 5, 10 and 15tha^{-1}.

Soil sampling: The initial core soil samples were collected before the experiment using cores of 159 cm^3. The five soil samples were bulk together after collections and used for determination of pre-planting soil chemical properties and particle size distribution (PSD) while pre-planting soil physical properties were determined using core soil samples except PSD. Undisturbed core soil samples of 159 cm^{3}were collected from each plot at 90 days after planting (DAP) and used for the determination of post plant physical analysis. Similarly, soil samples were also collected at 90 DAP at the depth of 0-20 cm

Physical parameters: Bulk density and total porosity were determined as described by Blake and Hartage (1986). Gravimetric moisture content (GMC) and hydraulic conductivity were calculated following the procedure as outlined by Obi (2000) and Landon (1991). Bouyoucous hydrometer method was used to determine particle size distribution (Gee and Bauder 1986) and textural triangle was used to determine textural class of the soil.

Chemical parameters: Organic carbon was determined by the method of Nelson and Sommers (1982). Total nitrogen was determined using modified kjeldahl disjetion (Bremner and Mulvaney 1982). Bray 11 method was used to determine available phosphorous (Olsen and Sommers 1982). Exchangeable bases were determined using the method of Chapman (1982). The complexiometric titration method was used to determine the Ca and Mg while Na and k were determined in 1N ammonium acetate by flame photometry. Effective cation exchangeable capacity (ECEC) and base saturation were determined (Chapman 1982). The pH of the soil was determined using a suspension of soil and distilled water in the ratio of 2:5-soil: water. After stirring for 30 minutes the pH value was read using a glass electrode pH meter (Mclean1982).

Plant parameters: Four plants were selected and tagged at random from each plot. Pods harvested from the tagged plants were weighed and pod length was also determined. Plant height was taken from the soil surface to the apical tip of the plant. The length and breadth of the plant leaf were measured to obtain the leaf area index, which was estimated

as its length multiplied by its maximum width and number of leaves determined by counting the number of leaves on each of the tagged plant.

RESULTS AND DISCUSSION
Initial properties of soil and manure

The textural class of the soil was sandy loam and the soil pH was 5.6. The soil had low organic matter, total nitrogen, and exchangeable bases (Table 1). The pH of the manure was 8.2. The manure had higher values of nutrient status than the soil, hence, the reason for the application of organic amendments such as manure to increase soil nutrient content.

Soil physical properties: The soil bulk density did not differ significantly among different treatments and control. The order of increased of total porosity was control < 5tha^{-1} <10tha^{-1}< 15tha^{-1}. Control recorded the lowest gravimetric moisture content of 9%. This observed moisture content in control was lower than moisture content in 5tha^{-1}, 10tha^{-1}and 15tha^{-1} by 22, 67 and 100%, respectively. The control recorded lowest hydraulic conductivity of 12.40 cmhr^{-1} whereas that of plots amended with manure ranged between 14.12 – 22.36 cm hr^{-1} with lowest and highest values observed in 5 tha^{-1}and 15 tha^{-1}, respectively. The application of composted manure reduces the bulk density and

Table 1. Result of initial soil properties and manure

Parameters	Soil	Manure
Sand (%)	57.80	
Silt (%)	24.80	
Clay (%)	17.40	
Texture	Sandy loam	
Ph	5.60	8.20
P (mg kg^{-1})	32.90	65.00
N (%)	0.14	1.68
C/N ratio (%)	10.36	6.58
OC (%)	1.45	11.05
Om (%)	2.99	19.04
Ca(Cmol$_{(+)}$kg^{-1})	4.00	20.01
Mg (Cmol$_{(+)}$kg^{-1})	2.00	7.09
K (Cmol$_{(+)}$kg^{-1})	0.128	6.90
Na (Cmol$_{(+)}$kg^{-1})	0.128	3.80
EA(Cmol$_{(+)}$kg^{-1})	1.20	5.61
TEB (Cmol$_{(+)}$kg^{-1})	0.26	30.91
ECEC (Cmol$_{(+)}$kg^{-1})	7.46	36.52
BS (%)	83.91	84.64
BD (gcm^{-3})	1.54	
TP (%)	42.00	
GMC (%)	6.00	

increased the soil total porosity. Bulk density and total porosity decreased and increased, respectively with increase in the quantity of manure applied. Njoku et al (2017a) observed that rice biochar, wood ash and rice husk dust has positive influence on bulk density and total porosity. Similarly, the application of manure recorded improvement in gravimetric moisture content and hydraulic conductivity being increased with higher application of manure. This is in line with the observation made by Uguru et al (2015) on their study of effect of rice husk dust on selected soil physical properties and maize grain yield in Abakaliki, Southeastern Nigeria. Turner et al (2005) showed that beneficial effects of organic soil amendments include decreased soil bulk density, increased water holding capacity, total porosity, aggregate stability, saturated hydraulic conductivity, water infiltration rate, and biochemical activity. There was a significant changes among the treatment studied with regard to soil pH, organic C, total N, C/N ratio and available P in all treatments Similarly, control had the lowest organic carbon of 1.25%. This lowest organic carbon in control was 46, 20 and 180% lower than organic carbon in 5tha^{-1}, 10tha^{-1} and 15tha^{-1}, respectively. Lowest total N of 0.084% was observed in control while that of plots amended with manure ranged between 0.112-0.154% with plot of 15tha^{-1} recording the highest value. The order of increase in C/N ratio was control = 10tha^{-1} < 5tha^{-1} < 15tha^{-1}. Also, control recorded lowest available P of 20.10mgkg^{-1}. This lowest available P in control was lower than available P in 5tha^{-1}, 10tha^{-1} and 15tha^{-1} by 25, 39 and 67%, respectively.

Soil exchangeable bases: There was a significant changes among the treatment studied with respect to exchangeable bases (Table 3). The order of increase of in Ca was control <5tha^{-1}<10tha^{-1}<15tha^{-1}. Mg in control was lower than in 5tha^{-1}, 10tha^{-1} and 15tha^{-1} by 25, 75 and 100%, respectively. Control recorded lowest K value of 0.092 Cmol$_{(+)}$kg^{-1} while K values in treated plots ranged between 0.108-0.149Cmol$_{(+)}$kg^{-1}. The order of increase in Na content was Control <5tha^{-1}<10tha^{-1}< 15tha^{-1}. The order of increase in total exchangeable bases was control <5tha^{-1}< 10tha^{-1}<15tha^{-1}. The lowest EA value of 0.64 Cmol$_{(+)}$kg^{-1}was observed in control. This observed EA in control was lower than EA in 5tha^{-1}, 10tha^{-1} and 15tha^{-1} by 163, 38 and 50, respectively. The control recorded the lowest ECEC value of 5.63Cmol$_{(+)}$kg^{-1}whereas, ECEC in treated plots ranged 7.52-11.66Cmol$_{(+)}$kg^{-1}. The order of increase in base saturation was 5tha^{-1} < Control < 10tha^{-1}<15tha^{-1}.The study showed positive improvement in soil chemical properties with manure. The improvement was increased with increase in manure. This was in agreement with Njoku et al (2017b) in cucumber as amended by rice husk dust, biochar and woodash applications in Abakaliki, southeastern Nigeria. Eghball (2002) obtained an increase in soil organic carbon after four years of manure application where about 25% organic matter was retained in the soil carbon pool. Njoku and Mbah (2012) and Njoku et al (2017b) observed that used of organic waste as an amendment increases soil pH which is in line with this study, the increase in pH might be as a result of higher exchangeable bases in composted manure than that of the soil. There were higher exchangeable bases in plots

Table 2. Effect of manure on soil properties

Treatment	Bulk density (gcm^{-3})	Total porosity (%)	Gravimetric moisture content (%)	Hydraulic conductivity (cm hr^{-1})	pH	Organic carbon (%)	Total N (%)	C/N ratio	Available P (mg kg^{-1})
Control	1.57	41.00	9.00	12.40	5.60	1.25	0.08	14.88	20.10
5 tha^{-1}	1.52	45.00	11.00	14.12	5.60	1.82	0.11	16.25	25.20
10 tha^{-1}	1.42	47.00	15.00	16.03	5.80	1.45	0.11	12.94	27.90
15 tha^{-1}	1.33	50.00	18.00	22.36	5.90	3.50	0.15	22.73	33.60
CD (p=0.05)	0.66	3.84	1.80	3.96	0.79	1.96	0.03	7.98	4.55

Table 3. Effect of composted manure on exchangeable bases, TEB, EA, ECEC and BS

Treatment	Ca	Mg	K	Na	ECEC (Cmol$_{(+)}$ kg^{-1})	TEB	EA	BS (%)
Control	3.20	1.60	0.09	0.096	5.63	4.99	0.64	88.63
5tha^{-1}	3.60	2.00	0.11	0.13	7.52	5.84	1.68	77.66
10tha^{-1}	4.00	2.80	0.15	0.13	7.96	7.08	0.88	88.95
15tha^{-1}	7.20	3.20	0.15	0.15	11.66	10.70	0.96	91.77
CD (p=0.05)	3.57	1.43	0.06	0.05	9.30	9.50	0.80	28.50

TEB = total exchangeable bases; EA = exchangeable acidity; ECEC = effective cation exchange capacity, BS = base saturation

Table 4. Effect of manure on plant parameters studied

Treatment	Pod length (cm)	Plant height (m)	Leaf area index	Plant yield (t ha^{-1})
Control	17.84	1.65	59.96	6.42
5tha[-1]	20.75	2.04	75.25	8.55
10tha[-1]	24.62	2.28	89.79	7.87
15tha[-1]	29.79	2.92	107.00	10.98
CD (p=0.05)	4.50	0.06	8.88	2.58

amended with manure than that of unamended plots and also the higher the rate of manure applied the higher the exchangeable bases. Uguru et al (2016) observed an increased exchangeable base with an increase in organic amendment applied in maize

Plant parameter: The order of increase in pod length was control < 5tha[-1] < 10tha[-1] < 15tha[-1]. The lowest plant height of 1.65 m was observed in control. This plant height observed in control was lower than plant height in 5tha[-1], 10tha[-1] and 15tha[-1] by 24, 38 and 77%, respectively. Control recorded the lowest leaf area index of 59.96 while leaf area index in amended plots ranged between 75.25-107.00 with plot with 15tha[-1] recording the highest value. The order of increase in plant yield was control < 5tha[-1] < 10tha[-1] < 15tha[-1].Improvement of soil properties as a result of application of manure resulted to the increase in the yield of cucumber. Similarly, the higher the application of manure the higher the yield of cucumber observed. Similarly, Mbah et al (2017) observed higher yield of cucumber with an increase of the hardwood biochar applied. Njoku et al (2017a,b) observed higher yield of cucumber in plots amended with manure.. Eifediyi and Remison (2010) showed that wastes can improve the growth and yield of cucumber.

CONCLUSION

The manure improves soil productivity and the improvement increased with an increase in the quantity of manure applied. The manure is very cheap and easy to procure, since it generated from organic wastes. The application of manure as organic fertilizer improve the productivity of the soil and will assist in waste disposal and management. Therefore, the study recommended the use of manure to improve the productivity of the soils of the study area that area sandy loam and is poor major plant nutrients and exchangeable bases.

REFERENCES

Atkinson CJ, Fitzgerald JD and Hipps NA 2010. Potential mechanisms for achieving agricultural benefits from iochar application to temperate soils. *A Review of Plant and Soil* **337**: 1-18.

Blake GR and Hartage KH 1986. Bulk Density In: Klute A. (ED). *Methods of Soil Analysis part* 1. American Society of Agronomy No. 9 Madison, Wisconsin, 365-375.

Bremner JM and Mulvaney CS 1982. Nitrogen. In Page AI, Miller RH and Keeney DR (Eds.), *Method of Soil Analysis, Part 2*, Agronomy Monograph 9, 2nd ed. Madison: ASA. pp. 159-165.

Chapman HD 1982. Total exchangeable bases. In: Black CA, editor, *Methods of Soil Analysis Part 2.* Chemical and microbiological properties. Madison (WI): American Society of Agronomy: 902-904.

Eghball B 2002. Soil properties as influenced by phosphorus and nitrogen based manure and compost Applications. A*gronomy Journal* **94**: 128-135.

Eifefiyi EK and Remision SU 2009. The effects of inorganic fertilizer on the yield of two varieties of cucumber (*Cucumis sativus*). *Report and Opinion* **1**(5): 74 - 80.

Eifefiyi EK and Remision SU 2010. Growth and yield of cucumber (*Cucumis sativus*) as influenced by farm yard manure and inorganic fertilizer. *Journal of Plant Breeding and Crop Science* **2**(7): 216-220.

Federal Department of Agriculture and Land Resources 1987. *Reconnaissance Soil Survey of Anambara State Nigeria*. Soil Report FDALR, Kaduna.

Gee GW and Bauder J W 1986. Particle size analysis by hydrometer method, a simplified method for routine textural analysis and sensitivity test of mineral parameters. *Soil Science Society of America Journal* **43**:1004-1007.

Hesse PR 1998. Potential of organic materials for soil improvement pp: 557-569. **In**: International Rice Research Institute (eds), *Proceedings of the National Conference on Organic Matter and Rice*, Nov. 7-11, Manila, Philippines.

Lahmann NA, Tannen A, Dassen T and Kottner J 2011. Friction and shear highly associated with pressure ulcers of residents in long-term care – Classification Tree Analysis (CHAID) of braden items. *Journal of Evaluation Clinical Practice* **17**: 168-173.

Landon JR 1991. *Booker Tropical Soil Survey and Agric. Land Graduation in the Tropics and Sub-tropics*. Book Tate, New York.

Mbah CN, Njoku C, Okolo CC and Attoe EE2017. Amelioration of a degraded ultisol with hardwood biochar: Effects on soil physico-chemical properties and yield of cucumber (*Cucumis sativus L)*. *African Journal of Agricultural Research* **12**(21): 1781-1792.

Mclean EO 1982. Soil pH and lime requirements. In: edited by Page et al. *Methods of Soil Analysis part II*. American Society of Agronomy **9:** 199 - 234.

Mbagwu JSC 1985. Subsoil productivity of an Ultisol in Nigeria as influenced by organic waste and inorganic fertilizers amendments. *Soil Science* **140:** 436-444.

Nelson DW and Sommers LE1982. Total Carbon, Organic Carbon and Organic Matter: *In*: AL Page,

RH Miller and DR Keeney). *Methods of soil analysis Part* 2. Chemical and Microbiological Properties, pp: 539-579.

Njoku C and Mbah CN 2012. Effect of burnt and unburnt rice husk dust on maize yield and soil physico-chemical properties of an Ultisol in Nigeria. *Biological Agriculture and Horticulture* **28**(1): 49-60.

Njoku C, Inyang ED and Agwu JO 2017a. Soil physical properties and yield of cucumberas influenced by biochar, wood ash and rice husk dust applicationin Abakaliki Southeastern Nigeria. *IOSR Journal of Agriculture and VeterinaryScience* **10**(8): 21-25.

Njoku C, Agwu JO, Uguru BN, Igwe TS, Ngene PN, Igwe, OF, Ajana AJ and Obijianya CC 2017b. Soil chemical properties and yield of cucumber as affected by rice husk dust, biochar and woodash applications in Abakaliki, Southeastern Nigeria.

IOSR Journal of Applied Chemistry **10**(7): 61-66.

Nwite JC, Igwe CA and Wakatsuki T 2008. Evaluation of sawah rice management system in an Inland valley in Southeastern Nigeria: Soil chemical properties and rice yield. *Paddy and Water Environment* **6:** 299-307.

Obi ME 2000. Soil Physics. In: *Compendum of lectures*. Atlanto Publishers, Nsukka, Nigeria 1-128pp.

Olsen SR and Sommers LE 1982. Phosphorus. In: Page AL, Miller RH, Keeney DR, edition. *Methods of soil analysis. Part 2.* Chemical and microbiologica properties. 2nd ed. Madison (WI): *American Society of Agronomy*. pp 539-579.

Turner CA, Williams RW and Tillet R 2005. Inferring pathogen inactivation from the surface temperatures of compost heaps. *Bioresource Technology* **96**: 521- 529.

Uguru BN, Mbah CN and Njoku C 2015. Effect of rice husk dust on selected soil physical properties and maize grain yield in Abakaliki, Southeastern Nigeria. *Global Advanced Research Journal of Agricultural Science* **4**(12): 878-886.

Uguru BN, Njoku C and Mbah CN 2016. Influence of rice dust on exchangeable bases and acidity on an ultisol and maize growth in Abakaliki, South Eastern Nigeria. *Scientia Agriculture* **13**(3): 156-162.

Influence of Zinc Nutrition and Green Leaf Manuring on Dry Matter Yield, Nutrient Uptake and Economics of Rice Cultivation

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Abstract: Field experiment was conducted during *Rabi* season of 2015-2016 to study the potential of zinc nutrition and green leaf manuring on dry matter production, nutrient uptake and available soil nutrients and economics of rice. Application of 100% recommended dose of fertilizer (RDF) (NPK 150:50:50) + green leaf manure (GLM) @ 6.25 t ha^{-1} + ZnSO$_4$ @ 12.5 kg/ha as basal + 1.0% foliar spray of ZnSO$_4$ increased the N, P, K and Zn uptake and registered higher values of dry matter yield. Soil available nutrients after harvest of the crop was higher under the application of 100% RDF + GLM @ 6.25 t ha^{-1} + 0.5% foliar spray of ZnSO$_4$. The higher net return and benefit cost ratio were with application of 100% RDF + GLM @ 6.25 t / ha + ZnSO$_4$ @ 12.5 kg ha^{-1} as basal + Foliar spray of ZnSO$_4$ @ 1.0%. The 100% RDF registered the lower gross and net return.

Rice (*Oryza sativa* L.) is the most important and major food grain in the world. There are many constraints for successful production of crops especially edaphic factors. Edaphic factors like soil reaction, nutrient availability and physical characteristics soil plays major role in soil productivity and among this, soil fertility is essential for crop growth, which is needed to be improved through agronomic management practices for sustainable production. Soil fertility is managed by improving the nutrient availability to the crops for better growth by applying external high analysis fertilizer. Rice is the crop, which is more responsive to fertilizer application. Among the nutrients, micronutrients play key role in quantitative and qualitative aspects of crop production and zinc is considered to be the most important nutrient next to N, P and K. High pH and high calcareousness or alkalinity reduces zinc availability. Rice is very sensitive to low Zn supply in submerged rice soils and therefore, considered compulsory element for rice that should be replenished in the form of chemical fertilizer for enhancing the yield and quality of the grain. Zinc is also involved in growth and metabolism, including enzyme activation, metabolism of carbohydrates, lipids, nucleic acids, gene expression and regulation, protein synthesis and reproductive development of plants. Zinc availability to plants limits due to inherently infertile soils, micronutrient depletion by intensification of cultivation and poor mobility of Zn into and within plant. To overcome these problems, it is essential to identify efficient agronomic management methodologies to increase the availability of zinc. Zn exists in various pools with different rates of solubility, mobility and plant availability

(Adriano 2001). This partitioning of Zn is influenced by soil pH, clay content, organic matter and sesquioxides. Therefore application methods of Zn fertilizer should be an essential practice for soil fertility management.

Green manures, being succulent and fast degrading under submerged condition, might act as effective electron acceptor and this property may influence the chemical reduction of all metallic cations thereby favouring the utilization of nutrients in general and Zn in particular by rice (Mythili et al 2003). By incorporation of the green manure or green leaf manure N application can be reduced. The availability of nutrients is increased with the incorporation, which enhances the uptake of applied nutrients. Prakash et al (2017) found that, application of zinc as foliar spray at critical growth stage of crop growth with organic manuring reduces the pH towards the neutral and enhances the availability of zinc in the plants resulting higher growth and yield of rice. Keeping this idea in mind, the present experiment was conducted to study the effect of zinc and green leaf manuring on nutrient uptake, available soil nutrients and economic benefits of rice.

MATERIAL AND METHODS

Field experiment was conducted at Agricultural College and Research Institute, Killikulam during *rabi* season of 2015-2016. The farm is geographically located in the southern part of Tamil Nadu at 8°46' N latitude and 77°42' E longitude at an altitude of 40 m above mean sea level. The experimental site is situated in semi-arid tropical region. The mean annual rainfall of 786.6 mm is received in 40 rainy days.

The mean maximum and minimum temperature of the location were 33.4 °C and 23.6 °C, respectively. The soil of the experimental field is sandy clay loam in texture. The fertility status was low in available nitrogen (237 kg ha^{-1}), medium in available phosphorus (18 kg ha^{-1}) and potassium (240 kg ha^{-1}), Organic carbon was 0.64 %, pH (1:2 soil water suspension) 7.4 and diethylene triamine penta acetic acid (DTPA) extractable Zn in soil was 0.8 mg kg^{-1} of soil. The experiment was laid out in randomized block design, replicated thrice using ADT (R) 45 as the test variety. There were twelve treatments (Table 1) and the recommended dose of fertilizer *viz.*, 150:50:50 kg NPK ha^{-1} was applied to all the plots. The N was applied in the form of urea (46 % N), the basal dose N was adjusted with N supplied by DAP, the P was applied in the form of DAP (18 % N and 46 % P$_2$O$_5$) and K was applied in the form of MOP (60 % K$_2$O). N and K applied in four equal splits *viz.,* one at basal and remaining at active tillering, panicle initiation and heading stages along with N. Leaves and twigs of *Glyricidia maculata* @ 6.25 t ha^{-1} was collected from the farm and incorporated in the respective plots at ten days before transplanting. After incorporation, the field was puddled two times and leveled two days prior to planting. Zinc sulphate 12.5, 25, 37.5 kg ha^{-1} was mixed with sand to uniform distribution and applied as basal before the transplanting to the respective plots as per the treatment. Zinc sulphate at 0.5 and 1% foliar spray was given twice times *viz.,* at active tillering and panicle initiation stage.

Plant and soil analysis: Plant samples collected for dry matter estimation at harvest stage from the respective treatments were oven dried and finely ground in Wiley mill and used for estimating N, P, K and Zn. The per cent of the nutrient content was multiplied by the respective dry matter production and N, P, K and Zn uptake values were worked out. Post-harvest soil samples were also drawn treatment wise and air dried under shade and sieved through 2 mm sieve and used for analysis of N (alkaline permanganate method), P (Olsen's method), K (neutral normal ammonium acetate method)and Zn (DTPA method). Economics was calculated based on the cost of prevailing market rate of inputs and yield of rice. Gross and net returns were calculated along with benefit: cost ratio .

Statistical analysis: The data pertaining to the experiment were subjected to statistical analysis using AGRES (Data Entry Module for AgRes Statistical software version 3.01, 1994 Pascal Intl. Software Solutions) for Analysis of Variance (ANOVA). Differences between mean values were evaluated for significance using Least Significant Difference (LSD) at 5% probability level.

RESULTS AND DISCUSSION

Dry matter yield: The dry matter production increased as the stage of the crop progressed from tillering and attained the maximum level at harvest. Application of 100% RDF + GLM @ 6.25 t ha^{-1} + ZnSO$_4$ @ 12.5 kg ha^{-1} as basal + foliar

Table 1. Effect of zinc and green leaf manuring on dry matter production, yield and economics of rice

Treatment	Tillering (kg ha^{-1})	Panicle initiation (kg ha^{-1})	At harvest (kg ha^{-1})	Grain yield (kg ha^{-1})	Straw yield (kg ha^{-1})	Gross return (Rs ha^{-1})	Net return (Rs ha^{-1})	B:C ratio
T$_1$ - 100% RDF	1426	8483	12659	5776	6739	89528	53814	2.51
T$_2$- T$_1$,+ ZnSO$_4$ @ 25.0 kg ha^{-1} as basal	1587	9144	13408	6166	7127	95368	58654	2.60
T$_3$- T$_1$ + ZnSO$_4$ @ 37.5 kg ha^{-1} as basal	1669	9317	13737	6322	7257	97634	60420	2.62
T$_4$- T$_1$ + f.s. of ZnSO$_4$ @ 0.5%	1470	8739	12947	5888	6773	90971	54037	2.46
T$_5$- T$_1$ + f.s. of ZnSO$_4$ @ 1.0%	1508	8995	13124	6009	6850	92653	55619	2.50
T$_6$- T$_1$ + GLM @ 6.25 t ha^{-1} + ZnSO$_4$ @ 12.5 kg ha^{-1} as basal	1788	9783	14234	6569	7460	101205	63811	2.71
T$_7$- T$_1$ + GLM @ 6.25 t ha^{-1} + ZnSO$_4$ @ 25.0 kg ha^{-1} as basal	1812	9987	14659	6751	7625	103888	66494	2.74
T$_8$- T$_1$ + GLM @ 6.25 t ha^{-1} + ZnSO$_4$ @ 37.5 kg ha^{-1} as basal	1851	10002	14864	6850	7757	105466	68072	2.74
T$_9$- T$_1$ + GLM @ 6.25 t ha^{-1} + f.s. of ZnSO$_4$ @ 0.5%	1684	9444	13854	6384	7296	98496	59882	2.55
T$_{10}$- T$_1$ + GLM @ 6.25 t ha^{-1} + f.s. of ZnSO$_4$ @ 1.0%	1717	9510	13933	6410	7339	98937	60223	2.56
T$_{11}$- T$_1$ + GLM @ 6.25 t ha^{-1} + ZnSO$_4$ @ 12.5 kg ha^{-1} as basal + f.s. of ZnSO$_4$ @ 0.5%	1869	10097	15218	6991	7886	107549	68435	2.75
T$_{12}$- T$_1$ + GLM @ 6.25 t ha^{-1} + ZnSO$_4$ @ 12.5 kg ha^{-1} as basal + f.s. of ZnSO$_4$ @ 1.0%	1952	10242	15806	7105	8072	109480	70266	2.79
CD (p=0.05)	190	514	682	452	514			

spray of $ZnSO_4$ @ 1.0% (T_{12}) produced the maximum of dry matter (1952 kg ha^{-1} at tillering, 10242 kg ha^{-1} at panicle initiation and 15806 kg ha^{-1} at harvest stage) and was statistically at par with the application of 100% RDF + GLM @ 6.25 t ha^{-1} + $ZnSO_4$ @ 12.5 kg ha^{-1} as basal + foliar spray of $ZnSO_4$ @ 0.5% (T_{11}). The dry matter production was low in control .The present study reveals that conjunctive use of organic manure (green leaf manure) with inorganic fertilizer enhanced dry matter accumulation in rice attaining maximum at maturity stage. The probable reason might be due to application of zinc sulphate as basal with green leaf manuring which provides good growth at earlier stages as well as the entire growth period which in turn increased leaf area, tiller numbers and in turn in higher DMP. Bisht et al (2006) and Pooniya and Shivay(2012) also made similar observations.

Nutrient uptake: The nutrient uptake was significantly influenced by application of 100% RDF + GLM @ 6.25 t ha^{-1} + $ZnSO_4$ @ 12.5 kg ha^{-1} as basal + 1.0% foliar spray (T_{12}). Soil plus foliar application of zinc with green leaf manure results in greater nutrient availability. The conjunctive use of green leaf manures and zinc which might have helped in gradual

mineralization processes and the balanced supply of nutrients are the reason for the higher uptake of nutrients (N, P, K and Zn) by the crop. Rajkumar, (2003) observed that the green leaf manure to rice along with recommended N, P and K significantly enhanced the uptake of N. The increased N uptake might be due to initial high N requirement of rice crop was met by the fertilizer N and subsequent requirement was supplied by decomposition process, assuring the continuous N supply throughout the crop period which enhanced the uptake of N as well as other nutrient as evident from the higher DMP production.

Soil available nutrients: Soil available nutrients varied depending on the fertilizer dose and green leaf manure application (Fig. 1). The post harvest available soil nutrients *i.e.* N, P, K and Zn was higher with application of RDF + GLM @ 6.25 t ha^{-1} + foliar spray of $ZnSO_4$ @ 0.5% (T_9) due to the addition of green leaf manure. On the contrary, the treatment that had more uptake of nutrients by rice crop shows comparably less soil available nutrient status. The gradual decline in the availability with the progress of crop growth was due to natural corollary occurring as result of the crop
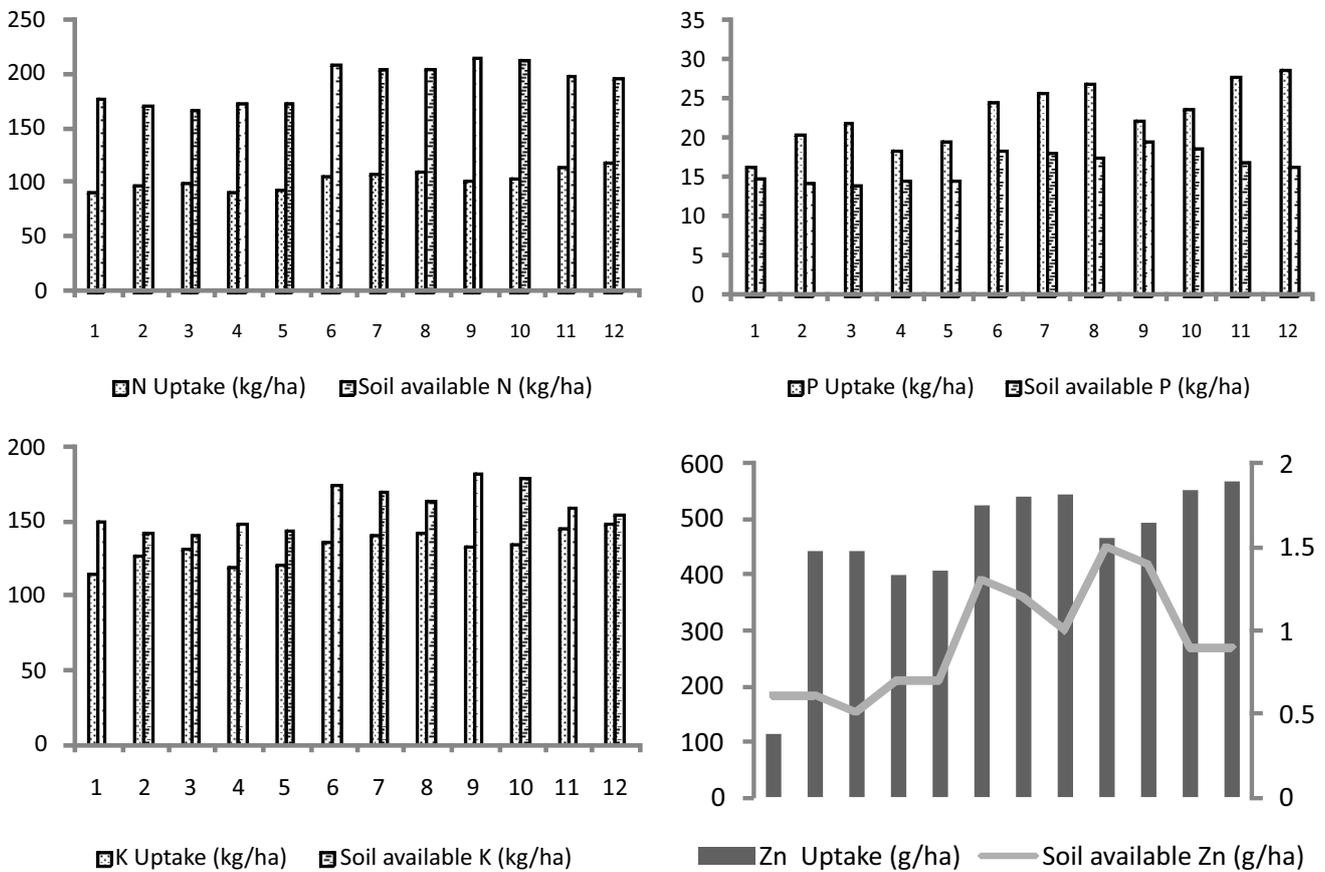

Fig. 1. Effect of zinc nutrition and green leaf manuring on nutrient uptake of rice

$$y = 106.74x + 2979.4$$
$$R^2 = 0.992$$

N uptake (kg/ha)

$$y = 244.97x + 8392.4$$
$$R^2 = 0.964$$

P uptake (kg/ha)

$$y = 87.81x + 2350$$
$$R^2 = 0.959$$

K uptake (kg/ha)

$$y = 6.2483x + 11169$$
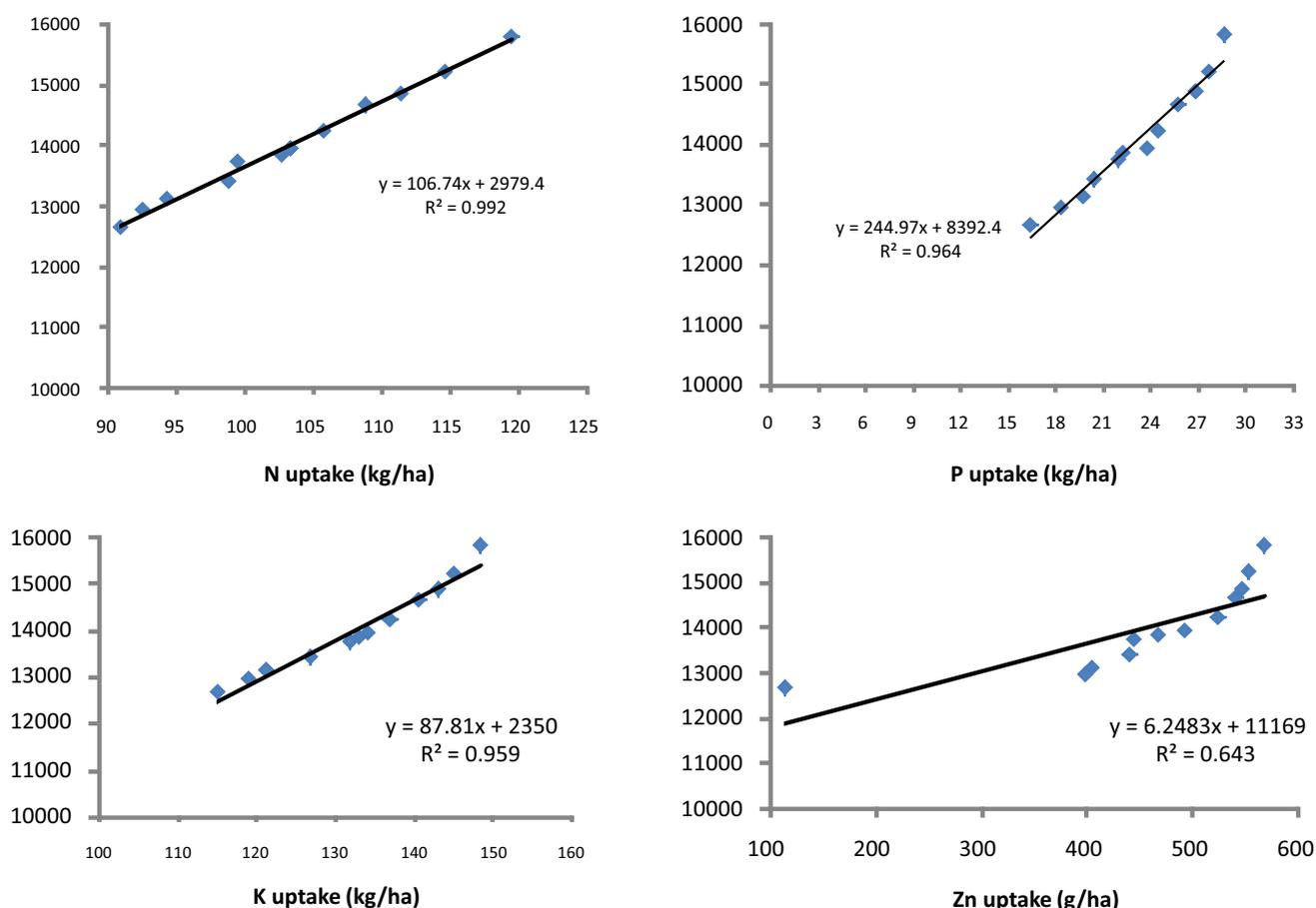$$R^2 = 0.643$$

Zn uptake (g/ha)

Fig. 2. Effect of zinc nutrition and green leaf manuring on nutrient uptake and dry matter yield of rice at harvest stage

removal. This might be due to improvement of soil environment by using green manuring which facilitated in better root proliferation that led to higher absorption of nutrients. Similar results were observed by Urkurkar et al (2010), Muthukumararaja and Sriramachandrasekharan (2014) and Ghoneim et al (2016).

Economics of Zn application in rice: The gross return and net return was higher with the application of 100% RDF + GLM @ 6.25 t ha^{-1} + ZnSO4 @ 12.5 kg ha^{-1} as basal + 1% foliar spray (T$_{12}$) (Rs. 1,09,480 and Rs. 70,266, respectively). The application of RDF along with GLM and zinc nutrition was effective to enhance the economic yield and in turn increased the net return. Lowest gross and net return were in 100% RDF alone without zinc and green leaf manure application (Rs. 89,528 and Rs. 53,814, respectively) due to less cost of cultivation and lesser yield. Higher B:C ratio of 2.79 was with the application of 100% RDF + GLM @ 6.25 t ha^{-1} + ZnSO4 @ 12.5 kg ha^{-1} as basal + 1.0% foliar spray followed by the same treatment with 0.5% ZnSO$_4$ foliar spray (T$_{11}$). The higher economic return was realized due to application of zinc and green leaf manure (Ghasal et al 2015 and Mohan Kumar 2012).

CONCLUSIONS

The uptake of nutrients increased with application of 100% RDF + GLM @ 6.25 t ha^{-1} + ZnSO$_4$ @ 12.5 kg ha^{-1} as basal + foliar spray of ZnSO$_4$ @ 1.0%. Higher soil fertility, in terms of soil available N, P$_2$O$_5$, K$_2$O and Zn was evidenced with application of 100% RDF + GLM @ 6.25 t ha^{-1} + Foliar spray of ZnSO$_4$ @ 0.5%. The yield increases with combine application of 100% RDF + GLM @ 6.25 t ha^{-1} + ZnSO$_4$ @ 12.5 kg ha^{-1} as basal + Foliar spray of ZnSO$_4$ @ 1.0%. The combine application of recommended dose of fertilizer, zinc as soil plus foliar with green leaf manuring increase the uptake of nutrients, in turn which increase the yield of the crop. The zinc nutrition as basal plus foliar spray with recommended dose of fertilizer with green leaf manuring acquired the higher net return, gross return and benefit cost ratio. Incorporation of green leaf manuring is economically viable source of nutrient application.

REFERENCES

Adriano CC 2001. *Trace elements in terrestrial environments.* Springer, New York, USA.

Bansal KN and Patel KC 1986. Effect of sources and levels of zinc

on the yield and composition of rice on Alfisol under field condition. *Journal of Agronomy and Crop Sciences* **157**: 24-30.

Brijesh Yadav, Khamparia RS and Rakeshkumar 2013. Effect of zinc and organic matter on various zinc fraction under direct-seeded rice in vertisol. *Indian Society of Soil Science* **61**(2): 128-133.

Duraisamy P, Kothandaraman GV and Chellamuthu S 1986. Availability and uptake of nitrogen and phosphorus as influenced by amendments and zinc in alkali soils. *Madras Agricultural Journal* **73:** 46-52.

Fageria NK, Dos Santos AB and Cobucci T 2011. Zinc nutrition of lowland rice. *Communications in Soil Science and Plant Analysis* **42**(1): 719-727.

FAO 2013. Global rice production. In: http://fao.org/news/story/jp/item.164713/code.

Ghasal PC, Shivay YS and Pooniya V 2015. Response of basmati rice (*Oryza sativa*) varieties to zinc fertilization. *Indian Journal of Agronomy* **60**(3): 403-409.

Ghoneim AM 2016. Effect of different methods of Zn application on rice growth, yield and nutrients dynamics in plant and soil. *Journal Agriculture and Economic. Research Institute* **6**(2): 1-9.

Gomez KA and Gomez AA 1984. *Statistical procedures for agricultural research.* I st Edn. John Wiley and Sons, New York. p*.* 680

IRRI. 2000. Nutritional Disorders and Nutrient Management in Rice. Manila, Philippines.

Khan MU, Qasim M and Khan I 2007. Effect of Zn fertilizer on rice grown in different soils of dera Ismail Khan. *Sarhad Journal of Agriculture* **23**(4): 1032-1040.

Marschner H 1995. *Mineral nutrition of higher plants.* Academic, San Diego. pp.889.

Mohan Kumar V 2012. *Studies on integrated nutrient management in rice*. M.Sc. (Ag.) Thesis. AC & RI, Killikulam, *Tamilnadu Agricultural University*, Coimbatore.

Muthukumararaja TM and Sriramachandrasekharan MV 2014. Enhancing rice productivity through integration of organics and zinc in a zinc deficient soil. *Journal of International Academic Research for Multidiciplinary* **2**(2): 359-368.

Mythili S, Natarajan K and Kalpana R 2003. Zinc nutrition in rice - A Review. *Agricultural Reviews* **24**(2): 136-141.

Prakash P. Hemalatha M, Velayutham A, Amutha R and Joseph M 2017 Growth and yield response of lowland rice to different application methods of zinc with green leaf manuring. *Agriculture Update* **12**(2): 403-408.

Prasad N and Prasad R 1983. Removal of N, P and K by rice-wheat double cropping system as affected by duration of rice variety, method of planting rice and levels and sources of N. *Plant and Soil* **70**(2): 287-295.

Rajkumar C 2003. *Study on the effect of different sources of nitrogen on growth and yield of rice*. M.Sc. (Ag.) Thesis. *Tamil Nadu Agricultural University*, Coimbatore.

Singh A and Shivay YS 2016. Effect of summer green manuring crops and zinc fertilizer sources on productivity, Zn-uptake and economics of *Basmati* rice. *Journal of Plant Nutrition* **39**(2): 204-218.

Singh A and Shivay YS 2016. Effect of summer green manuring crops and zinc fertilizer sources on productivity, Zn-uptake and economics of *Basmati* rice. *Journal of Plant Nutrition* **39**(2): 204-218.

Tisdale SL, Nelson WL, Beaton JD and Havlin JL 1993. *Soil fertility and fertilizers.* Macmillan Publishing Company. N.Y., USA.

Turkhede AB, Chowdhary BT, Chore CN, Kalpade HV, Jiotode DJ and Kalpande VV 1998. Effect of green manuring with *Gliricidia* leaves and fertility levels on yields and physico-chemical properties of the soil in low land paddy. *Crop Research* **16**(3): 300-303.

Urkurkar JS, Tiwari A, Chitale S and Bajpai RK 2010. Influence of long term use of inorganic and organic manures on soil fertility and sustainable productivity of rice (Oryza sativa)-wheat (*Triticum aestivum*) in inceptisols. *Indian Journal of Agricultural Sciences* **80**: 208-212.

Yaseen M, Hussain T, Hakeem A and Ahmad S 1999. Integrated nutrient use including Zn for rice. *Pakistan Journal of Biological Sciences* **2**: 614–616.

Zhao L, Wu L, Wu M and Li Y 2011. Nutrient uptake and water use efficiency as affected by modified rice cultivation methods with irrigation. *Paddy Water Environment* **9**: 25-32.

Changes in Weed Diversity and Biomass during Crop Growth in Three Age Chronosequence of Forest Fallows in Muallungthu Village, Mizoram

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Abstract: Mizoram Farmers are witnessing rapid ecological alteration due to human activities that makes them highly dynamic. In the present study, plant species diversity and aboveground biomass (AGB) and belowground biomass (ABG) were investigated at three age chronosequence of *Jhum* fallows in Muallungthu village, Aizawl. The species occurrence at each site was recorded at seasonal intervals for one year. Weed species diversity, IVI and AGB and ABG were estimated for each site seasonally. A total of 16 weed species representing 4 monocots and 12 dicots, predominantly annuals, belonging to 11 families were recorded from all sites. Total species count at each site was highest in rainy season and lowest in summer. Amongst the sites, 3 years showed greater species diversity and IVI, however species biomass was more in 10 years. The herbaceous vegetation showed a mosaic pattern, which was more pronounced in dry months than in wet months. *Ageratum conyzoides* was the most dominant species followed by *Chromolaena odorata and Gynura crepidioides* as co-dominant from all sites. The total weed biomass at these sites (63 to 176 g m^{-2}) showed wide spatial and temporal variations. In the drier months after rains, soil organic C and disturbance regimes greatly influence the species composition and diversity in this succession al agroforestry system. The study is important to formulate future weed management strategies in shifting agriculture in Mizoram.

Keywords: Weed diversity, Crop growth, Forest fallows, Shifting agriculture

Weeds are notorious plants for the growth of crops especially rice and wheat causing serious yield reduction in rice production worldwide. Annual worldwide rice yield loss by weed is 9.5% (Rabbani et al 2011**)**. Losses caused by weeds vary from one location to another, depending on the predominant weed flora and on the control methods practiced by farmers. A crop loss due to weed competition varies with the duration of weed infestation of the crop. The crop is likely to experience yield reduction, unless weeds are kept free during a part of its growing period (Azmi et al 2007). Long-term sustainability of agricultural systems has now become a major issue of global concern. Size of agriculture footprint has increased tremendously mainly due to its role in global climate change and degradation of natural resources (Kiers et al 2008). Weed infestation is more severe in rainfed than in the irrigated croplands (Hyvonen and Salonen 2002).

Due to human activities most areas are witnessing rapid ecological alterations that make them highly dynamic (Alberti et al 2003). Invasive species have been considered as the second largest threat to global biodiversity after habitat destruction (Gurevitchand Padilla 2004). Land-use change the resultant of increasing human population, has been recognized as one of the major drivers of future changes in biodiversity (Sala et al 2000). Weed succession and distribution patterns in rice fields are dynamic in nature. The composition of the weed flora may differ depending on location (Begum et al 2008). The information on the weed dynamics i.e., composition, abundance, importance and ranking is needed to formulate appropriate weed management strategies to produce optimum yields of rice (Begum et al 2005). Surveys are commonly used to characterize weed populations in cropping systems. In weed management program, a thorough survey is necessary to address the current weed problems in the rice field and survey information is absolutely important in building target oriented research programs (Boldt et al 1998). The distribution and nature of the weeds of the hilly area could be different due to salinity.

In the state of Mizoram (Northeastern, India), age-old slash and burn agriculture (*jhum*) is still the chief agronomic activity of the tribal people (Tripathi et al 2017), even though terrace cultivation (some part of Mizoram) was introduced about two decades ago to enhance yield and check soil erosion in this hilly region (Grogan et al 2012).The *jhum* field is heavily infested by a large variety of weed species favored by climatic conditions. The present study was undertaken to document the changes in weed species diversity in relation to seasons, sites and soil characteristics. The major objectives of the present study were: to identify the weed species; to study weed diversity, population structure and species

composition and to determine seasonal changes in weed biomass in *jhum* rice cultivated zone of Muallungthu village in Aizawl District, Mizoram.

MATERIAL AND METHODS

Study area description: Mizoram is located at North-Eastern part of India, covering an area of 21,081 km^2, which is situated at 21 $°$56'-24 $°$31' N latitude and 92 $°$16'-93°26' E longitude. Mizoram meaning lands of highlanders has undulating topography with several troughs and peaks that range from 800m to 2000m altitude. The State's topography is, by and large, mountainous with precipitous slopes forming deep gorges culminating into several streams and rivers. Mizoram has a pleasant climate generally cool in summer and not very cold in winter. The temperature varies between 20ºC and 30ºC during summer and between 11ºC and 21ºC in winter (Singh et al 2015). The experiment was conducted in Muallungthu (23°38' N lat., 92°43' E long., 985 m altitude) village in Aizawl district of Mizoram. Three different ages of jhum fallows 3 years (23$°$36'30″ N and 92$°$42'87″ E), 5 years (23$°$35'69″ N and 92$°$43'09″ E) and 10 years (23$°$35'66' N and 92$°$48'08' E) were selected.

Weeds composition and diversity: Floristic composition of the study site was recorded periodically during 2013 (using plots of 50 cm x 50 cm) in all three fallow (3 years – 23$°$36'30″ N and 92°42'87″ E; 5 years - 23$°$35'69″ N and 92°43'09″ E and 10 years - 23 $°$35'66' N and 92 $°$48'08' E) sites. In each site, every time 10 plots were laid at random locations to recover weed diversity. The phyto-sociological data were obtained during three seasons (summer, rainy and winter) at all the sites. The plant species collected were identified according to Gaur (1999) and Sharma (1980). Importance Value Index (IVI) of each species was calculated according to Curtis and McIntosh(1951); Risser and Rice (1971). Similarity among the study sites within and across different seasons was estimated using the Sorenson similarity index (Sorensen 1948) according to the following formula: S= 2c/a+b

Where, c= Number of common species between two plots (1 and 2); a = Number of species in plot 1; b = Number of species in sample plot 2.

Dominance-diversity curves were prepared by plotting species importance value index against the sequence of species (from highest to lowest IVI) (Whittaker 1975).

Diversity of each study site across different seasons was estimated, using five diversity indices (D_1-D_5). The symbols used in computing D_1 to D_5 are: S = total number of species, N=total sum of importance attribute of all species, pi = proportional importance of ith species (ni/N), ni = importance attribute of each species and Nmax = importance attribute of the most important species.

Species diversity indices

D_1, Species count (Number of species/area in the present study the no. of species that occurred in quadrats sampled)

D_2, Margalef index (Clifford and Stephenson 1975)=S-1/ln N

D_3, Menhinick index (Whittaker 1977)=S/sq root N

Information statistic indices

D_4, Shannon-index (H') (Shannon and Weaver 1949)= −Σpiln pi

D_5, Evenness (Pielou 1966) =D_4/lnS

Weed sampling and processing: Aboveground biomass (AG) and belowground biomass (BG) was estimated using three random quadrats of 50 cm x 50 cm per treatment plot every time. This way a total of 12 quadrats were laid every time per site with a total of 108 quadrats across the 3 selected study sites in three seasons. The plants inside the quadrats were uprooted and enclosed in ploythene bags. The collected plant samples were brought to the laboratory and were washed, dried at 60-80ºC for 36-48 hours and weighed.

RESULTS AND DISCUSSION

Diversity of weeds: A total of 16 plant species from 11 families (12 dicot and 4 monocot) were recorded during the study period. Considering all study sites together in a season, maximum flora was in the rainy season (11)followed by summer (10) seasons and winter (8). The herbaceous species belong to family are Asteraceae (6), Fabaceae(2), Apiaceae (1), Costaceae (1), Rubiaceae (1), Melostomaceae (1), Oxalidaceae (1), Phylanthaceae (1), Scrophuraliaceae (1), Compositae (1) andMalvaceae (1). In terms of total number of plant species during survey, the diversity order at each site was rainy >winter >summer (Table 1). Sharma et al (2016) also recorded similar diversity pattern. The species count and the range of its variation in different seasons at a site showed much higher diversity at 3 years compared to 5 and 10 years sites. The plant species that generally occurred at every study site across all seasons included *Ageratum conyzoides*, *Bidens pilosa*, *Chromolaena odorata, Gynura crepidioides*, *Mikania cordata.* Among seasons, herbaceous weed like *Ageratum conyzoides* were recorded as the most dominant species followed by *Knoxia corymbosa* and *Chromolaena odorata* as the leading dominants, however, *Ageratum indicum*, *Allardia glabra*, *Oxalis corniculata*, *Scopari adulcis* and *Spilanthes acemella* were least dominant species in all sites.

Dominance-diversity curves: In rainy season, *Ageratum conyzoides*, *Chromolaena odorata*, *Gynura crepidioides*, *Knoxia corymbosa* and *Mikania cordata* showed maximum resources and present in all sites. *Centella asiatica* was in 3

and 5 years site however absent 10 years site. *Oxalis corniculata* and *Scoparia dulcis* was in 5 and 10 years sites however it was absent in 3 years site. *Bidens pilosa* Linn. and *Spilanthes acemella* was in 5 years site however this resources was absent in both 3 and 10 years sites. In winter season, species found in all the sites were *Ageratum conyzoides*, *Chromolaena odorata*, *Gynur acrepidioides*, and *Mikania cordata*. *Bidens pilosa*, was in 5 s and 10 years sites, however this species s was absent in 3 years. *Knoxiacorymbosa* was in both 3 and 10 years but absent in 5 years site. *Allardia gabra* and *Spilanthes acemella* were in 5 years whereas absent in both 3 and 10 years sites. In summer season, species found in all sites were *Ageratum conyzoides*, *Biden pilosa*, *Chromolaena odorata*, *Gynur acrepidioides*, *Knoxi acorymbosa* and *Mikania cordata*. *Centella asiatica* was in 3 and 5 years sites, however this species was absent in 10 years site. *Ageratum indicum*, was only in 10 years, however absent in 3 and 5 years sites. *Oxalis corniculata*, *Scopari adulcis* and *Spilanthes acemella* was recorded only in 5 years. However, species like *Ageratum conyzoides*, *Biden pilosa*, *Chromolaena odorata*, *Gynur acrepidioides*, and *Mikania cordata* showed

dominance-diversity in all different sites (Fig. 1) and were recorded throughout the seasons. Mitja et al (2007) also documented similar results..

Seasonal changes in weed diversity: Different indices ranked the site diversity differently. The richness indices viz. species count (D_1) and Margalef index (D_2) were maximum in the rainy season at 5 years. However, in terms of information statistic indices (Shannon, D_4), 10 years showed the maximum value in this season. Besides, this site also showed maximum range of diversity variation across seasons. In contrast, the 3 years site in rainy season showed the lowest value. Dominance measures (Simpson index) showed higher values for sites showing lower diversity e.g. 3 and 5 years sites in rainy in particular. The highest values of dominance concentration (D_5) in rainy season and winter season were found at 3 years and 5 years. In summer, however, 3 years and 5 years sites showed maximum dominance concentrations. In the winter season,10 years site showed maximum evenness. In contrast, 3 years showed greater evenness in summer and 10 years in winter. In the present study, species evenness tended to be higher in the rainy season During rainy season soil moisture favored

Table 1. Seasonal changes in importance value index (IVI) in different fallow (3 years, 5 years and 10 years) periods

Name of the species	Rainy			Winter			Summer		
	3 yrs	5 yrs	10 yrs	3 yrs	5 yrs	10 yrs	3 yrs	5 yrs	10 yrs
Ageratum conyzoides Linn.	171.2	157.6	80.7	133.4	109.5	80.7	138.9	159.4	57.6
Ageratum indicum Linn.	-	-	-	-	-	-	-	-	40.0
Allardia glabra	-	-	-	-	28.6	-	-	-	-
Bidens pilosa Linn.	-	17.4	-	-	14.0	8.5	8.9	23.8	24.0
Centella asiatica	14.1	13.4	-	-	-	-	9.1	12.5	-
Chromolaena odorata Linn.	18.8	16.1	45.4	51.0	45.5	60.2	21.0	26.3	62.1
Gynura crepidioides Benth.	24.0	13.4	63.3	31.7	18.2	17.7	14.2	7.6	26.9
Knoxia corymbosa	53.5	21.8	31.6	75.5	-	88.4	89.2	14.7	68.0
Mikania cordata (Burm) B.L. Robinson	18.3	8.6	21.0	38.8	22.9	44.5	18.7	7.0	21.5
Oxalis corniculata	-	13.1	20.2	-	-	-	-	8.3	-
Scoparia dulcis	-	20.3	37.8	-	-	-	-	14.6	-
Spilanthes acemella Murr	-	18.5		-	61.2	-	-	25.9	-

Diversity indices	Rainy			Winter			Summer		
	3 years	5 years	10 years	3 years	5 years	10 years	3 years	5 years	10 years
D_1	43	66	56	39	57	55	43	46	46
D_2	0.71	1.36	0.94	0.73	1.35	0.95	0.59	0.91	0.79
D_3	1.31	0.71	1.83	1.34	0.69	1.85	1.51	1.71	1.58
D_4	0.72	0.31	0.92	0.75	0.3	0.95	0.93	0.87	0.88
D_5	0.6	0.58	0.21	0.47	0.59	0.19	0.36	0.3	0.26

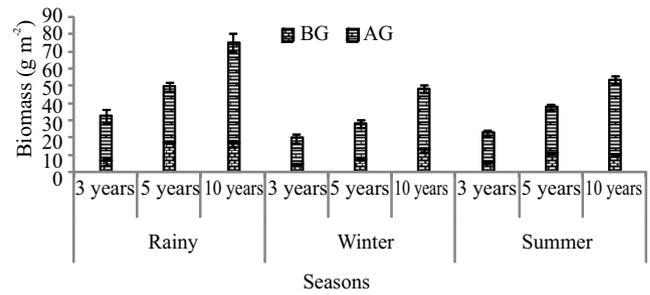D_1- Species count; D_2- Margalef; D_3- Shannon; D_4- Evenness; D_5- Simpson
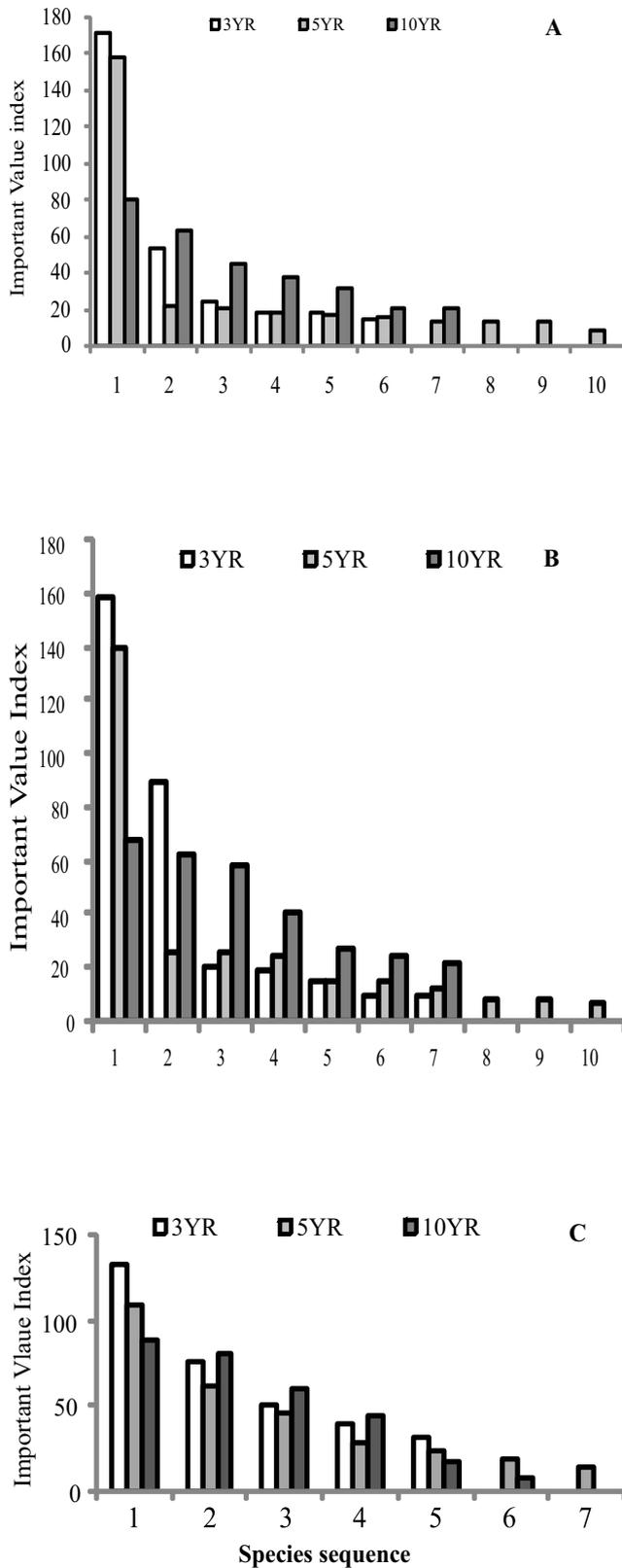
Fig. 2. Seasonal changes in aboveground (AG) and below-ground (BG) biomass (mean ± 1SE) in three age chronosequence of forest fallows (3, 5, and 10 years) following shifting cultivation

occurrence of larger number of the herbaceous plant species and their population on account of semi-arid climate of this area (Sharma and Upadhyaya 2002). However, only a few species occurred throughout the study period (e.g. *Ageratum conyzoides*, *Biden pilosa*, *Chromolaena odorata*, *Gynur acrepidioides*, and *Mikania cordata,* evidently due to the wide ecological amplitude of these species under the prevailing climatic conditions (Plieninger et al 2013). Total species count at each site (Table 2) in different seasons showed a common trend of maximum flora in rainy season and minimum in summer, suggesting a general increase in species diversity with moisture availability in tropical habitats. However, independent and variable diversity response of these habitats is intelligible in terms of range of diversity variation across different seasons. In this study, 5 and 10 years sites showed greater species diversity compared to 3 years sites. This appears likely due to better soil conditions at 5 and 10 years, and low soil nutrients in 3 years site. Reduction of plant diversity due to land-use change and environmental stress has been found in various ecosystems (Wilsey and Potvin 2000).

Comparison on weeds biomass with fallow periods: Among sites and seasons, the mean above and below ground biomass ranged between 17.17 -59.20 g m^{-2} and 3.96 - 16.77 gm^{-2} (Fig. 2). The 10 years and 5 years exhibited much greater standing weeds compared to 3 years may be due to shorter *jhum* cycle. Under short *jhum* cycle, such as 3 years or 5 years, community was maintained more or less in permanent state of arrested succession. However, when succession progresses for a longer period, such as 10 years or more, weed growth is suppressed by immigration of boreal elements .

CONCLUSION

Weed significantly reduces rice yield in shifting cultivation sites and therefore, ecological management of weed without herbicides has become a prerequisite in this

Fig. 1. Dominance-diversity curves of weeds across different sites (3 years, 3YR; 5 years, 5 YR and 10 years, 10 YR) and seasons (A-rainy, B-winter and C-summer)

region. This study concludes that the weeds are highly dynamic showing wide periodical variations in abundances and diversity in different age chronesequence sites of shifting cultivation, which exhibit that the weeds are sensitive to management practices. Further, different weeds species showed variations in their occurrences and maturity. This reflects that the thorough studies on weed biology may be of great help in managing problems of weed in the region. However, integrated approaches like use of certified seeds, increased crop seeding densities, cultivation of competitive variety, crop rotation, and water and fertilizer management followed by manual weeding can control weed efficiently. Further studies on weed species diversity from the forest Jhum would assist better management plans. The present analysis would be useful in developing future crop management and conservation plans through long-term monitoring of weed diversity in this region.

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REFERENCES

Aulakh MS, Khera TS, Doran JW, Singh K and Singh B 2000. Yields and nitrogen dynamics in a rice–wheat system using green manure and inorganic fertilizer. *Soil Science Society of America Journal* **64**: 1867-1876.

Azmi M, Juraimi AS and Mohamad Najib MY 2007..Critical period for weedy rice control in direct-seeded rice. *Journal of Tropical Agriculture and Food Science* **35**: 319-332.

Begum M 2006. *Biology and management of Fimbristylis miliacea (L.) Vahl.* Ph.D Thesis, University Putra Malaysia, Serdang Darul Ehsan, Malaysia.

Begum M, Juraimi AS, Azmi M, Rajan A and Syed-Omar SR 2005. Weed diversity of rice fields in four districts of muda rice granary area, northwest Peninsular Malaysia. Malays. *Applied Biology* **34**: 31-41.

Begum M, Juraimi AS, Azmi M, Syed Omar SR and Rajan A 2008. Weed flora of different farm blocks in block-1 of muda rice granary in peninsular Malaysia. *Journal of Bioscience* **19**: 33-43.

Boldt PE, Rosenthal SS and Srinivasan R 1998. Distributions of field bind weed and hedge bind weed in the USA. *Journal of Production Agriculture* **11**: 377-381.

Clifford HT and Stephenson W 1975. *An Introduction to Numerical Classification.* Academic Press, London.

Curtis JT and Mclntosh RP 1951. The upland forest continent in the Prairie forest border region of Wisconsin. *Ecology* **32**: 476-496.

Donald CM 1958. The interaction of competition for light and nutrient; *Australian Journal of Agriculture Research* **9**: 421-435.

Donald CM 1963. Competition among crop and pasture plant. *Advances in Agronomy* **15**: 111-118.

Gairola S, Sharma CM, Suyal S and Ghildiyal SK 2011. Species composition and diversity in mid altitudinal moist temperate forests of the Western Himalaya. *Journal of Forest Science* **27**: 1-15.

Gaur RD 1999. *Flora of the District Garhwal North West Himalaya.* Trans Media Srinagar (Garhwal), U.P., India.

Grogan P, Lalnunmawia F and Tripathi SK 2012. Shifting cultivation in steeply sloped regions: A review of management options and research priorities for Mizoram state, Northeast India. *Agroforestry Systems* **84**: 163-177.

Hayat K 2004. *Weed management strategies in direct seeded rice culture under the agro-ecological condition of Pakistan.* Ph.D. Thesis, Gomal University. D.I. Khan, Pakistan.

Hussain S, Ramzan M, Akhter M and Aslam M 2008. Weed management in direct seeded rice. *The Journal of Animal and Plant Science* **18**: 86-88.

Hyvonen T and Salonen J 2002. Weed species diversity and community composition in cropping practices at two intensity levels-a six-year experiment. *Plant Ecology* **154**: 73-81.

Kiers ET, Leakey RRB, Izac AJ, Heinemann A, Rosenthal E, Nathan D and Jiggins J 2008. Agriculture at a crossroads. *Science* **320**: 320–321.

Kim DS, Mashall EJP, Caseley JC and Brain P 2006. Modelling interactions between herbicide and nitrogen fertiliser in terms of weed response. *Weed Research* **46**: 480-491.

Kushwaha SPS, Ramakrishnan PS and Tripathi RS 1981. Population dynamics of *Eupatorium odoratum* L in successional environments following slash and burn agriculture (Jhum). *Journal of Applied Ecology* **18**: 529-536.

Menalled F 2008. *Integrated Strategies for Managing Agricultural Weeds: Making Dropping Systems Less Susceptible to Weed Colonization and Establishment*. MSU Extension Mont Guide (MT200808AG) New 7/2008.

Misra J, Pandey HN, Tripathi RS and Sahoo UK 1992. Weed population dynamics under 'jhum' (slash and burn agriculture) and terrace cultivation in northeast India. *Agriculture Ecosystems and Environment* **41**: 285-295.

Mitja D, Miranda IS, Velasquez E and Lavelle P 2008. Plant species richness and floristic composition change along a rice-pasture sequence in subsistence farms of Brazilian Amazon, influence on the fallows biodiversity. *Agriculture, Ecosystems and Environment* **124**: 72-84.

Mukherjee D and Singh RP 2005. Effect of low doses of herbicides on weeds, nutrientuptake and yield of transplanted rice (*Oryza sativa*). *Indian Journal of Agronomy* **50**: 194-196.

Pandey HN and Dubey SK 1989. Growth and population dynamics of an exotic weed *Partheniumhy sterophorus* Linn. *Proc· Indian Academy of Sciences* (*Plant Science*) **99**: 51-58.

Pielou EC 1966. Species diversity and pattern diversity in the study of ecological succession. *Journal of Theoretical Biology* **10**: 370-383.

Plieninger T, Gaertner M, Hui C and Huntsinger L 2013. Does land abandonment decrease species richness and abundance of plants and animals in Mediterranean pastures, arable lands and permanent croplands. *Environmental Evidence* **2**: 3.

Rabbani N, Bajwa R and Javaid A 2011. Interference of five problematic weed species with rice growth and yield. *African Journal of Biotechnology* **10**: 1854-1862.

Rai JPN and Tripathi RS 1984. Population dynamics of different seedling cohorts of two co-existing annual weeds, *Galinsog aciliate* and *G· parviflora*, on two contrasting sites. *Acta Oecol· Oecol· Plant·* **5**: 357-368.

Ramakrishnan PS 1993. *Shifting agriculture and sustainable development*: *an interdisciplinary study from north-eastern India* (Unesco and Oxford University Press) 424 p.

Ramzan M 2003. Evaluation of various planting methods in rice–wheat cropping system, Punjab, Pakistan. *Rice crop Report* 2003 – 04. pp: 4-5.

Richards MC 1993. The effects of agronomic factors on competition between cereals and weeds: the implications in integrated crop production. In: Proceedings of the *Brighton Crop Protection Conference-Weeds*, Brighton, UK,pp. 991-996.

Riser PG and Rice EL 1971. Diversity species in Oklahoma upland. *Forest Ecology* **52**: 870-880.

Saxena KG and Ramakrishnan PS 1984. Patterns of herbaceous vegetation development and weed potential under slash and burn agriculture (Jhum) in north-eastern India. *Weed Research* **24:** 137-144.

Shannon CE and Weaver W 1949. *The Mathematical Theory of Communication*. Urbana, III: Univ. Illinois Press.

Sharma CM, Mishra AK, Krishan R, Tiwari OP and Rana YS 2016.Variation in vegetation composition, biomass production, and carbon storage in ridge top forests of high mountains of Garhwal Himalaya. *Journal of Sustainable Forestry* **35**(2): 119-132.

Sharma LK 1980. *Floristic Studies of District Bulandshahr and Morphological Studies of Desmodium Desv. And Alysicarpus Neek. With Special Reference to Fruit Structure*. Ph.D. Thesis. Meerut University, Meerut, India.

Singh Sh B, Mishra BP, Tripathi SK 2015. Recovery of plant diversity and soil nutrients during stand development in subtropical forests of Mizoram. Northeast India, *Biodiversitas* **16**(2): 205-212

Singh Y, Singh B, Ladha JK, Khind CS, Gupta RK, Meelu OP and Pasuquin E 2004. Long-term effects of organic inputs on yield

and soil fertility in the rice–wheatrotation. *Soil Science Society of America Journal* **68**: 845-853.

Tripathi SK, Vanlalfakawma DC, Lalnunmawia F 2017. Shifting cultivation on steep slopes of Mizoram, India: Impact of policy reforms. *In*: Malcom Cairns (ed.) *Shifting cultivation policies: Balancing environmental and social sustainability*. CABI International. pp 393-413.

Whittaker RH 1975. *Communities and Ecosystem* McMillan, New York. 385p.

Whittaker RH 1977. Evolution of species diversity in land communities. pp. 1-67. *In:* M.K. Hecht, W.C. Steere and B. Wallace (eds.) *Evolutionary Biology*. Volume 10.Plenum, New York.

Wilsey BJ and Potvin C 2000. Biodiversity and ecosystem functioning: importance of species evenness in an old field. *Ecology* **81**: 887-892.

Zinke PJ, Sabhasri S and Kunstadter P 1978. Soil fertility aspects of the 'Lua' forest fallow system of shifting cultivation; in *Farmers in Forest* (eds) P Kunstadter, E C Chapman and S Sabhasri (Hawaii: East-West Centre), pp 134-159.

Analysis on Variations in Spectral Reflectance Characteristics of Coral Reef Benthic Compositions from Gulf of Mannar, Tamil Nadu, India

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Abstract: This study focussed on analysing the variations in spectral signature of different end members in coral reef benthic compositions with respect to varying monsoon conditions and varying chlorophyll concentrations from Gulf-of-Mannar, India. The *in-situ* measurements were made at two different time periods for same end-members at same geographical locations; the first set of *in-situ* measurements were collected during Pre-Monsoon season (March-2018) and the second set of *in-situ* measurements were collected during Monsoon season (August-2018). RAMSES-TriOS Hyperspectral radiometer was used to collect the Up-welling radiance and Downwelling irradiance for the visible and Near Infra-Red spectral region (350-900 nm) and WET-Star Fluorometer was used to collect the chlorophyll concentration. Necessary processing steps were carried out to retrieve the spectral signature for all end-members. Further, derivative analysis was carried out to identify the minor variations among spectral signatures. All the end-members provide a consistency in terms of spectral shape and spectral magnitude. It denotes that, the spectral pattern won't change with respect to varying monsoon conditions and different chlorophyll concentration.

Keywords: Coral-reefs, *in-situ* measurement, Pre-monsoon and monsoon, Variations in spectral shape and magnitude

Coral reefs are appearing to be the sensitive indicators of regional climate change. Hence, it is of immediate importance to improve our ability to detect and monitor changes in their ecosystems. Comparing with traditional methods, remotely sensed imageries can be act as a tool for quantitative and systematic monitoring of coral reefs at broad synoptic scale (Sarah Hamylton 2011) and many studies have explored the potential of remote sensing in mapping and monitoring of coral reefs (Kutser et al 2003, Goodman and Ustin 2007 and Rongyong Huang et al 2018). These satellite imageries require the collection of *in-situ* reflectance spectra (spectral signatures) to categorize various end members. The spectral signatures, if they are unique, can be used for automatic identification and mapping of any components across space and time (Campbell 2006). Numbers of researchers have measured the *in-situ* spectral reflectance of coral reef benthos and substrates across various locations (Hochberg et al 2004, Kandasami Nimalan et al 2018). Previous studies reported the complex scenario of existence of unique spectral signatures for coral reef ecosystem. Because, spectral reflectance characteristics of features within a coral reef environment are optically similar, so confusion can arise in identification. Thus, the understanding on basic properties of spectral characteristics on coral reef species is essential and it is also necessary to study in detail about the spectral seperability of various

bottom components in a coral reef environment before its identification can be made using remote sensing imageries.

Studies based on spectral information in identifying the species of different type of corals are tried and were successful. Many of the previous studies (Dan Lubin et al 2001 and Hochberg and Atkinson 2003) utilised the derivative analysis and provided most reliable results in terms of identifying minor variations in spectral characteristics of coral reef ecosystem. Kandasami Nimalan et al (2018) have analysed the spectral characteristics of various coral reef benthic compositions using derivative analysis and concluded that the first order derivative analysis can be helpful in discrimination of corals by family-wise, second order derivative analysis can be helpful in discrimination of species among Acropora family and third order derivative analysis can be helpful in discrimination of coral reef benthic compositions from other benthic compositions. The information on variations in spectral characteristics of coral reef benthic composition with respect to varying monsoon condition on same geographical location and varying chlorophyll concentration on same season are lacking. Hence, this study attempted to analyse the variations in spectral characteristics of different end members in coral reef benthic compositions with respect to varying monsoon conditions and varying chlorophyll concentrations from Gulf of Mannar, India. Further, to identify the minor variations in

terms of spectral shape and spectral magnitude among the spectral signatures of coral reef benthic compositions, derivative analysis was performed.

MATERIAL AND METHODS

Study area: Government of India has established the Gulf-of-Mannar Biosphere Reserve, in 1989, is one among the four major reef areas in India, located on the South-Eastern coast. Reefs in the GoM are developed around 21 uninhabited islands that lies between the latitude of 8^0 47' N to 9^0 15'N and longitude of 78^0 12'E to 79^0 14'E covering an area of 623 ha along the 140 km stretch between Tuticorin and Rameswaram in the state of Tamil Nadu, India. As many as 133 species of corals and its reef of fringing and patchy type are present at 5 m depth around the islands.

Processing overview: This approach for analysing variations in the spectral characteristics of coral reef benthic compositions initially involved the *in-situ* data collection, followed by necessary processing steps to retrieve the spectral characteristics of corresponding end member and finally identifying the variations in spectral characteristics of different benthic compositions on different monsoon condition and varying chlorophyll concentration with respect to spectral shape and spectral magnitude using derivative analysis. An overview of the processing procedure is described here in (Fig.1).

In-situ data collection: *In-situ* down-welling radiance (E_d) and up-welling irradiance (L_u) of coral reef benthic compositions are recorded using RAMSES-TriOS Hyperspectral radiometer ranges between the wavelengths of 350 – 900 nm at a bandwidth of 3 nm. Measurements are recorded for each sample with the help of one radiance and one irradiance sensor. The L_u sensor was kept pointing downward to measure the upwelling radiance from the object; whereas, E_d sensor is kept pointing upward to measure the down-welling irradiance from sun. The radiometric sensors (E_d and L_u) are kept parallel to each other but facing opposite sides such that one is looking downward towards the end-member and other is looking upward towards the sea surface. Intense care is taken to avoid boat shadowing and instrument self-shadowing effects during the deployment. All the measurements are recorded between 10:00 to 15:00 hours, prevailing low tide conditions, within the solar zenith angle of less than 30° and sensor viewing angle of 35°-40°, and also we made sure that there are no clouds in the path between sunlight and end-member during the measurements.

Spectral analysis: To retrieve the spectral characteristics of measured *in-situ* data like sub surface remote sensing reflectance (r_{rs}) and remote sensing reflectance (R_{rs}) Equation (1) and (2) are used. Sub surface remote sensing

reflectance (r_{rs}) is the measure of ratio between the radiance exhibited by a target object (L_u) to the sun irradiance (E_d). It is therefore defined as

$$r_{rs} = L_u/E_d \qquad (1)$$

Remote sensing reflectance (R_{rs}) is the measure of 1-r_F/n^2_w (approximately equals to 0.545) times of Sub Surface remote sensing reflectance (Mobley 1999). Where, "r_F" is the Fresnel reflectance of the surface as seen from the water (0.02 to 0.04) and "n_w" is the real part of the index of refraction of sea water (1.34). It is therefore defined by;

$$R_{rs} = 0.545*r_{rs} \qquad (2)$$

No radiometric calibration of the spectral data was necessary, since the values used in the analysis are reflectance values and not radiance measures. Spectral properties of the end-members are analysed with the help derivative analysis which have been examined by many researchers to identify the minor variations in spectral shape. Derivative spectroscopy uses the changes in spectral reflectance with respect to wavelength in order to sharpen the spectral features. Thus, it allows components of the spectrum to be more clearly separated (Rundquist et al 1996). The simplest method of finding derivatives is by dividing the difference between successive spectral values by the wavelength interval separating them (Demetriades-shah et al 1990).

The formula that is been generally used to calculate the derivatives are;

$$(ds/d\lambda)_i = [R_{rs}(\lambda_i) - R_{rs}(\lambda_j)] / [\lambda_i - \lambda_j] \qquad (3)$$

Here, the $R_{rs}(\lambda_i)$ refers to the Remote sensing reflectance value of the wavelength "i" and $R_{rs}(\lambda_j)$ refers to the Remote sensing reflectance value of the wavelength "j". Whereas, $\lambda_i - \lambda_j$ is the difference between consecutive wavelengths, that is constant throughout the spectrum (1 nm).

RESULTS AND DISCUSSION

Necessary processing steps were carried out using 'Equation (1)-(2)' to retrieve the spectral characteristics of measured *in-situ* data and that has been resampled to 1 nm interval across a spectral range of 350 - 900 nm. Finally, a spectral reflectance signature for each end-member is obtained by averaging the number of measurements made for that particular end-member.

Hypothesis-1: Variations resulting from different monsoons

The variation in spectral response of same end-members in different monsoon season is tested using its spectral shape and spectral location of reflectance maximum for all the end members. The Spectral reflectance signature, First order derivatives and Field photograph for Porites lobdata is shown in Figure 2 (a), (b) and (c). The spectral reflectance signature,
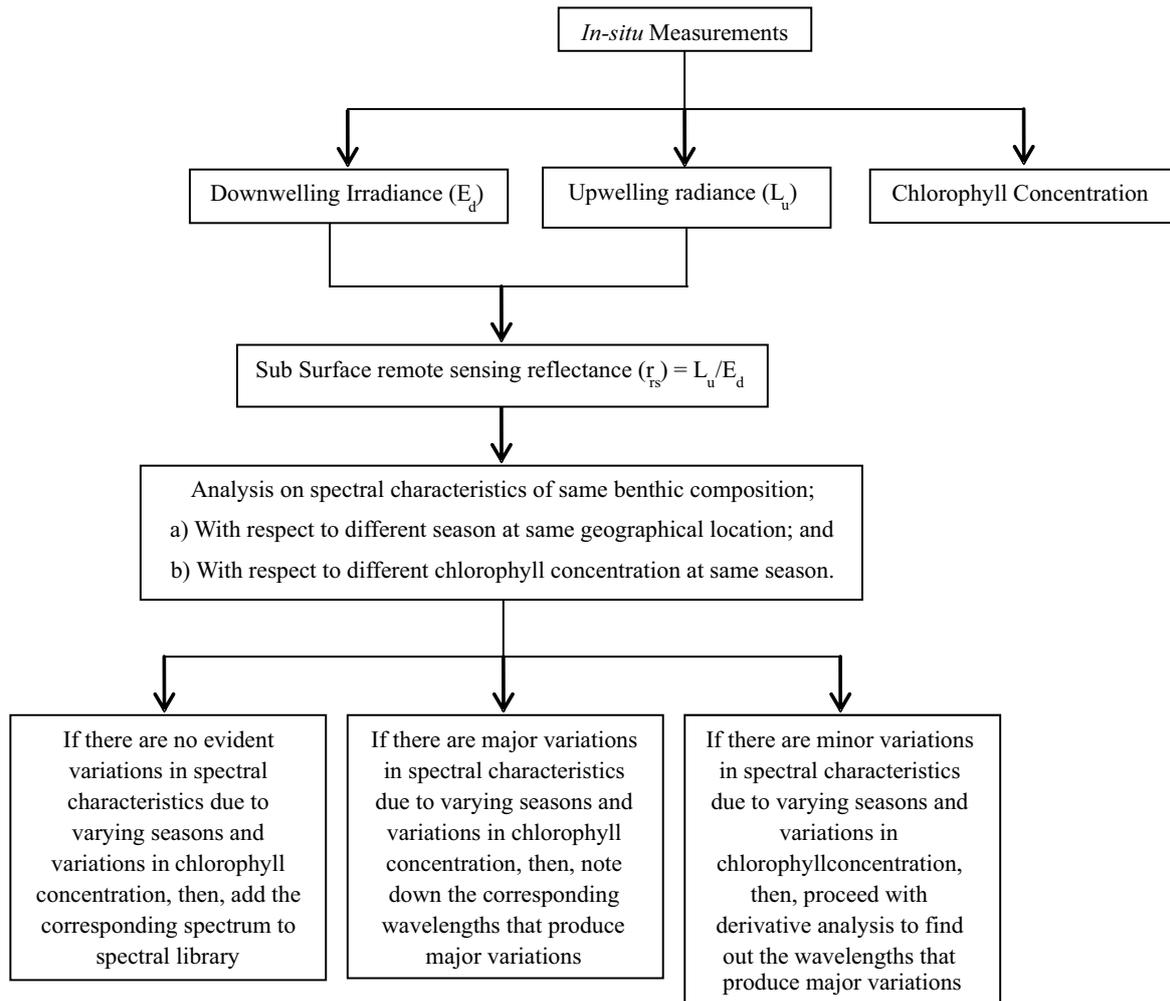
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┌─────────────────────────────┐
│   In-situ Measurements      │
└─────────────────────────────┘
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| Downwelling Irradiance (E_d) | Upwelling radiance (L_u) | Chlorophyll Concentration |

Sub Surface remote sensing reflectance (r_{rs}) = L_u/E_d

Analysis on spectral characteristics of same benthic composition;

a) With respect to different season at same geographical location; and

b) With respect to different chlorophyll concentration at same season.

| If there are no evident variations in spectral characteristics due to varying seasons and variations in chlorophyll concentration, then, add the corresponding spectrum to spectral library | If there are major variations in spectral characteristics due to varying seasons and variations in chlorophyll concentration, then, note down the corresponding wavelengths that produce major variations | If there are minor variations in spectral characteristics due to varying seasons and variations in chlorophyllconcentration, then, proceed with derivative analysis to find out the wavelengths that produce major variations |

Fig. 1. Processing methodology

first order derivatives and field photograph for *Acropora nobilis* is in Figure 3 (a), (b) and (c); *Favia speciosa* in Figure 4 (a), (b) and (c); Bleached coral in Figure 5 (a), (b) and (c); Sea-grass in Figure 6 (a), (b) and (c). The geographical locations of *in-situ* measurements recorded during pre-monsoon and monsoon seasons were given in Table 1.

There are certain features that are most common in the spectral signatures among the species. The end-members of *Porites lobdata, Favia speciosa* and *Acroporn nobilis* exhibit the triple peaked pattern first reported by (Hochberg and Atkiston 2000) exhibiting peaks around 570, 710 and 805 nm. Second peak of the triple peaked pattern falls near 710 nm is slightly higher in magnitude than peaks located at 570 and 805 nm. A peak between 550 – 555 nm appears to be a common feature of sea-grass reflectance over wide geographic locations (Karpouzli et al 2004). The spectral location of reflectance maximum for Acropora Nobilis, Favia Speciosa and Porites Lobdata almost similar (located on 715 nm), which will cause confusion in analysis among each of

the individual end-members (Table 2).

In order to overcome this confusion, first order derivative analysis is performed. The derivative analysis was carried out using 'Equation (3)' and it doesn't add any information that is already contained in zero order spectra (Talsky 1994). Diagnostic spectral locations beyond the 750 nm are discarded due to the less effective water penetrating capabilities of light at longer wavelengths (Wettle et al 2003). The reflectance maximum position was unique for each end-member shifted from 715 to 711 nm for *A. nobilis*, from 715 to 693 nm for *F. speciosa*, from 715 to 696 nm for *P. lobdata*, from 574 to 571 nm for bleached coral and from 705 to 696 nm for sea grass. While comparing among pre-monsoon and monsoon season, with respect to spectral shape all the end-members except *A. nobilis* exhibits a similar shape and with respect to spectral location of reflectance maximum, there has been a minor variation in their positions. *A. nobilis* has a spectral location of reflectance maximum at 711 nm at pre-monsoon season and 707 nm at monsoon season (Table 3).

The consistency in spectral locations of reflectance maximum between pre-monsoon and monsoon season indicates that spectral signatures have its consistent shapes among different monsoon seasons.

Hypothesis-2: Variations resulting from different chlorophyll concentrations

Water quality is one of the most important factors determining the long-term health of coral reef ecosystem. An

Table 1. Geographical locations of *in-situ* measurements during pre-monsoon and monsoon seasons

Details of benthic composition	Latitude	Longitude
Porites lobdata	9⁰ 15.024'	79⁰ 12.792'
Bleached coral	9⁰ 14.686'	79⁰ 14.183'
Acropora nobilis	9⁰ 15.053'	79⁰ 12.718'
Favia speciosa	9⁰ 15.052'	79⁰ 12.705'
Sea-grass	9⁰ 15.058'	79⁰ 12.521'
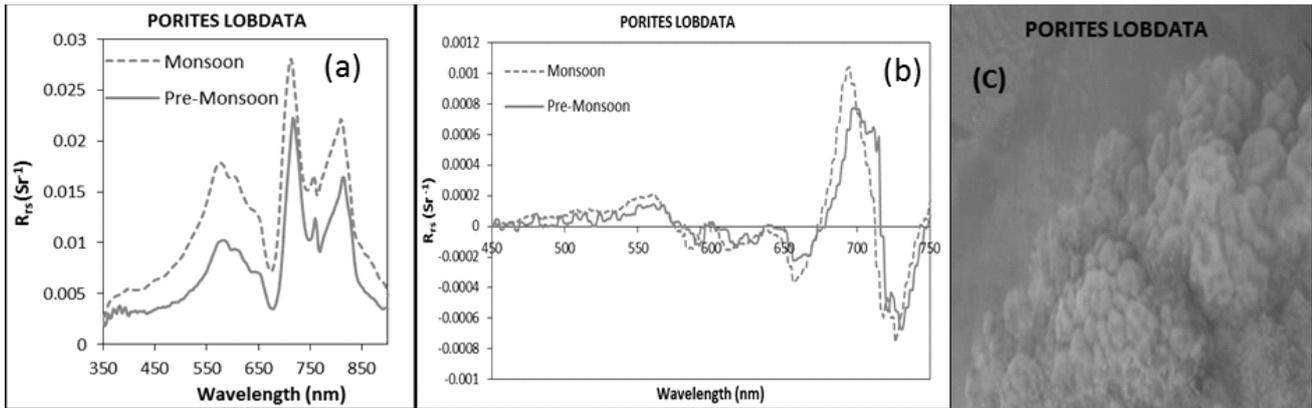
Fig. 2. (a) Spectral reflectance signature; **(b)** First order derivatives and **(c)** Field photograph of *Porites lobdata*
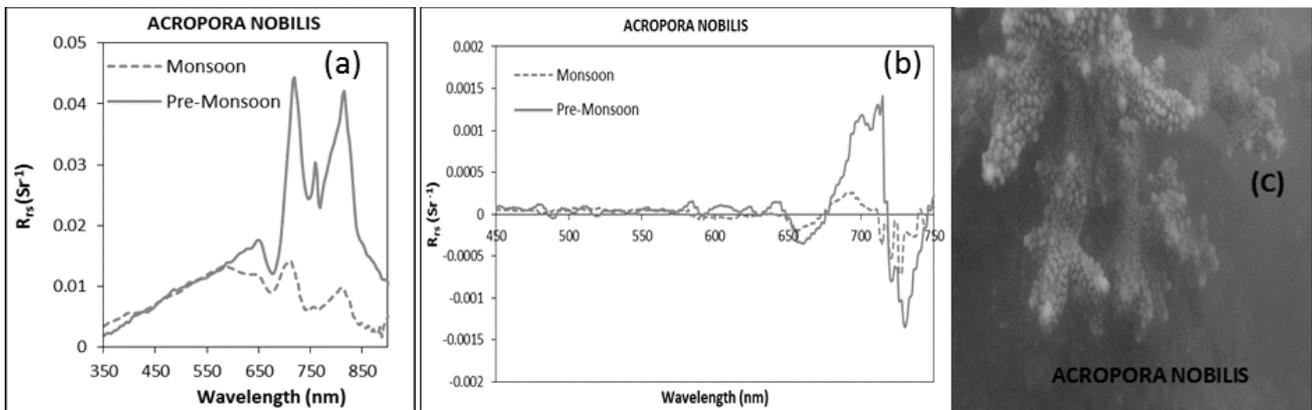
Fig. 3. (a) Spectral reflectance signature; **(b)** First order derivatives and **(c)** Field photograph of *Acropora nobilis*
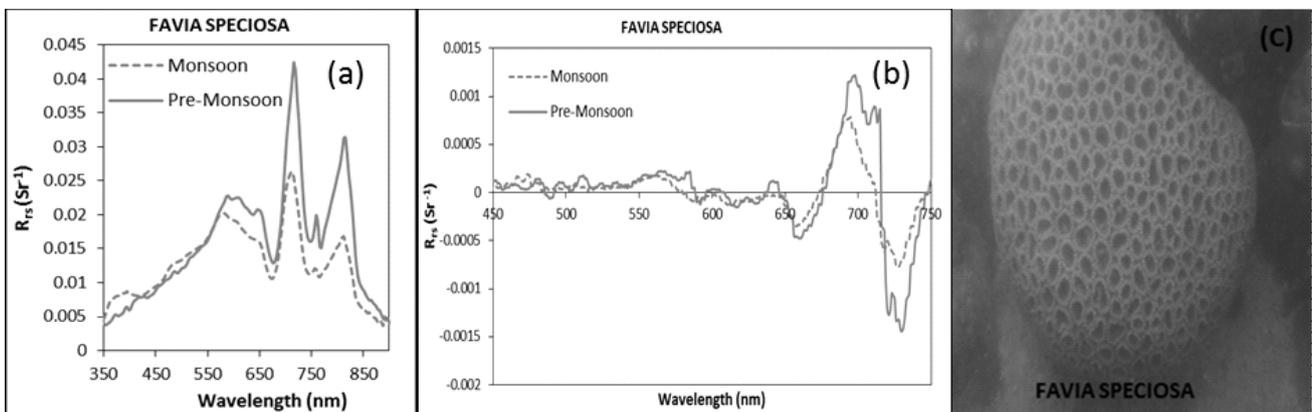
Fig. 4. (a) Spectral reflectance signature; **(b)** First order derivatives and **(c)** Field photograph of *Favia speciosa*

increased nutrient content usually leads to an increase in chlorophyll concentrations in coastal waters because of increased phytoplankton biomass. Concentrations of the plant pigment chlorophyll a are useful proxy indicator of the amount of nutrients incorporated into phytoplankton biomass. Generally, chlorophylls absorb light most strongly in the blue portion of the electromagnetic spectrum as well as the red portion (Muneer et al 2014). Conversely, it is a poor absorber of green and near-green portions of the spectrum.

The variation in spectral reflectance of same end-members in different chlorophyll concentration at same season is tested using spectral shape and spectral location of reflectance maximum for all the end members. The spectral reflectance signature of individual end-member collected from the different locations that has different chlorophyll a concentrations (Fig. 7).

While comparing all the end-members, with respect to spectral shape all of them exhibit a similar shape irrespective
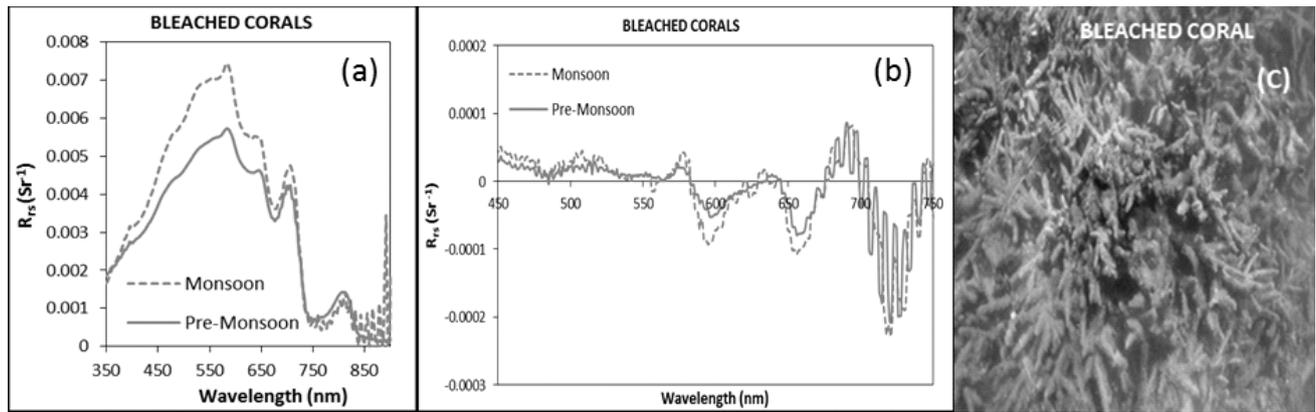
Fig. 5. (a) Spectral reflectance signature; **(b)** First order derivatives and **(c)** Field photograph of Bleached coral
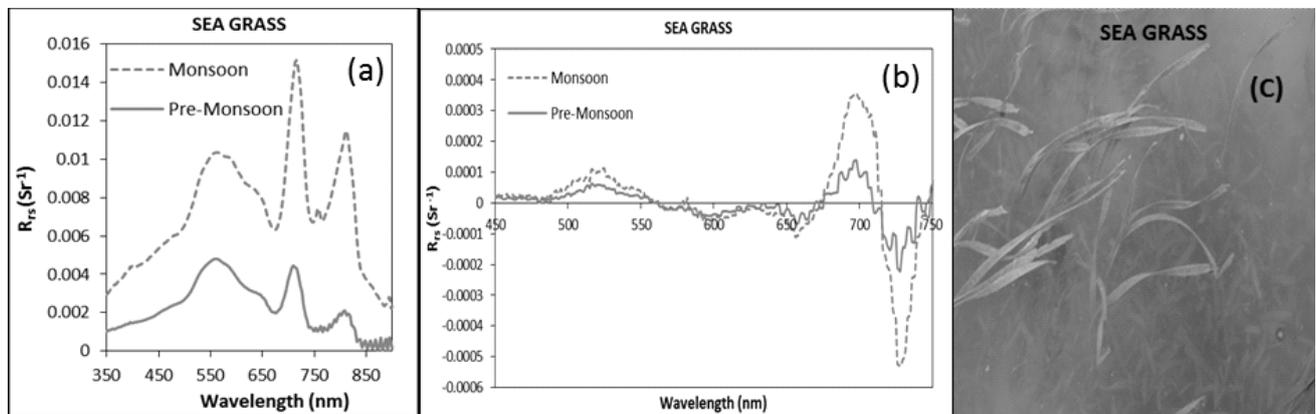
Fig. 6. (a) Spectral reflectance signature; **(b)** First order derivatives and **(c)** Field photograph of Sea-grass

Table 2. Spectral location of reflectance maximum of end-members with respect to different monsoon seasons

Season	*A. nobilis*	*F. speciosa*	*P. lobdata*	Bleached Coral	Sea-grass
Pre-monsoon	715 nm	715 nm	715 nm	574 nm	705 nm
Monsoon	709 nm	706 nm	709 nm	578 nm	712 nm

Table 3. Spectral location of reflectance maximum of end-members after derivative analysis

Season	*A. nobilis*	*F. speciosa*	*P. lobdata*	Bleached Coral	Sea-grass
Pre-monsoon	711 nm	693 nm	696 nm	571 nm	696 nm
Monsoon	707 nm	689 nm	692 nm	579 nm	693 nm

of the chlorophyll a concentration. The peak of coral species followed a three peaked pattern exhibiting peaks around 570, 710 and 805 nm. Whereas, a peak between 550-555 nm which appears to be a common feature of sea-grass reflectance over geographic regions. Meanwhile, while comparing all the end-members with respect to spectral location of reflectance maximum, there has been a minor variation in their positions (Table 4). *F speciosa* has a spectral location of reflectance maximum at 715 nm at the location that contains high chlorophyll concentration and 711 nm at the location that has low chlorophyll concentration. Likewise, the spectral locations of reflectance maximum for other end-members were given in Table 5.

For more authentications, the magnitude of reflectance maximum was also considered and analysis has been done. Favia Speciosa has a magnitude of reflectance maximum of 0.0278 s_r^{-1} at the location that contains high chlorophyll concentration and has a magnitude of reflectance maximum of 0.0254s_r^{-1} at location that contains low chlorophyll concentration (Table 6). The location that has high chlorophyll concentration tend to produce more magnitude of reflectance maximum and vice-versa. Since, the higher the

Table 5. Spectral location of reflectance maximum of end-members with respect to varying chlorophyll concentration

Spectral location of reflectance maximum	Chlorophyll condition	*F. speciosa*	*P. Lobdata*	Sea-grass
	High concentration	715 nm	709 nm	551 nm
	Low concentration	711 nm	706 nm	544 nm

amount of chlorophyll in any location, the higher will be the amount of absorption.

CONCLUSION

This study have analysed the spectral reflectance characteristics of various coral reef benthic compositions with particular emphasis on variations resulting from different Monsoons and different chlorophyll concentrations. While comparing among pre-monsoon and monsoon seasons, with respect to spectral shape all the end-members except *Acropora nobilis* exhibits a similar shape and with respect to spectral location of reflectance maximum, there has been a minor variation in their positions. All the end-members, with respect to spectral shape exhibit a similar shape. With
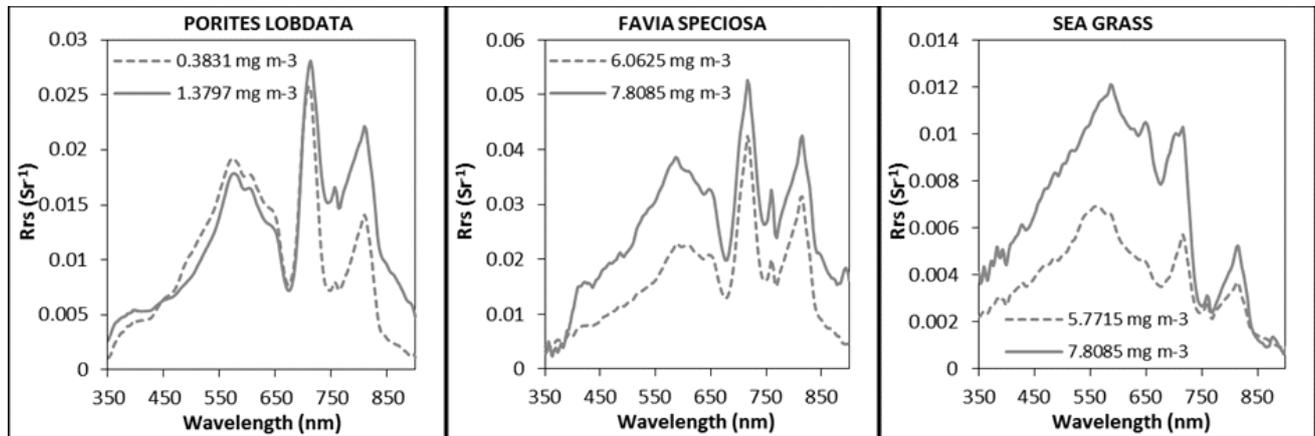

Fig. 7. Spectral reflectance signature of various end-members with varying chlorophyll a concentrations

Table 4. Chlorophyll concentration of various end members and its geographical locations

Chlorophyll concentration (mg m⁻³)	*F. speciosa*	*P. lobdata*	Sea grass
Location-1	0.3831 (Latitude: 9⁰ 14.628' Longitude: 79⁰ 14.057')	1.0317 (Latitude: 9⁰ 15.041' Longitude: 79⁰ 12.660')	0.5068 (Latitude: 9⁰ 14.949' Longitude: 79⁰ 12.204')
Location-2	1.3797(Latitude: 9⁰ 15.024' Longitude: 79⁰ 12.792')	1.4842 (Latitude: 9⁰ 15.052' Longitude: 79⁰ 12.705')	1.0317 (Latitude: 9⁰ 15.041' Longitude: 79⁰ 12.660')

Table 6. Magnitude of reflectance maximum of end-members with respect to varying chlorophyll concentration

Magnitude of reflectance maximum	Chlorophyll condition	*F. speciosa*	*P. Lobdata*	Sea-grass
	High concentration	0.0278 s_r^{-1}	0.0506 s_r^{-1}	0.0116 s_r^{-1}
	Low concentration	0.0254 s_r^{-1}	0.0407 s_r^{-1}	0.0065 s_r^{-1}

respect to spectral location of reflectance maximum, there has been a minor variation in their positions and with respect to magnitude of reflectance maximum. The location that has high chlorophyll concentration tend to produce more magnitude of reflectance maximum and vice-versa. The consistency in spectral locations of reflectance maximum and magnitude of reflectance maximum denotes that, irrespective of varying monsoon conditions and different chlorophyll concentration, the spectral signatures will have its consistent patterns.

ACKNOWLEDGEMENT

REFERENCES

Campbell JB 2006. *Introduction to remote sensing,* 4th Edition, New York: Guilford Publications.

Dan Lubin, Wei Li, Phillip Dustan, Charles H. Mazel and Knut Stamnes 2001. Spectral signatures of coral reefs: Features from space. *Remote Sensing of Environment* **75**(1): 127-137.

Demetriades-Shah TH, Steven and Clark 1990. High resolution derivative spectra in remote sensing. *Remote Sensing of Environment* **33**: 55-64.

Goodman JA and Ustin SL 2007. Classification of benthic composition in a coral reef environment using spectral unmixing. *Journal of Applied Remote Sensing* **1**: 1-16.

Hochberg EJ and Atkinson MJ 2000. Spectral discrimination of coral reef benthic communities, *Coral Reefs* **19**: 164-171.

Hochberg EJ and Atkinson MJ 2003. Capabilities of remote sensors to classify coral, algae and sand as pure and mixed spectra. *Remote Sensing of Environment*, **85**: 174-189**.**

Hochberg EJ, Atkinson MJ, Apprill A and Andréfouët S 2004.Spectral reflectance of coral. *Coral reefs* **23**: 84-95.

Kandasami Nimalan, Muniappan Thanikachalam and Tune Usha 2018. Hyperspectral signatures of coral reef species and bottom types from gulf of Mannar, India. *Indian Journal of Geo-marine Sciences* (in press).

Karpouzli E, Malthus TJ and Place CJ 2004. Hyperspectral discrimination of coral reef benthic communities in the western Caribbean. *Coral Reefs* **23**: 141-151.

Kutser T, Dekker AG and Skirving W 2003. Modelling spectral discrimination of Great Barrier Reef benthic communities by remote sensing instruments. *Limnology and Oceanography* **48**: 497-510.

Muneer Sowbiya, Kim EunJeong, Park Jeong Suk and Lee Jeong Hyun 2014. Influence of green, red and blue light emitting diodes on multiprotein complex proteins and photosynthetic activity under different light intensities in lettuce leaves. *International Journal of Molecular Sciences* **15**(3): 4657-4670.

Mobley CD 1999. Estimation of the remote-sensing reflectance from above-surface measurements. *Applied Optics* **38**(36): 7442-7455.

Rongyong Huang, Kefu Yu, Yinghui Wang, Wenhuan Wang, Lin Mu and Jikun Wang 2018. Method to design a live coral cover sensitive index for multispectral satellite images. *Optic Express* **26**: A374-A397.

Rundquist DC, Han L, Schalles JF and Peake JS 1996. Remote measurement of algal chlorophyll in surface waters: The case for the first derivative of reflectance near 690 nm. *Photogrammetric Engineering and Remote Sensing* **62**: 195-200.

Sarah Hamylton 2011. Estimating the coverage of coral reef benthic communities from airborne hyperspectral remote sensing data: multiple discriminant function analysis and linear spectral unmixing, *International Journal of Remote Sensing* **32**(24): 9673-9690.

Talsky G 1994. *Derivative spectrophotometry: low and high order.* John Wiley and Sons, United States.

Wettle M, Ferrier, Lawrence and Anderson 2003. Fourth derivative analysis of Red Sea coral reflectance spectra. *International Journal of Remote Sensing* **24**(19): 3867-3872.

Precipitation and Rainy Day Trends in Kashmir Valley, Jammu & Kashmir, India

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Abstract: The aim of the present study is to analyze rainfall time series over a period of 38 years (1980-2017) in Kashmir valley. The study analyzed annual trends in rainfall and rainy days at seven major districts of Kashmir Valley namely Srinagar, Budgam, Baramulla, Anantnag, Kulgam, Pulwama and Kupwara to interpret trends in precipitation over the Kashmir Valley. The time series of rainfall and rainy-day trends were analyzed using parametric linear regression and non-parametric Mann-Kendall tests. The magnitude of the trend was quantified using Sen Slope index. No significant variation was observed in rainfall and rainy days in Srinagar, Budgam, Anantnag, Kulgam and Pulwama districts. A significant decreasing trend was observed in the annual rainy days of district Kupwara and both annual rainfall and number of rainy days showed a significant decreasing trend for district Baramulla. The results obtained from the analysis suggest that there has been no significant change in the climate of Kashmir valley over last 38 years
.

Keywords: Rainfall, Rainy days, Linear regression, Mann-kendall, Temperate region

The last century has witnessed climate change and global warming as one of the serious environmental concerns to confront humankind. Though the topic of climate change is vast, the varying pattern of precipitation justifies the urgency of a methodological attention towards the problem. Changes in precipitation are likely to affect the availability of food supply and the incidence of water related catastrophes activated by extreme events. Analysis of precipitation on different scales of time and space has shown a small positive global trend, while large areas are characterized by negative trends (IPCC 2014). Water resources will be most affected by changes in precipitation since it is the main driving force of the land phase of the hydrologic cycle and future climate change will affect agriculture, increasing the risk of hunger and water scarcity (Misra 2014). It will also result in rapid melting of glaciers leading to floods (Riebeek 2010). Changes in the distribution of precipitation would affect the spatial and temporal distribution of runoff, soil moisture and groundwater reserves (Kumar 2012) which would alter the frequency of droughts and floods (Kang et al 2009). The changes in precipitation will result in changes in rate of evaporation as well as rise in temperature (Lorenz et al 2010). All these changes will together affect soil moisture profoundly and level of soil moisture controls the moisture flow into rivers.

A number of meteorological studies have been conducted out for analyzing the trends in temperature and precipitation in different regions of the Himalayas. Warming temperature trends have been observed for many mountain ranges of South Asia comprising the Hindu Kush, Karakoram Himalaya belt (Viviroli et al 2007). Seasonal temperatures of the Himalayas also exhibit a strong warming trend (Immerzeel et al 2010). Increase in temperature also results in early runoff from snow and ice (Kaser et al 2010, Siderius et al 2013). Projected climate change models like SDSM (Statistical Downscaling Model) and ANN (Artificial Neural Network) have also predicted a warming trend in future (Parvaze et al 2016). The occurrence of natural calamities such as droughts, floods, cyclones and heat waves has increased in India in the recent past (Goswami et al 2006). The trend of precipitation is shifting towards an increase of heavy precipitation events and long dry spells. In J&K, Ladakh and Kashmir regions experienced catastrophic flash floods in 2008 and 2014. The present study was aimed to study the trends exhibited by rainfall and rainy days over Kashmir Valley in major districts of Kashmir Valley.

MATERIAL AND METHODS

The State of Jammu and Kashmir is located between 32°17' and of 37°5' North latitudes and 73°26' and 80°30' and 81° East longitudes. Kashmir valley lies in the temperate zone of the state. The valley has an elevation range of 1500 to 4200 m a.s.l. The meteorological data for the seven districts Srinagar, Budgam, Kulgam Anantnag, Pulwama,

Kupwara and Baramulla was obtained from Regional Meteorological Centre Srinagar was obtained for a period of 38 years (1980-2017). Observed daily maximum temperature, minimum temperature and precipitation data were reduced to annual time series of cumulative precipitation and rainy days. The numbers of rainy days per year for the same period were also computed. The time series were then analyzed for presence of trends using parametric and non-parametric approaches.

In order to detect trends in climatic and hydrological variables, several statistical methods have been put to practice (Whang et al 2009, Sonali and Kumar 2013, Sayemuzzan et al 2015 and Ahmad et al 2017). These methods may be parametric or non-parametric. The parametric trend analysis was performed using linear regression method while Mann-Kendall test was used for non-parametric trend analysis. The magnitude of the trend was quantified using another index, Sen Slope which is also non-parametric.

Linear regression trend: A straight line is fitted to the data and tested in order to determine whether the slope is different from zero or not. For a straight line of the form y = a + bx the test statistic t is calculated and the significance of test was assessed using "Student's t-test". Trend analysis is performed by fitting the simple regression equation separately for each parameter over years for the period 1980-2017. The software used for performing the trend analysis was MS-Excel. A simple linear regression (SLR) was used for determining the trend in the rainfall data.

Mann-Kendall test: The Mann-Kendall statistic S of a series x is calculated as (Mann 1945, Kendall 1975).

$$S = \sum_{i=1}^{n-1} \sum_{j=i+1}^{n} \mathrm{sgn}(X_j - X_i)$$

Where,

$$\mathrm{sgn}(\theta) = \begin{cases} 1 \text{ if } \theta > 0 \\ 0 \text{ if } \theta = 0 \\ -1 \text{ if } \theta < 0 \end{cases}$$

Test static

$$Z_{MK} = \begin{cases} \dfrac{S-1}{\sqrt{\mathrm{Var}(s)}} & S > 0 \\ 0 & S = 0 \\ \dfrac{\sqrt{S+1}}{\mathrm{Var}(s)} & S < 0 \end{cases}$$

The variance associated with the test static S is calculated as.

$$\mathrm{Var}(s) = \frac{n(n-1)(2n+5) - \sum_{i=1}^{n} t_i i(i-1)(2i+5)}{18}$$

Null Hypothesis for No Trend

$\Rightarrow$ $|Z_{MK}| < Z_{standard}$ at a given significance level

Standard Normal Variate (Z standard) at 5% significance level = 1.960

Sen-Slope Estimate: The slope of n pairs of data points was estimated using the Theil–Sen's estimator (Theil, 1950 and Sen, 1968) which is given by the following relation:

$$\beta = Median\left(\frac{x_j - x_i}{j - i}\right) \text{ for all value of } i < j$$

β is the robust estimate of the trend magnitude.

For 'n' observations, N=n (n-1)/2 values of â are possible. The median of these values is taken as the overall estimator of â. An 'upward trend' is indicated by a positive value of â indicates, while a 'downward trend' is specified by a negative value of â (Xu et al 2007).

RESULTS AND DISCUSSIONS

District Kupwara: Generally, winter is cold and severe with temperature falling as low as minus 10 °C in the upper parts of the district during December to February. Maximum

Table 1. GPS location of different districts of Kashmir Valley

District	Lat. (N)	Long (E)	Altitude (amsl)
Anantnag	33.43	75.09	1603
Baramulla	34.12	74.20	1562
Budgam	34.01	74.47	1560
Kulgam	33.39	75.01	1705
Kupwara	34.25	74.18	1609
Pulwama	34.54	74.53	1582
Srinagar	34.03	74.48	1564

Table 2. Annual trend of rainfall and rainy days in different districts of Kashmir valley

Time series	District	Mann Kendall		Linear Regression	
		Test Z	Result	Test Z	Result
Rainfall	Kupwara	0.078	NS	-1.175	NS
	Pulwama	0.600	NS	-0.328	NS
	Srinagar	0.980	NS	0.658	NS
	Kulgam	0.146	NS	-1.232	NS
	Budgam	0.765	NS	0.185	NS
	Baramulla	0.016	S	-2.017	S
	Anantnag	0.549	NS	-1.181	NS
Rainy days	Kupwara	0.029	S	-2.03	S
	Pulwama	0.920	NS	-0.21	NS
	Srinagar	0.870	NS	0.25	NS
	Kulgam	0.320	NS	-1.23	NS
	Budgam	0.811	NS	0.35	NS
	Baramulla	0.017	S	-2.02	S
	Anantnag	0.195	NS	-1.18	NS

temperature goes up to 35 °C in June, July and August in the plains. All areas except some parts of Karnah tehsil receive heavy snow fall. Average annual rainfall of about 1063.0 3 mm was recorded in the area (Fig. 2).

The results revealed a slight decreasing trend in both rainfall and number of rainy days for the district. The trend obtained for rainfall insignificant by both linear regression and Mann-Kendall test (Table 2). However, the trend exhibited for number of rainy days was found to be statistically significant by both tests. The Sen Slope estimate for the decreasing trend of rainy days was -0.455 days yr^{-1}.

District Pulwama: The average rainfall in Pulwama is 788.9 mm and the average temperature varies between 1.2 to 24.5°C. Very small decreasing trends were observed for both rainfall and number of rainy days. The linear regression as well as Mann-Kendall test showed that the rends were insignificant (Table 3).

District Srinagar: The mean annual rainfall in the district is 820 mm. The annual rainfall as well as number of rainy days at this station showed a small increasing trend (Fig. 4). Model projections for the same region also indicate a slight increase

Fig. 3. Annual trend of rainfall and rainy days in district Pulwama

Fig. 4. Annual trend of rainfall and rainy days in district Srinagar

Fig. 1. Monthly normals of precipitation and temperature for Kashmir Valley during the period 1980-2017

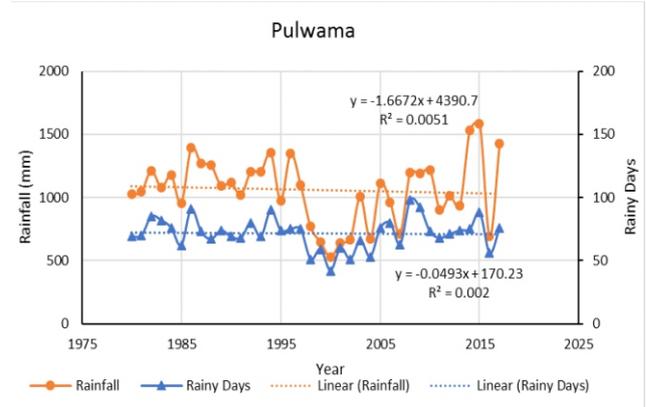**Fig. 2.** Annual trend of rainfall and rainy days in district Kupwara

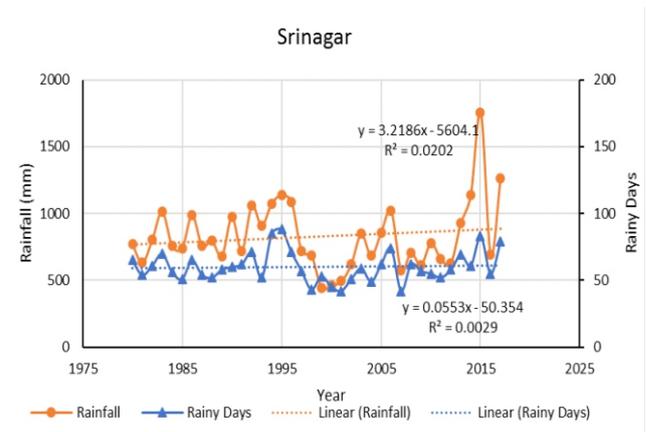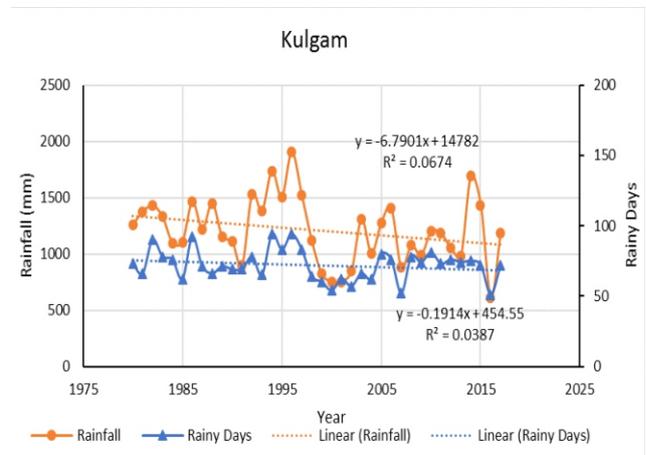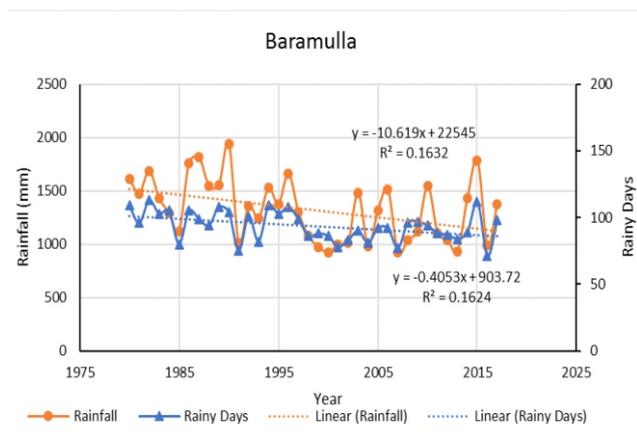**Fig. 5.** Annual trend of rainfall and rainy days in district Kulgam

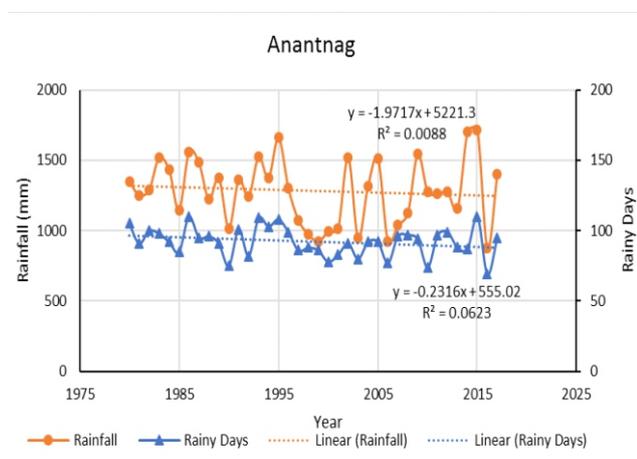**Fig. 6.** Annual trend of rainfall and rainy days in Baramulla Anantnag

Fig. 7. Annual trend of rainfall and rainy days in district Anantnag

in precipitation for the region in future (Parvaze et al 2017).

The trends were however found insignificant by both student's t-test as well as Mann-Kendall test (Table 2).

District Kulgam: The normal annual rainfall in the district is 1218 mm. There was slight decreasing trend in both rainfall and number of rainy days for the district (Fig. 5). The trends were however found insignificant by both student's t-test as well as Mann-Kendall test (Table 1).

CONCLUSIONS

Rainfall and number of rainy days did not show any statistically significant trends with respect to time for Anantnag, Budgam, Srinagar, Kulgam and Pulwama districts. However, a significant decreasing trend was observed in the annual rainy days for Kupwara district and both rainfall and rainy days for Baramulla district. The trends exhibited by these climatic variables in other months showed very small insignificant trends. The study suggest that there

has been no significant change in the climate of Kashmir valley over last 38 years.

REFERENCES

Parvaze S, Ahmad Latief, Parvaze S and Kanth RH 2017. Climate Change Projection in Kashmir Valley (J and K). *Current World Environment* **12**(1): 107-115.

Ahmad L, Parvaze S, Parvaze S and Kanth RH 2017. Parametric and non-parametric time series trend analysis of temperature and rainfall in Srinagar, Kashmir. *The Ecoscan* **11**(1&2): 007-11.

Dore MH 2005. Climate change and changes in global precipitation patterns: what do we know? *Environment International* **31**(8): 1167-81.

Goswami BN, Venugopal V, Sengupta D, Madhusoodana M S and Xavier PK 2006. Increasing trend of extreme rain events over India in a warming environment. *Sciencemag* **314 (**5804) 1442-45.

Immerzeel W, W Van, Beek L P and Bierkens M F 2010. Climate change will affect the Asian water towers. *Science* **328**(5984): 1382-1385.

IPCC 2014. Climate change. In *The IPCC Assessment Report*. In: Houghton JT, Meira Filho LG, Callander BA, Harris N, Kattenberg A, Maskell K (eds). Cambridge University Press: New York.

Kang Y, Khan S and Ma X 2009. Climate change impacts on crop yield, crop water productivity and food security–A review. *Progress in Natural Science* **19(**12): 1665-1674.

Kaser G, Grosshauser M and Marzeion B 2010. Contribution potential of glaciers to water availability in different climate regimes. *Proceeding of National. Acadamy Science*. USA. **107**: 20223-20227.

Kendall MG 1975. *Rank Correlation Measures*; Charles Griffin: London, UK, 97-116.

Kumar CP 2012. Climate change and its impact on groundwater resources. *International Journal of Engineering and Science* **1**(5): 43-60.

Lorenz DJ, DeWeaver ET and Vimont DJ 2010. Evaporation change and global warming: The role of net radiation and relative humidity. *Journal of Geophysical Research Atmospheres* **115** (D20).

Misra AK 2014. Climate change and challenges of water and food security. *International Journal of Sustainable Built Environment* **3**(1): 153-165.

Mann HB 1945. Nonparametric tests against trend. *Econometrica* **13:** 245-259.

Parvaze S, Parvaze S, Haroon S, Khurshid N, Khan JN and Ahmad L 2016. Projected change in climate under A2 Scenario in Dal Lake Catchment Area of Srinagar City in Jammu and Kashmir. *Current World Environment* **11**(2) 429-438.

Riebeek H 2010. Global Warming, featured articles, *Earth Observatory*. Accessed April 13, 2014.

Sayemuzzaman M, Jha MK and Mekonnen A 2015. Spatiotemporal long-term (1950-2009) temperature trend analysis in North Carolina, United States. *Theoretical and Applied Climatology* **120**(1-2): 159-171.

Sen PK 1968. Estimates of the regression coefficient based on Kendall's tau. *Journal American Statistical Association* **63**(324): 1379-1389.

Sonali P and Kumar DN 2013. Review of trend detection methods and their application to detect temperature changes in *India. Journal .Hydrology* **476***:* 212-227.

Siderius C, Biemans H, van Walsum PEV, van Ierland EC, Kabat P and Hellegers PJGJ 2016. Flexible strategies for coping with rainfall variability: Seasonal adjustments in cropped area in the Ganges basin. *PLoS ONE* **11**(3): e0149397.

Thiel H 1950. A rank-invariant method of linear and polynomial regression analysis, Part 3. In Proceedings of Koninalijke Nederlandse Akademie van Weinenschatpen A **53**:1397-1412.

Viviroli D, Dürr HH, Messerli B, Meybeck M and Weingartner R 2007. Mountains of the world – water towers for humanity: typology, mapping and global significance. *Water Resources Research* **43**(7): W07447.

Wang H, Schubert S, Suarez M, Chen J, Hoerling M, Kumar A and Pegion P 2009. Attribution of the seasonality and regionality in climate trends over the United States during 1950-2000. *Journal Clim*ate **22**(10): 2571-2590.

Xu Z X, Li JY and Liu CM 2007. Long term trend analysis for major climate variables in the Yellow River basin. *Hydrological Processes* **21**(14): 1935-1948.

Snow Cover Estimation of Western Himalayas using Sentinel-2 High Spatial Resolution Data

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Abstract: The seasonal fractional snow cover area mapping for the hydrological year October 2017 to September 2018 in Miyar and Bhaga basin of western Himalayas in Lahaul & Spiti district of Himachal Pradesh has been carried out using Sentinel 2 (A&B) high spatial resolution data of 10m. The snow cover area has been estimated using NDSI, NIR/SWIR ratioand S3 index. In order to overcome the misclassification of water as snow, NIR/SWI Rratiohas been used. For the exact classification of parameters and the threshold value selection, statistical analysis using the spectral response of the pixels has been used for NIR/SWIR ratio. The S3 index has been used to detect the snow cover under vegetation (pine trees). The average snow cover area for the accumulation period (october 2017 till May 2018) is estimated to be approximately 1376.505 km^2, which is 56.06 % of the total basin area and for Bhaga basin (approximately 1094.041 km^2), which is 65.12 % of total basin area.This indicate that nearly, 54% and 58% of accumulated snow area has been melted in Miyar basin and Bhaga basin during summer (June-September 2018), respectively. To the best of our knowledge, the present proposed study is the first attempt to utilize Sentinel-2 data for Himalayan snow cover monitoring.

Keywords: Snow cover area, Sentinel 2, NDSI, Accumulation, Ablation

Cryosphere (which includes snow, rivers and lake ice, ice gaps, ice sheets, glaciers and frozen ground) are considered as the important natural sensor for providing climate variability indication. The Himalaya contain one of the largest concentration if glaciers outside of polar regions and receive seasonal snow fall during winter. The extent of snow cover changes during winter and spring, because the seasonal snow starts ablating during spring. The melt water from these glaciers forms the important source of run-off in Northern part of India during summer months (Kulkarni 2001). Hence, mapping of snow cover is important to monitor the climatological and hydrological factors. The glaciers of Himalayas are difficult to explore and study but remote sensing facilitated the study of glaciers in Himalayas. Multi-temporal and multispectral satellite data are successfully used to monitor snow cover in a vast and rugged Himalayas. The scientific community has used different medium resolution satellite datasets like Landsat (MSS, TM and OLI), AWIFS, MODIS etc. for mapping snow cover area (Negi et al 2009). There are certain challenges in monitoring the snow cover with medium resolution sensor (spectral and temporal resolution) including accuracy. The recent launch by European space agency, named Sentinel-2 (A- year 2015 and B-year 2017) carriers Multispectral Imager (MSI) payload acquiring multispectral data in 13 bands with spatial resolution of 10, 20 and 60 m. The availability of Sentinel-2

data with a finer resolution of 10m covering a swath of 290Km with a combined revisit period (Sentinel-2 A&B) of 5 days has helped in overcoming the resolution problem and also helped in expedite the monitoring of snow cover area in an effective way. In present study aerial extent of snow cover has been mapped using snow indices based on the reflection of snow in each region of electromagnetic spectrum.

MATERIAL AND METHODS

Data source and study area: Sentinel 2 (A&B) data is available for free download for research purpose from the website www.scihub.copernicus.eu. Sentinel-2 data is available in three different data products namely,

- Level-1B – Top of atmospheric radiances in sensor geometry
- Level-1C – Top of atmospheric reflectances in cartographic geometry
- Level-2A – Bottom of atmospheric reflectances in cartographic geometry.

For the present study Level-1C Top of atmospheric reflectances in cartographic geometry has been used for the period September 2017 to September 2018. For the month August 2018, Landsat-8 data has been used due to unavailability/heavy cloud cover of Sentinel-2 data. Miyar and Bhaga basins are the major sub-basins of Chenab river of western Himalayas in Lahaul and Spiti district of Himachal

Pradesh. The spatial extent of Miyar basin is 32°40′0″N–33°10′0″N and 76°30′0″E–77°0′0″E, covers area of 2412 square km which consists of 173 glaciers and the spatial extent of Bhaga basin is 32° 28'19.7" N- 33°0'9.9"N and 76°56'6.3"E -77°25' 23.7" E covers area of 1680 square km which consists of 231 glaciers (Fig. 1).

$$NDSI=\frac{(Green - SWIR)}{(Green + SWIR)}$$

The snow cover mapping/estimation is available in literature has made use of coarse/medium resolution satellite data. The Sentinel-2 Level-1C high resolution data has been downloaded from Copernicus Open Access Hub. For the present study the band-3 (green 10m), band-4 (red 10m), band-8 (NIR 10m) and band-11 (SWIR 20m) has been used. The band-11 (SWIR) with 20m resolution has been resampled from 20m to 10m spatial resolution using nearest neighborhood algorithm. The entire data processing has been carried out using ERDAS IMAGINE and QGIS software. The above mentioned bands were layer stacked after resampling process for calculation of band ratios/band indexes namely NDSI, NIR/SWIR and S3 as shown in Fig. 2 process flow. Initially, basin boundary has been delineated

Fig. 1. Location map of study area

from Drainage maps from Irrigation Atlas of India and the same hasbeen used for all the satellite datasets to mark the study area. The Miyar basin area has been covered in a single scene with a relative orbit number R005 and tile number T43SFS. The Bhaga basin area has been covered in two scenes with relative orbit number R005 & R105 and tile number T43SFS & T43SGS, respectively.

Normalized difference snow index (NDSI): NDSI is widely used for snow cover mapping using satellite data (Kulkarni et al 2002). NDSI has the capability to discriminate the ice/snow from the cloud. NDSI is based on the high and low reflectances of snow in visible (green) and short wave infrared (SWIR) region respectively. In order to discriminate the snow pixels from non-snow pixels, a threshold value of NDSI > 0.4 (Kulkarni et al 2010) has been used. The threshold NDSI > 0.4 classifies snow/ice, water bodies and snow under shadow as snow pixels (Negi et al 2009).

$$NIR/SWIR=\frac{NIR - SWIR}{NIR + SWIR}$$

NIR/SWIR ratio: The misclassification of water pixels as snow pixels by NDSI may sometimes results in over estimation of snow cover. During winter, the entire basin is snow covered; hence snow cover mapping using NDSI may not lead to overestimate of snow cover. During post winter/summer, the frozen layer of water bodies will be misclassified as snow pixels on application of NDSI resulting in overestimate of snow cover. So, in order to overcome the misclassification of water pixels as snow pixels, a water mask has been derived from summer data using Near Infrared (NIR)/ Short Wave Infrared (SWIR) ratio. The spectral response of the pixels has been analyzed by taking 100 sample points inside the basin area. With NDSI as a function of NIR/SWIR index scatter plot for snow pixels and water pixels has been shown the Fig.3.

From the scatter plot, a suitable threshold of 0.37 has been obtained to mask the water pixels from the snow pixels.

S3 index: As the study area Miyar and Bhaga basins have a reasonable amount of vegetation (pine trees) cover, it is necessary to estimate the snow cover under vegetation. In order to identify the snow under vegetation S3 index has been used (Negi et al 2009). This index uses red, NIR and SWIR band reflectances to identify the snow under vegetation pixels which reduces the error in mapping of snow cover area.

$$S3=\frac{NIR (Red - SWIR)}{(NIR+Red) (NIR+SWIR)}$$

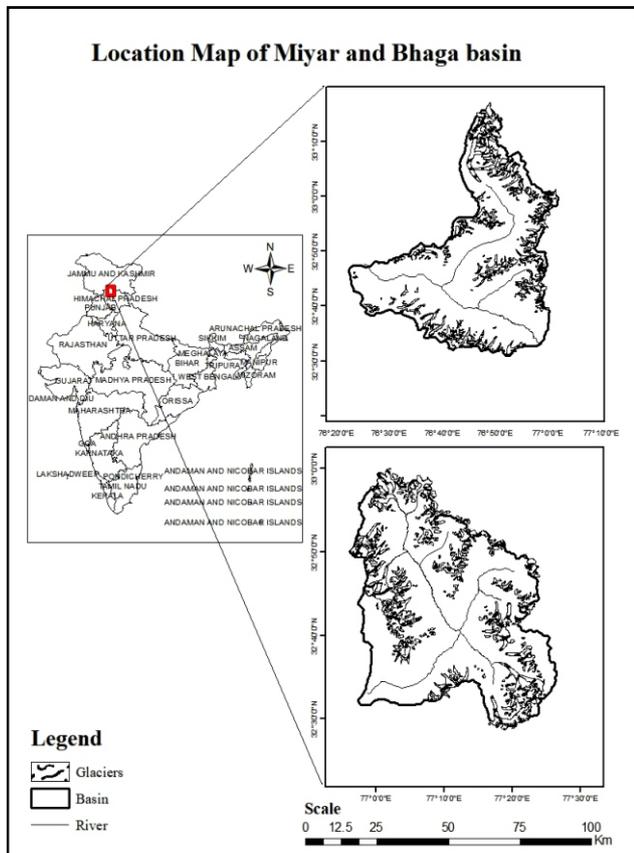The threshold value 0.18 (Shimamura et al 2006) has been used for snow cover mapping.

RESULTS AND DISCUSSION

For individual scenes, the band ratios/indexes have been processed. The water mask using the NIR/SWIR ratio from September 2017 data has been created applying a suitable threshold. The NDSI>0.4 and S3>0.18 images were combined for the final snow cover product to which the water mask was applied. The automated model built for this process is shown in Figure 4. All data processing has been carried out for individual scenes and the final snow cover map has been mosaicked before applying the basin mask (Suresh et al 2018). The proposed study has been called as fractional snow cover, as it provides a high spatial resolution snow cover product with high accuracy especially in the regions of discontinuous snow and snow and land switching. Heavy seasonal snow fall has been recorded in the last week of September 2018 in Lahaul and Spiti valley, Himachal Pradesh (IMD Shimla) (Fig. 5a). September 23rd, 2018 data has also been processed for Miyar basin and shown in Figure 5(b). Since, it is the seasonal snow fall; this has not been
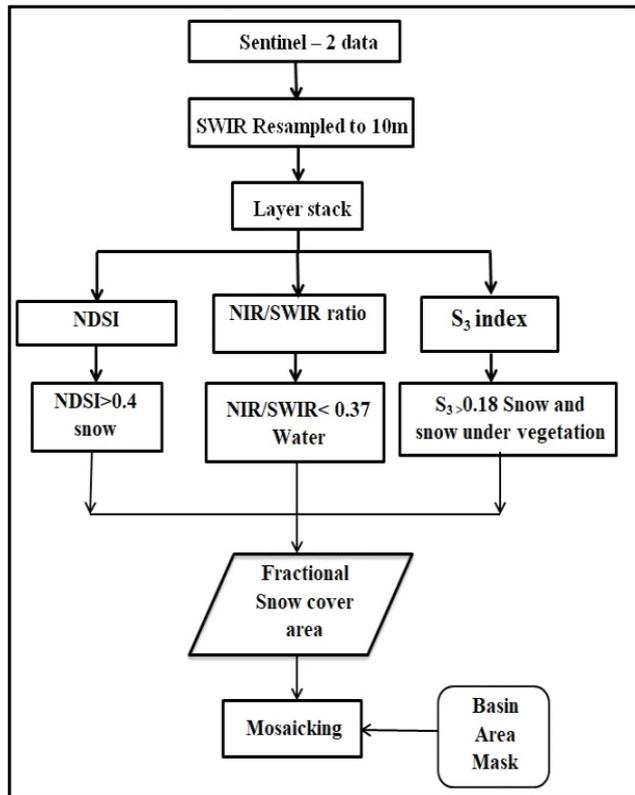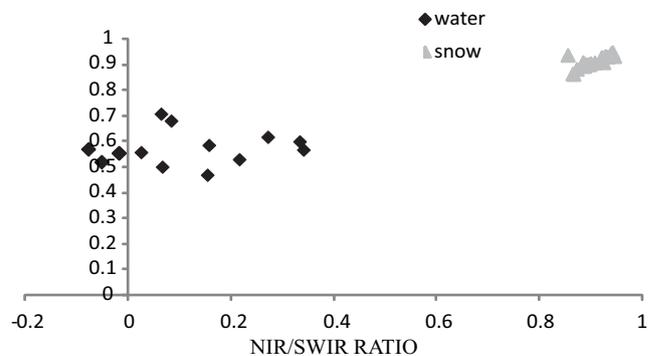

Fig. 2. Process flow

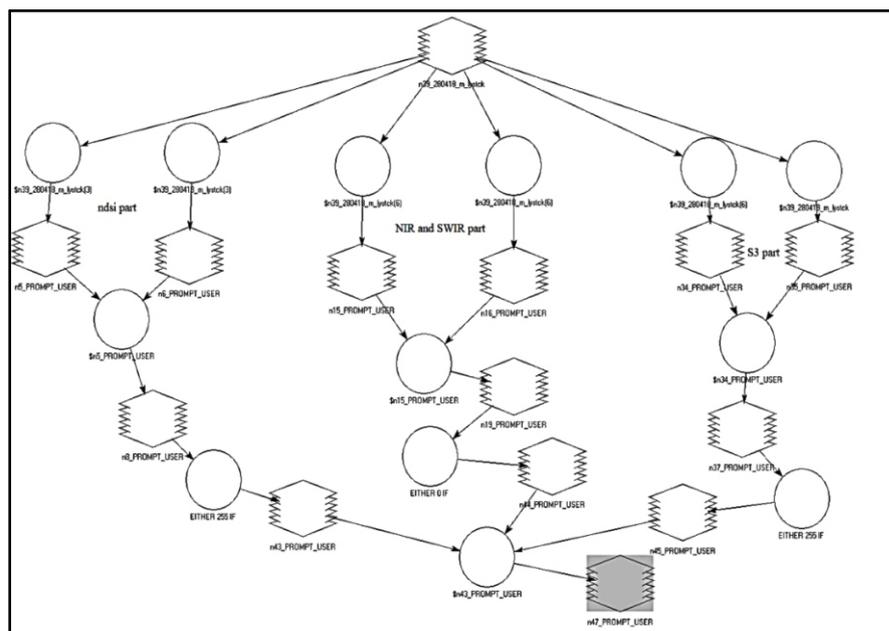**Fig. 3.** Scatter plot of normalized difference snow index as a function of NIR/SWIR index

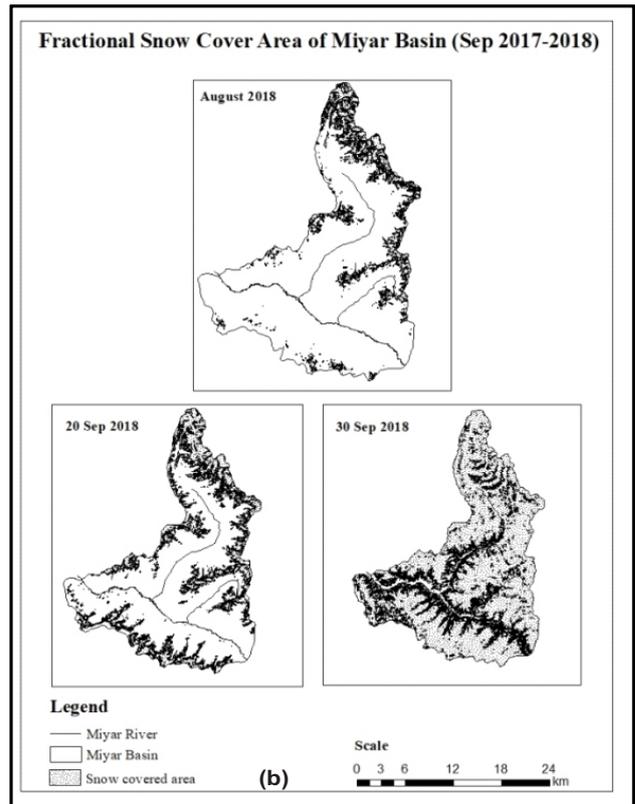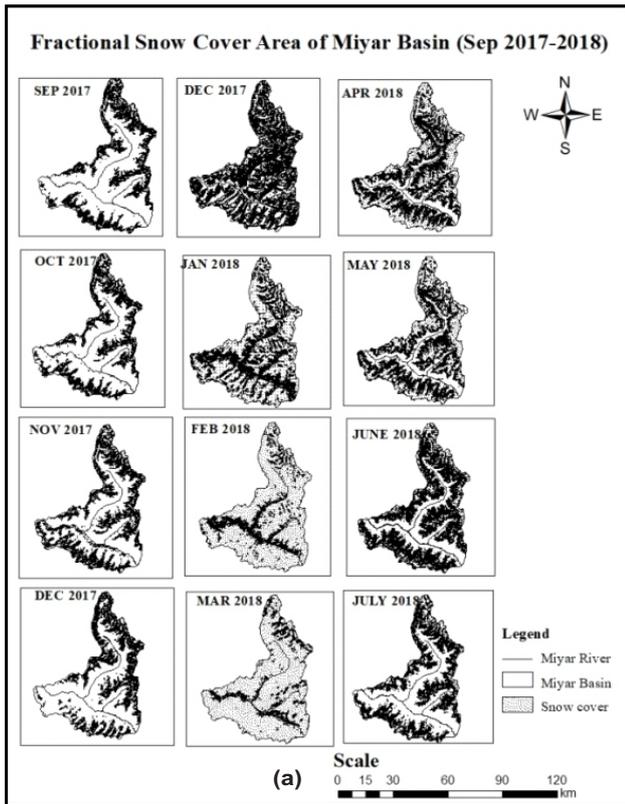**Fig. 4.** Automated model generated for estimation of snow cover area

Fig. 5. a) Fractional snow cover maps of Miyar basin from September 2017 till July 2018, b) Fractional snow cover maps of Miyar basin from August 2018 till September 2018
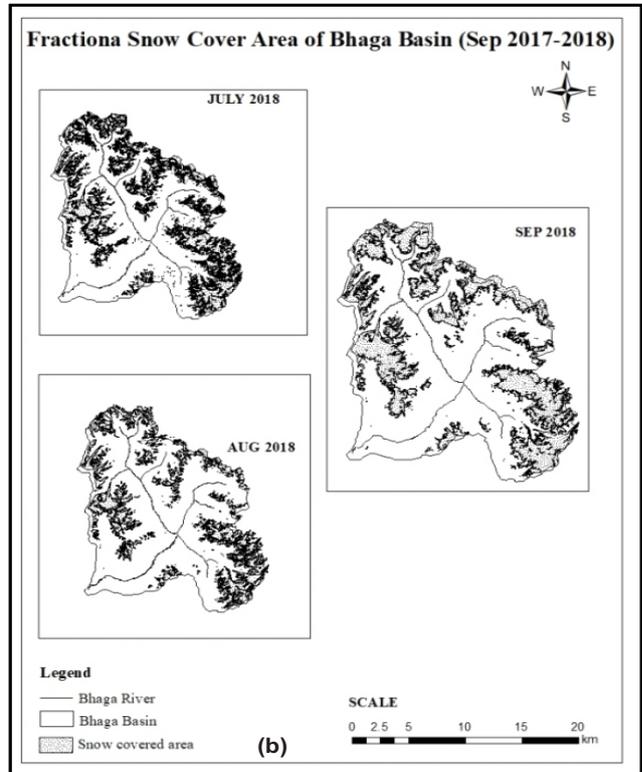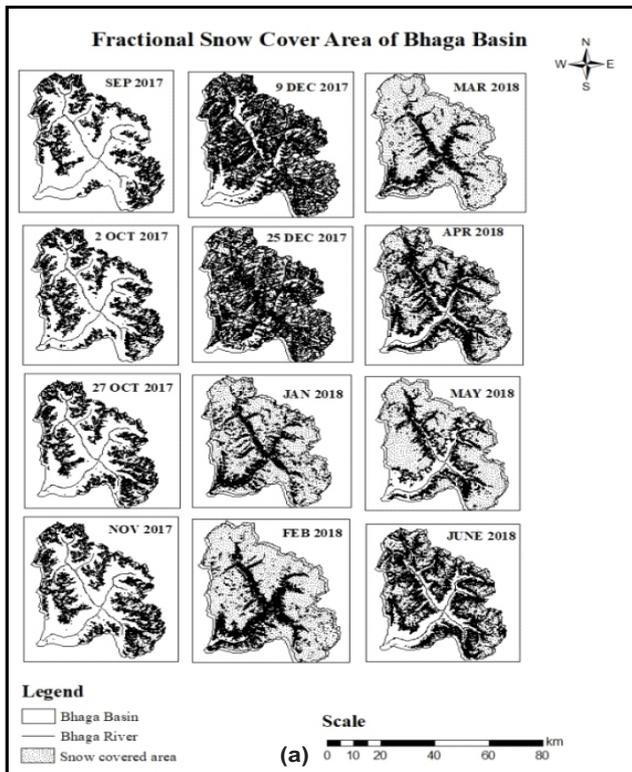

Fig.6. a) Fractional snow cover maps of Bhaga basin from September 2017 till June 2018, b) Fractional snow cover maps of Bhaga basin from July 2018 till September 2018
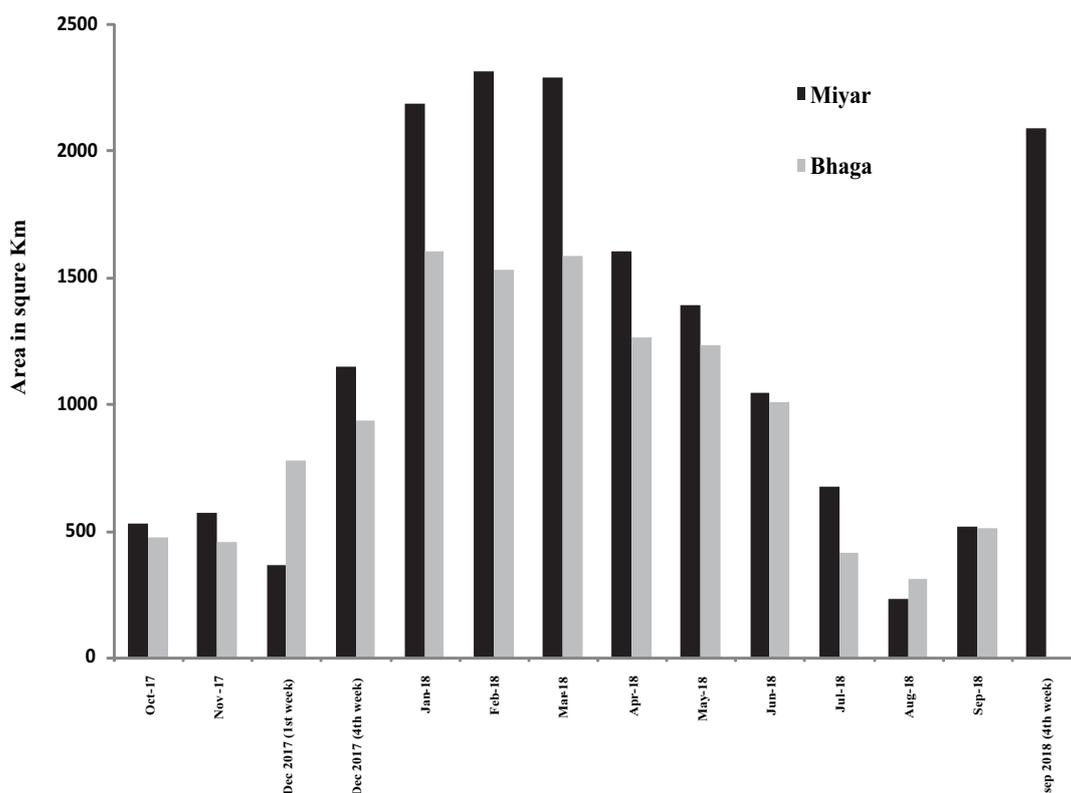
Fig. 7. Fractional snow area curve for Miyar and Bhaga basin

accounted for calculation of accumulation and melts area of Miyar basin. Figure 6 represents the fractional snow cover map of Bhaga basin. For Bhaga basin satellite data was not available during the last week of September 2018.

From this study, it has been observed that the average snow cover area for the accumulation period (October 2017 to September 2018) of the hydrological year 2017- 2018 is approximately 1376.505 square Km for Miyar basin which approximately is 57.06% of total basin area and 1094.041 square Km for Bhaga basin which is approximately 65.12% of total basin area. Nearly, 54 and 58 % of accumulated snow area has been melted in Miyar basin and Bhaga basin respectively for the hydrological year 2017-2018 (October 2017 to September 2018). The snow cover distribution curve shows that the snow cover area starts building up from November and increases during winter showing peak snow fall in January-February, and gradually decreasing in March-April due to onset of summer (Fig. 7).

CONCLUSION

Aerial extent of snow cover has been mapped and analyzed for the hydrological year of 2017-2018 (October-2017 to September-2018). Nearly 113 scenes (sentinel 2A & 2B and Landsat 8) have been processed for Miyar and Bhaga basins. Significant amount of melting has been observed,

approximately 54 and 58% of snow covered area for Miyar and Bhaga basin, respectively during ablation period. The scope of the present study is limited for estimation of snow cover area melted and not quantification in terms of melt water runoff. To the best of our knowledge, the present proposed study is the first attempt to utilize Sentinel-2 data for Himalayan snow cover monitoring.

REFERENCES

Bajracharya SR, Maharjan SB, Shrestha F, Bajracharya and Baidya S 2014. *Glacier status in Nepal and decadal change from 1980 to 2010 based onlandsat data.* Kathmandu, International Center for Integrated Mountain Development.

Gurung Deo Raj, Kulkarni A, Giriraj Amarnath, San Aung Khun and Shrestha Basanta 2011. Monitoring of seasonal snow cover in Bhutan using remote sensing technique, *Current Science* **101:** 1364-1370.

Gurung DR, Kulkarni AV, Giriraj A, Aung KS, Shrestha B and

Srinivasan J 2011. Changes in seasonal snow cover in Hindu Kush-Himalayan region. *The Cryosphere Discussions* **5:** 755-777.

Immerzeel WW, Droogers P, de Jong SM and Bierkens MFP 2009. Large-scale monitoring of snow cover and runoff simulation in Himalayan river basins using remote sensing. *Remote Sensing of Environment* **113:** 40-49.

Kaur R, Saikumar D and Kulkarni AV 2009. Variations in snow cover and snowline altitude in Baspa basin. *Current Science* **96:** 1255-1258.

Khan Amir, Pant Naresh and Ravindra, Rasik 2016.Current status of Hhimalayan cryosphere and adjacent mountains. *Geological Society* **462:** 1-6.

Kulkarni A, Rathore B, Singh S and Ajai 2010. Distribution of seasonal snow cover in central and western Himalayas. *Annals of Glaciology* **54:** 123-128.

Kulkarni A, Rathore B, Singh S and Bahuguna MI 2011. Understanding changes in Himalayan cryosphere. *International Journal of Remote Sensing* **32:** 601-615

Kulkarni AV, Mathur P, Rathore BP, Suja Alex, Thakur N and Manoj 2002. Effect of global warming on snow ablation pattern in the Himalaya. *Current Science* **83:** 120-123.

Kulkarni AV, Srinivasulu J, Manjul SS and Mathur P 2002. Field based spectral reflectance to develop NDSI method for the snow cover. *Journal of Indian Society of Remote Sensing* **30:** 73-80.

Negi HS, Kulkarni V and Semwal BS 2009, Estimation of snow cover distribution in Beas Basin, Indian Himalaya using Satellite data and Ground measurements. *Journal of Earth System Science* **118:** 525.

Rathore BP, Kulkarni AV and Sherasia NK 2009. Understanding future changes in snow and glacier melt runoff due to global warming in Wangar Gad basin, India. *Current Science* **97:** 1077-1081.

Subramaniam S, Suresh Babu AV, Sivasankar E, Venkateshwar Rao V and Behera G 2011. Snow cover estimation from resourcesat-1 AWiFS-Image processing with an automated approach. *International Journal of Image Processing* (IJIP) **5:** 298-320.

Suresh D and Kiran Yarrakula 2018. GIS based multi-criteria decision making system for assessment of landslide hazard zones: Case study in the Nilgiris, India. *Indian Journal of Ecology* **45**(2): 286-291.

Shimamura Y, Izumi T and Matsuyama H 2016. Evaluation of a useful method to identify snow-covered areas under vegetation-comparisons among a newly proposed snow index, normalized difference snow index, and visible reflectance. *International Journal of Remote Sensing* **27:** 4867-4884.

Xiao X, Shen Z and Qin X 2001. Assessing the potential of vegetation sensor data for mapping snow and ice cover: A normalized difference snow and ice index. *International Journal of Remote Sensing* **22:** 2479-2487.

Diversity, Structure and Regeneration Pattern of Tree Communities in Kanawar Wildlife Sanctuary of Himachal Pradesh, North West Himalaya, India

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Abstract: The protected areas of the Indian Himalayan Region are mostly under or unexplored. The present study was conducted in Kanawar Wildlife Sanctuary, Himachal Pradesh, to; assess the vegetation for community diversity, regeneration pattern, impact of climate change and suggest the management options. Total 69 sites were assessed, between, 1620-3460m amsl and 35 tree communities were recorded. *Picea smithiana* was dominant community. *Cupressus torulosa* community represented maximum tree density (680.0 Ind ha^{-1}) whereas, *Taxus wallichiana-Abies pindrow* mixed community had maximum total basal area (111.44 m^{2}ha^{-1}). Highest diversity of trees was in *Aesculus indica-Prunus cornuta-Cornus macrophylla* mixed (2.50) whereas, its maximum values for seedlings and saplings were in *Picea smithiana* and *Cedrus deodara* communities. The regeneration patterns of tree species within the communities indicated different patterns of seedlings and saplings. *Abies pindrow*, *Quercus semecarpifolia*, and *Pinus wallichiana* communities showed altitudinal shift changing pattern of community compositions. This could be as a consequence of climate change. Therefore, monitoring of these communities, awareness programmes for the local inhabitants and involvement of local communities and forest department in the restoration of degraded forest are suggested.

Keywords: Diversity, Conservation, Species richness, Regeneration pattern, Kanawar wildlife sanctuary

The Himalaya is the world's youngest and highest mountain, possessing diverse vegetation and thus, important locations for research into ecology and biodiversity conservation (Sheng 2001). The Indian Himalayan Region (IHR- latitudes 27°-38°N and longitudes 72°-89° E) ranging from Arunachal Pradesh to Jammu & Kashmir and rising up to an altitude of > 8000m amsl is one of the major repositories of biodiversity (Pant et al 2009). The region harbour about 18,440 plant species in various habitats (Singh and Hajra 1996). The rich repository of floral species meets need of inhabitants of the area. They utilize the natural recourses according to their necessities and preferences. The increasing population is responsible for the increase in demand of economical plant, has been resulted in the habitat degradation, overexploitation and population depletion of the natural resources. Anthropogenic activities like urbanization, industrialization, deforestation, habitat loss, fragmentation, pollution and invasion of alien species and global climate change (IUCN 2003). In addition these factors have caused reduction in the ecosystem services namely, provisioning, cultural, regulating and supporting. Biodiversity assessment has gained much attention due to its major impact on the practice of conservation (Naidu et al 2018). Keeping in view the importance and values of biodiversity of the Indian Himalayan Region, a Protected Area Network (PAN) has been established in the form of Biosphere Reserves, National Parks and Wildlife Sanctuaries to conserve the ecosystems, species and habitats respectively. A majority of these Protected Areas (PAs) are unexplored or under explored. Therefore, there is a need to the assessment of vegetation qualitatively and quantitatively. So that actual status of vegetation could be recognized. The biodiversity of Himachal Pradesh is depleting rapidly due increase in anthropogenic activities and climate change.

In general, number of studies have been carried out on the diversity and composition of vegetation across the IHR (Joshi and Samant 2014, Pant and Samant 2012, Sharma et al 2014, Singh et al 2016, Arya et al 2001, Prasad and Sharma 2018 and Devi et al 2018). In particular, in the protected areas of IHR, a very few studies are available (Joshi and Samant 2014, Rana and Samant 2009, Singh and Samant 2010 and Thakur et al 2015). Therefore, present study has been conducted in Kanawar Wildlife Sanctuary of Kullu District, Himachal Pradesh during 2015-2017 to study the site and habitats characteristics, assess the diversity of tree species, delineate tree communities, assess regeneration pattern and suggest conservation options.

MATERIAL AND METHODS

The study was conducted in Kanawar Wildlife Sanctuary (KWLS), which was established in 1954, under section 26 of WPA, 1972 with an area of 61 Km^2. It lies between 31^{0}55' to 32^{0}01'N latitudes and 77^{0}17' to 77^{0}23'E longitudes with an altitudinal range, 1,600-4,800m amsl. The study area is a very narrow valley with high mountains on both sides. The high mountains allow a couple less hours of light than in other areas. Grahan nallah is the major drainage and forms one of the tributaries of river Parbati. The study area supports diverse vegetation including ecologically and economically important sensitive biodiversity elements namely, medicinal, wild edible, rare endangered, native and endemic plants. In the Sanctuary, numerous thatches (sheep resting places) are present. Two villages i.e., Grahan and Thunja are located in the Sanctuary. The soil mainly comprises of lateritic, red, sandy, loamy and alluvial types which depends upon the lithology and the effects of various agencies from time to time. The area is mainly represented by sub-tropical, temperate, sub-alpine and alpine vegetation. The climate of the area is typically temperate, sub-alpine and alpine types and consists of mainly three distinct seasons i.e., summer (mid April-mid June), rainy (mid June-September) and winter (November-mid March). The area receives precipitation both in the form of rainfall and snowfall. The temperate and sub-alpine forests are mainly dominated by broad leaved deciduous, evergreen and evergreen coniferous species and alpine meadows are dominated by alpine shrubs and herbaceous species.

Survey, samplings, data compilation and analysis: Surveys were conducted between 1620-3460m amsl in KWLS during 2015-2017 for the rapid sampling of floristic inventory. The sampling of the vegetation was done during June to August. Sites were selected on each and every accessible aspect along the topographical gradient. Habitats were identified based on the physical characters and dominance of the vegetation. Sites having closed canopy with high percent humus and moisture were considered as moist habitats whereas low percent of the same as dry habitats. The site having >50% boulders of the ground cover were considered as bouldary habitat, and the site with high anthropogenic pressures were considered as degraded habitat. In each site, a plot of 50x50 m was laid. Trees (cbh ≥ 31.5 cm), saplings (cbh 10.5-31.4cm) and seedlings (cbh <10.5 cm) were sampled by randomly placed 10, 10x10m, quadrats. For data collection from the quadrats and analysis for various ecological parameters standard ecological methods (Singh and Singh, 1992, Dhar et al1997, Singh and Samant 2010) were followed.

The collected samples of species were identified with the help of local and regional floras and research papers (Polunin and Stainton 1984, Dhaliwal and Sharma 1999 and Singh and Raw 2000). For data analysis standard methods were followed (Curtis and McIntosh 1950, Mueller- Dombois and Ellenberge 1974, Singh and Singh, 1992, Singh and Samant 2010) . Communities were identified based on the Importance Value Index (IVI). The IVI has been calculated as sum of relative frequency, relative density and relative basal area. The abundance of different sites was pooled to get community averages in terms of density, frequency, total basal area and IVI. Species diversity (H') was calculated using Shannon and Weaver (1963) and species richness by Menhinik's Index given by Whittaker (1977). For the assessment of impact of climate change on floristic diversity, observations on the species composition of the communities and altitudinal shift of the species based on the recruits i.e., seedlings and saplings were taken, and possible impacts of climate change were analyzed.

RESULTS AND DISCUSSION

Site and habitat characteristics: Total 69 plots were assessed, between, 1620-3460m amsl which represented total 07 habitats (shady moist, dry, bouldary, alpine, rocky, moist, riverine and degraded). Among these, shady moist (35 sites) followed by dry habitat (13 sites) represented maximum sites (Table 1). Maximum sites were in North West (21 sites) aspects followed by West (15 sites) aspect. The slope varied from 05-65.

Community diversity and distribution pattern: Thirty five tree communities were identified based on importance value index (IVI) between 1620-3460m. Among the communities, *Picea smithiana)* community represented the maximum sites (10), followed by *Pinus wallichiana* (8), *Quercus semecarpifolia* (7), *Cedrus deodara* and *Betula utilis* (5, each), *Abies pindrow* (4) and *Prunus cornuta* (2) and remaining communities were represented by one site only (Table 1). The communities having a comparatively wide altitudinal range of distribution were *Pinus wallichiana, Abies pindrow, Cedrus deodara, Quercus semecarpifolia, Picea smithiana, Betula utilis* and *Prunus cornuta.*

Structural pattern: Amongst forest communities, total tree density was ranged from 80.0-680.0 ha^{-1} with total basal area, 0.478-111.44 m^{2}ha^{-1}. *Cupressus torulosa* community had *maximum* tree density (680.0 ha^{-1}), followed by *Quercus semecarpifolia* and *Taxus wallichiana-Abies pindrow* mixed communities. Minimum density was recorded in *Aesculus indica-Betula alnoides* mixed community (80.0 ha^{-1}). *Taxus wallichiana-Abies pindrow* mixed community showed maximum total basal area (111.44 m^2 ha^{-1}) followed by *Aesculus indica*, *Abies pindrow*, *Toona sinensis*, *Cedrus*

Table 1. Community types, density (trees, saplings, seedlings), topographical representation, IVI and total basal area (TBA) in the KWLS

Community type	SR	Aspect/s	AR (m)	Habitat/s	Slope (°)	TBA (m²ha⁻¹)	Density (Ind/ha)			IVI of dominant spp.
							Trees	Saplings	Seedlings	
Aesculus indica-Betula alnoides mixed	1	SW	1944	DE	50	0.48	80	730	4520	101.84
A. indica-Prunus cornuta-Cornus macrophylla mixed	1	NW	2281	Riv	45	1.08	190	220	140	94.44
Abies pindrow	4	W, NE	2473-3080	D,SM,	30-65	76.96	546	212.5	270	204.29
A.pindrow-Acer cappadocicum mixed	1	E	2711	SM	20	10.39	240	1060	350	120.0
A. indica	1	NW	2375	SM	30	104.06	200	60	240	216.64
Betula alnoides	1	NE	1840	B	30	12.17	230	280	320	185.76
B. alnoides-Alnus nitida mixed	1	SW	1620	Riv	5	2.00	190	20	20	124.48
B. utilis	5	NW, NE,W,N	2870-3460	SM, A, B, R	5-50	10.6	352	132	70	290.14
Buxus wallichiana	1	W	2375	SM	25	14.56	370	220	200	156.81
Celtis australis-Cornus macrophylla mixed	1	SW	2133	SM	45	11.33	510	140	200	103.07
C. australis-Toona sinensis mixed	1	NW	1899	SM	30	3.68	330	138	177.5	80.86
C. deodara	5	SW,NE,E,NW	1699-2414	SM	5-55	53.99	456	40	10	220.55
C. deodara-Pinus wallichiana mixed	1	NE	1725	SM	30	23.33	430	240	340	146.15
C. deodara-Pinus wallichiana-Rhododendron arboreum mixed	1	NW	2058	Riv	45	4.62	360	20	420	68.83
C.deodara-Rhus chinensis mixed	1	N	2042	M	30	3.61	210	50	-	111.12
Corylus jacquemontii- Quercus semecarpifolia mixed	1	NE	2634	M	25	12.25	270	-	-	97.43
Cupressus torulosa	1	SE	1710	Riv	8	51.58	680	70	-	300
Carpinus viminea	1	SW	2005	SM	45	7.04	510	440	180	187.48
C.viminea-Betula alnoides mixed	1	SW	1830	SM	55	13.3	430	110	60	126.83
Morus serrata-Prunus cornuta mixed	1	SW	2507	SM	35	2.01	220	394.1	669.1	120.50
Prunus cornuta	2	E,NW	2724-2769	SM, B	15	27.47	412	158.75	185	177.94
P. smithiana	10	NW,SW, N,W	2309-2518	SM, D, B	15-65	42.03	403	340	360	203.14
Picea smithiana-Pinus wallichiana mixed	1	W	2305	D	45	11.8	190	78.75	168	119.92
Pinus wallichiana	8	W,SW, E,NW	1690-2669	SM, D, B	35-65	22	526	170	100	218.76
P. wallichiana-Cedrus deodara mixed	1	NW	1835	B	55	10.85	540	140	-	133.55
Quercus floribunda-Pinus wallichiana mixed	1	W	1883	SM	45	1.87	260	170	60	124.71
Q. glauca-Cedrus deodara	1	W	2040	SM	15	8.44	320	340	60	101.53
Q. semecarpifolia	7	SE, NW,S,W,SW	2735-3365	SM, D, R, B	15-65	48.56	640	410	471.7	227.43
Rhus chinensis	1	NW	1991	SM	45	22.79	420	270	-	230.973
R. chinensis-Celtis australis mixed	1	N	2020	SM	10	12.54	460	40	180	117.21
R. chinensis-Toona sinensis mixed	1	SE	2020	SM	15	10.31	570	340	-	128.87
Taxus wallichiana -Abies pindrow mixed	1	N	2808	SM	45	111.44	590	120	110	145.0
Toona sinensis	1	W	1960	SM	20	56.26	410	490	100	175.43
T. sinensis-Celtis australis mixed	1	NW	1975	SM	35	5.51	470	160	140	146.36
T.sinensis-Rhododendron arboreum mixed	1	SE	1899	M	10	6.61	510	160	-	146.07

Abbreviations used: N=North; S=South; E=East; W=West; NE=North East; NW=North West; SE=South East and SW=South West; B= Bouldery; DE=Degraded; D=Dry Forest; Riv=Riverine; R=Rocky; SM=Shady Moist; AR=Altituinal range; and SR=Sites represented

deodara, *Cupressus torulosa* and *Betula alnoides* mixed community showed minimum total basal area (0.478 m²ha-¹).

Species richness: Total 39 tree species were recorded and species richness of trees within the tree communities ranged from 3-15. Among the communities, it was highest for *Pinus wallichiana* (15 spp.), followed by *Picea smithiana, Cedrus deodara, Celtis australis-Cornus macrophylla* mixed and *Aesculus indica-Prunus cornuta-Cornus macrophylla* mixed *Toona sinensis -Celtis australis* mixed and *Quercus semecarpifolia and Corylus jacquemontii- Quercus semecarpifolia* mixed communities. Species richness of saplings was highest in *Picea smithiana* (14 spp.) and *Pinus wallichiana* (11 spp.) communities. Seedlings species richness was also highest in *Picea smithiana* and *Pinus wallichiana* (35 spp. each) communities.

Species diversity (H'): Species diversity (H') was ranged between 0.0-2.50 for trees, whereas, its values for the seedlings and saplings were 0.62-1.86 and 0.56-2.08 respectively (Table 2). Highest diversity of trees was in *Aesculus indica-Prunus cornuta-Cornus macrophylla* mixed community followed by *Celtis australis-Cornus macrophylla* mixed community. Highest species diversity for saplings was in *Picea smithiana* community followed by *Pinus wallichiana community.* Highest species diversity for *seedlings* was in *Cedrus deodara* community followed by *Picea smithiana community.*

Regeneration status of forest communities

In the KWLS, the number of species in seedlings and saplings varied from community to community. Based on the recruits *i.e.,* saplings and seedlings the communities can be categorized into following types:

1. **Communities having highest regeneration of the dominant species:** Sixteen tree communities i.e., *Abies pindrow*, *Abies pindrow-Acer cappadocicum* mixed, *Betula utilis, Buxus wallichiana, Cedrus deodara, Cedrus deodara-Pinus wallichiana-Rhododendron arboreum* mixed*, Picea smithiana, Picea smithiana-Pinus wallichiana* mixed, *Pinus wallichiana, Prunus cornuta, Quercus semecarpifolia, Quercus glauca-Cedrus deodara* mixed*, Rhus chinensis, Rhus chinensis-Toona sinensis* mixed*, Toona sinensis,* and *Toona sinensis -Celtis australis* mixed communities showed highest regeneration of dominant species [(Fig.1 (1-16)]. Such communities may likely to persist for posterity.

2. **Communities with highest regeneration of co-dominant species:** Six communities i.e., *Betula alnoides-Alnus nitida* mixed*, Celtis australis-Cornus macrophylla* mixed*, Cedrus deodara-Rhus*

chinensis mixed*, Carpinus viminea, Pinus wallichiana-Cedrus deodara* mixed*,* and *Quercus floribunda-Pinus wallichiana* mixed communites showed highest regeneration of co-dominant species [(Fig.1 (17-22)]. Such communities may likely to be replaced by co-dominant species having high regeneration.

3. **Communities having poor or no regeneration of dominant and co-dominant species:** Nine communities i.e., *Aesculus indica, Aesculus indica-Betula alnoides* mixed*, Aesculus indica-Prunus cornuta-Cornus macrophylla* mixed*, Betula alnoides, Corylus jacquemontii-Quercus semecarpifolia* mixed*, Cupressus torulosa, Cedrus deodara-Pinus wallichiana* mixed*, Rhus chinensis-Celtis australis* mixed and *Toona sinensis-Rhododendron arboreum* mixed communities showed poor or no regeneration of dominant species [(Fig.1 (23-31)]. This indicated that these communities may likely to be replaced by other species.

4. **Mixed tree communities with highest regeneration of one of the dominant species:** Four communities i.e., *Celtis australis-Toona sinensis* mixed, *Carpinus viminea-Betula alnoides mixed, Morus serrata-Prunus cornuta mixed* and *Taxus wallichiana-Abies pindrow* mixed communities showed highest regeneration of one of the dominant species [(Fig.1 (32-33)]. This indicated that the mixed community may shift in dominant type in near future.

Impact of climate change on tree communities: Climate change leads, altitudinal shift of the species and compositional changes of the communities. While analyzing the altitudinal distribution and compositional changes of the tree communities the altitudinal shift of a few species and compositional changes of the tree communities have been in the present study.

Of the total species distributed within the tree communities, three tree species namely, *Abies pindrow*, *Quercus semecarpifolia*, and *Pinus wallichiana* showed altitudinal shift based on the expansion of seedlings and saplings (Fig. 2).

Abies pindrow:16 plots of 2500 m² were laid between 2281-3365m to study the altitudinal shift of the species (Fig.2). In the plots, mature individuals density ranged from 20-670 Ind/ha, saplings 10-710 ha⁻¹ and seedlings 10-710 ha⁻¹. Maximum density of mature individuals was between 2700-2900m and recruits between 2700-2800m. Below the 2700m, the density of mature trees, saplings and seedlings

Table 2. Community wise species diversity (H') of trees, saplings and seedlings in KWLS

Community types	Species diversity (H')		
	Trees	Saplings	Seedlings
Aesculus indica-Betula alnoides mixed	1.73	1.60	1.33
A. indica-Prunus cornuta-Cornus macrophylla mixed	2.50	1.82	1.33
Abies pindrow	0.77	1.07	1.23
A. pindrow-Acer cappadocicum mixed	0.82	0.86	0.69
Aesculus indica	0.97	-	0.69
Betula alnoides	1.58	1.44	1.00
B. alnoides-Alnus nitida mixed	1.08	0.69	-
B. utilis	0.15	1.35	0.62
Buxus wallichiana	1.30	0.58	-
Celtis australis-Cornus macrophylla mixed	2.07	1.84	1.45
C. australis-Toona sinensis mixed	1.79	1.47	0.69
Cedrus deodara	0.88	1.55	1.86
C. deodara-Pinus wallichiana mixed	1.38	0.69	-
C.deodara-Pinuswallichian,-Rhododendron arboreum mixed	1.57	1.55	1.49
C. deodara-Rhus chinensis mixed	1.55	0.69	1.34
Corylus jacquemontii- Quercus semecarpifolia mixed	1.98	1.33	-
Cupressus torulosa	-	-	-
Carpinus viminea	1.44	0.68	-
C. viminea-Betula alnoides mixed	1.45	1.63	1.40
Morus serrata-Prunus cornuta mixed	1.53	1.64	1.01
Prunus cornuta	1.28	0.94	0.95
Picea smithiana	1.53	2.08	1.51
P. smithiana-Pinus wallichiana mixed	1.43	0.69	0.69
P. wallichiana	1.35	2.00	1.18
P. wallichiana-Cedrus deodara mixed	1.39	1.55	-
Quercus floribunda-Pinus wallichiana mixed	1.29	1.24	0.69
Q. glauca-Cedrus deodara	1.30	1.18	0.69
Q. semecarpifolia	0.71	0.82	0.72
Rhus chinensis	0.75	1.00	-
R. chinensis-Celtis australis mixed	1.75	0.56	1.01
R. chinensis-Toona sinensis mixed	1.71	1.62	-
Taxus wallichiana -Abies pindrow mixed	0.85	1.42	1.16
Toona sinensis	1.44	1.68	1.17
T. sinensis -Celtis australis mixed	1.98	1.75	0.69
T. sinensis -Rhododendron arboreum mixed	1.67	0.98	-

was low as compared to altitudinal zone 2700-2900m.

Quercus semecarpifolia:16 plots of 2500 m² were laid between 2359-3460m to study the altitudinal shift of the species (Fig. 2). In the plots, mature individuals density ranged from 10-880 ha⁻¹; saplings 10-550 ha⁻¹ and seedlings 10-600 ha⁻¹. Maximum density of mature individuals has been recorded between 2800-3300m and recruits between 3000-3300m. Below the 2800m, the density of mature trees, saplings and seedlings was low as compared to altitudinal zone 2800-3300m.

Pinus wallichiana:31 plots of 2500 m² were laid between 1690-3365 m to study the altitudinal shift of the species (Fig. 2). In the plots, mature individuals density ranged from 10-930 Ind ha⁻¹; saplings 10-160 ha⁻¹ and seedlings 10-220 ha⁻¹. Maximum density of mature individuals has been recorded between 1600-2500m and recruits between 1700-3300m.

Based on the mature individuals and recruits, study indicated that in Kanawar Wildlife Sanctuary *Abies pindrow*, *Quercus semecarpifolia*, and *Pinus wallichiana* showed upward shift Also, changing pattern of community
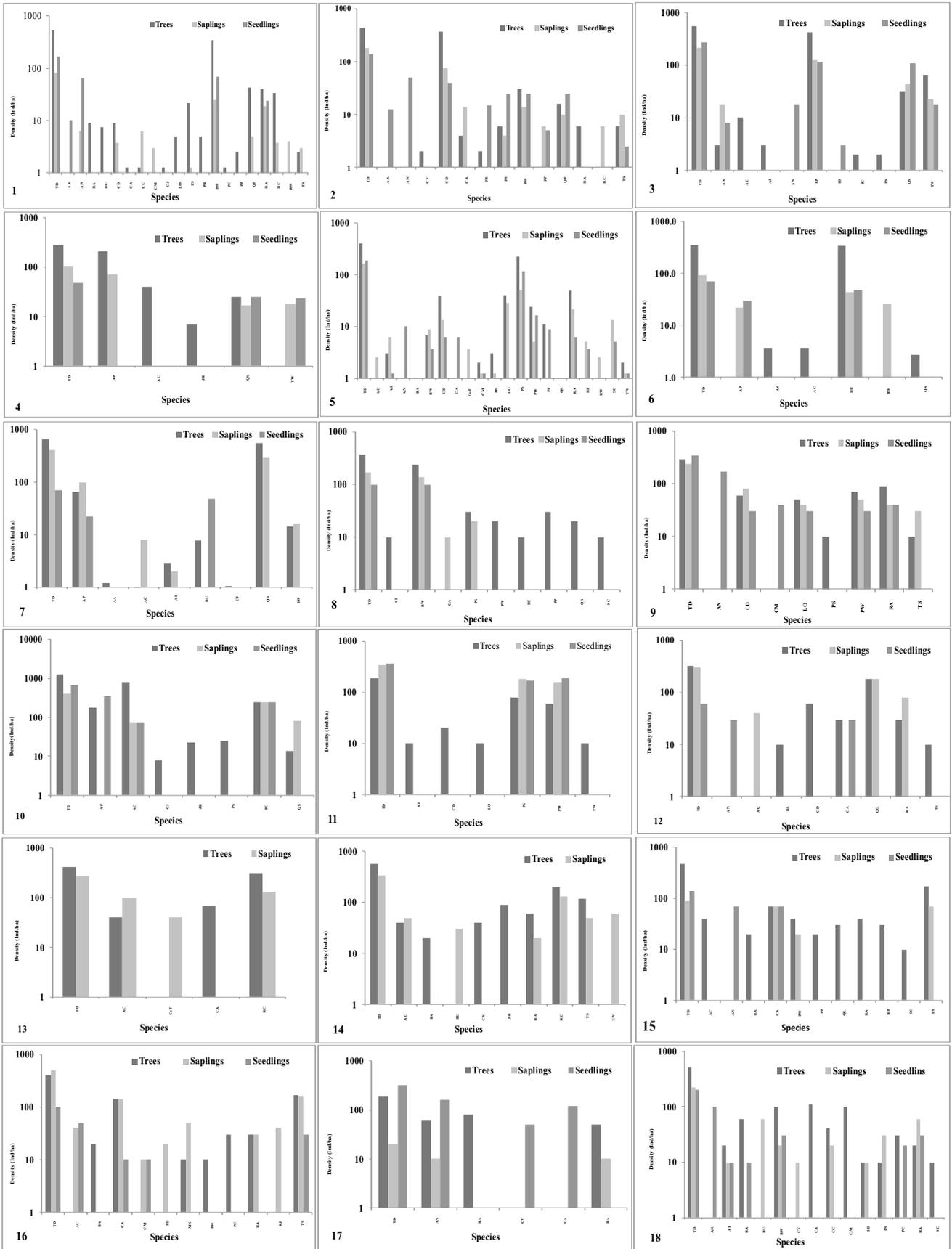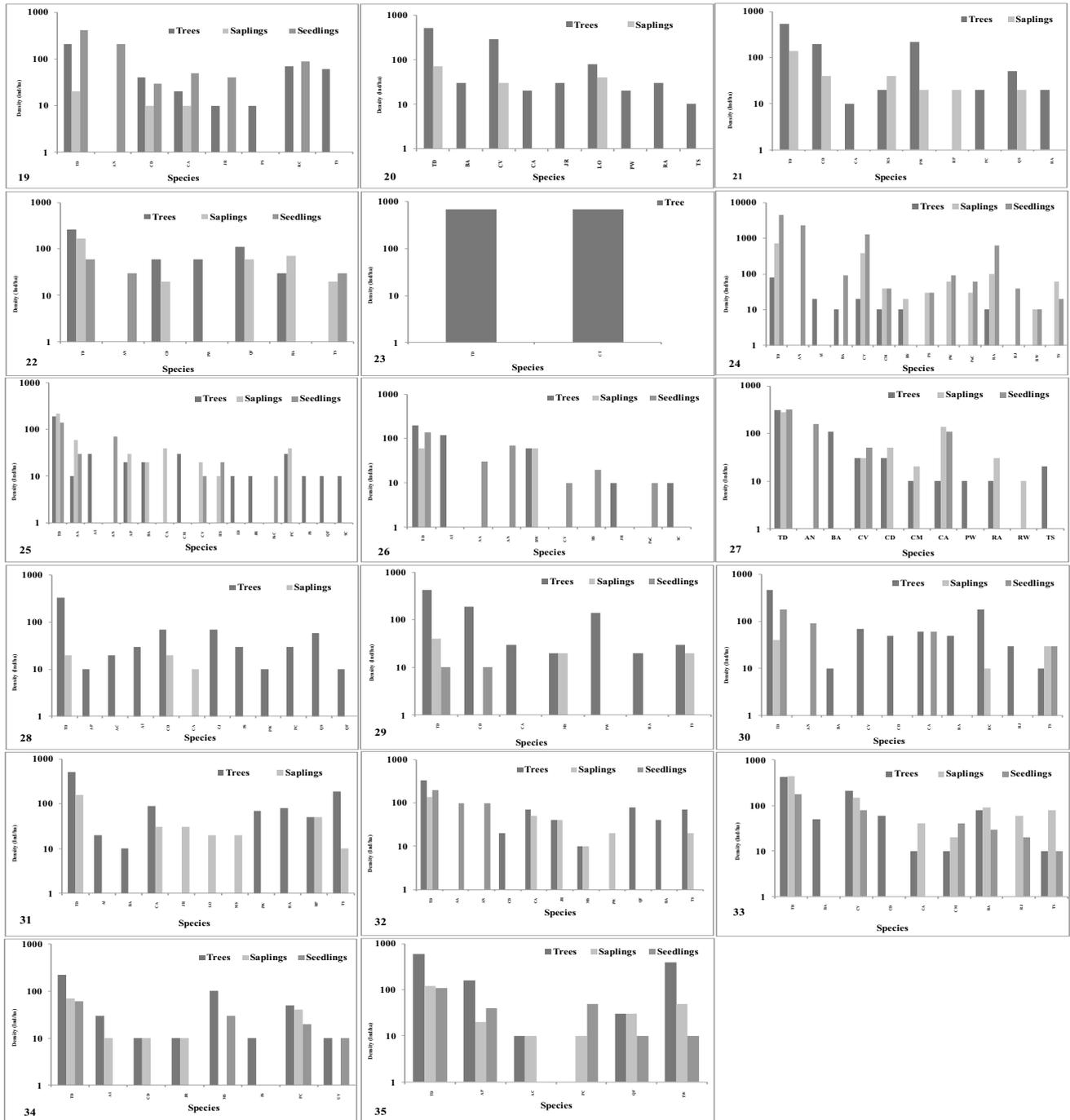
Fig. 1. Population structures of tree communities showing regeneration patterns

Abbreviations used: 1=*Pinus wallichiana*, 2=*Cedrus deodara*, 2=*Abies pindrow*, 4=*Abies pindrow-Acer cappadocicum* mixed, 5=*Picea smithiana*, 6=*Betula utilis*, 7= *Quercus semecarpifolia*, 8=*Buxus wallichiana*, 9=*Cedrus deodara-Pinus wallichiana-Rhododendron arboreum* mixed, 10=*Prunus cornuta*, 11=*Picea smithiana-Pinus wallichiana* mixed, 12=*Quercus glauca-Cedrus deodara* mixed, 13=*Rhus chinensis*, 14=*Rhus chinensis-Toona sinensis* mixed, 15=*Toona sinensis-Celtis australis* mixed, 16=*Toona sinensis*, 17=*Betula alnoides-Alnus nitida* mixed, 18=*Celtis australis-Cornus macrophylla* mixed, 19=*Cedrus deodara-Rhus chinensis* mixed, 20=*Carpinus viminea*, 21=*Pinus wallichiana-Cedrus deodara* mixed, 22=*Quercus floribunda-Pinus wallichiana* mixed, 23=*Cupressus torulosa,*24=*Aesculus indica-Betula alnoides* mixed, 25=*Aesculus indica-Prunus cornuta-Cornus macrophylla* mixed, 26=*Aesculus indica*, 27=*Betula alnoides*, 28=*Corylus jacquemontii-Quercus semecarpifolia* mixed, 29=*Cedrus deodara-Pinus wallichiana* mixed, 30=*Rhus chinensis-Celtis australis* mixed, 31=*Toona sinensis-Rhododendron arboreum* mixed, 32=*Celtis australis-Toona sinensis* mixed, 33=*Carpinus viminea-Betula alnoides* mixed, 34=*Morus serrata-Prunus cornuta* mixed, 35=*Taxus wallichiana-Abies pindrow* mixed, AA=*Acer acuminatum*, AC=*Acer cappadocicum*, AI=*Aesculus indica*, AN=*Alnus nitida*, AP=*Abies pindrow*, BA=*Betula alnoides*, BU=*Betula utilis*, BW=*Buxus wallichiana*, CA=*Celtis australis*, CeT=*Celtis tetrandra*, CC=*Cornus capitata*, CD=*Cedrus deodara*, CJ= *Corylus jacqumontii*, CM=*Cornus macrophylla*, CT=*Cupressus torulosa*, CV=*Carpinus viminea*, HS=*Hipphophe salcifolia*, ID=*Ilex dipyrena*, JR=*Juglans regia*, LO=*Lyonia ovalifolia*, MS=*Morus serrata*, PC=*Prunus cornuta*, PoC=*Populus ciliata*, PP=*Pyrus pashia*, PS= *Picea smithiana*, PW=*Pinus wallichiana*, QF=*Quercus floribunda,*QG=*Quercus glauca*, QL=*Quercus oblongata*, QS=*Quercus semecarpifolia*, RA=*Rhododendron arboreum*, RJ=*Rhus javanica*, RP=*Robinia pseudoacacia*, RW=*Rhus wallichiana*, SC=*Symplococcus chinensis*, TS=*Toona sinensis and UV=Ulmus villosa.*

compositions indicates the changing patterns. This could be as a consequence of climate change.

In view of rapid loss of biodiversity, conservation of potential communities and habitats is essential for its sustenance. In order to sustain the life of resident species, adequate management practices for species, populations, habitats and communities in tune with the dynamics of the ecological changes are required. The KWLS which represents subtropical to alpine zones have been explored between 1620-3460m amsl. Total 35 tree communities were identified, which indicated the unique topography and microclimatic conditions of the area supporting diverse communities, habitats and equally diverse vegetation. Among the identified communities, sixteen communities showed highest regeneration of dominant species in the sapling layer, indicating that these communities persist for posterity. Six communities showed highest regeneration of co-dominant species in sapling layer, such communities may likely to be

replaced by co-dominant species having high regeneration. Nine communities showed poor or no regeneration of dominant and co-dominant species in sapling layer, indicating that these communities may likely to be replaced by other species. On other hand four mixed communities showed highest regeneration of one of the dominant species, indicating that the mixed community may shift in dominant type in near future. Most of the species present in these communities are used for fuel, fodder, house building, making agricultural tools and miscellaneous purposes indicating high anthropogenic pressures which may lead to rapid degradation of forests. Total tree density ranged from 80.0-680.0 Ind ha^{-1}, and total basal area (TBA) from 0.478-111.44 m^{2}ha^{-1} which is almost comparable to values reported earlier from IHR (Rana and Samant 2009, Pant and Samant 2012, Sharma and Samant 2013, Sharma et al 2014 and Thakur et al 2015). Tree diversity (0.0-2.50) and richness (3-15) in KWLS is comparable to values reported by Joshi and Samant (2004),
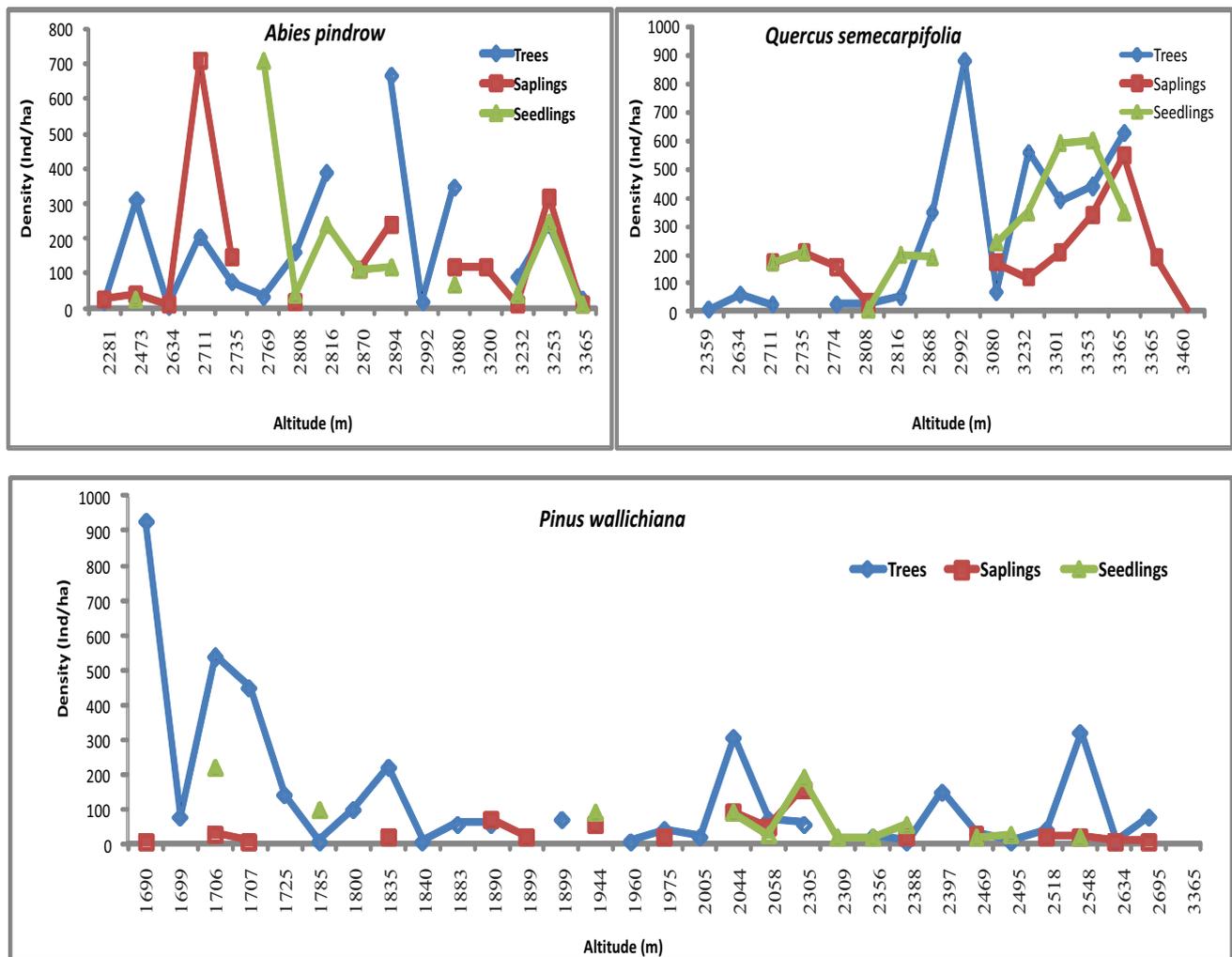

Fig. 2. Density of trees, saplings and seedlings of species along an altitudinal gradient
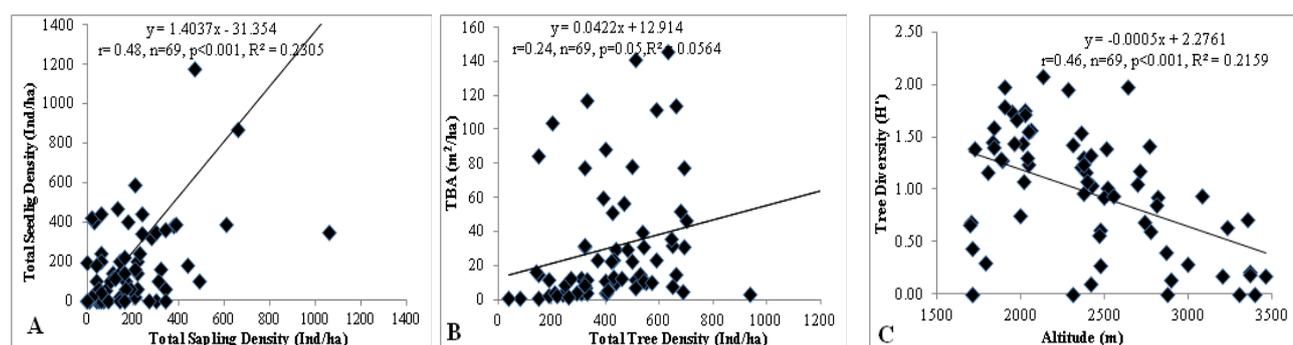
Fig. 3. Correlation between (A) Total saplings density and total seedlings; (b) Total basal area and total tree density; and (C) Altitude and tree diversity of sites

Pant and Samant (2012) and Sharma and Samant (2013).

Altitudinal shift of the species such as *Abies pindrow, Pinus wallichiana* and *Quercus semecarpifolia* was found in the present study. *Pinus wallichiana* showed both upward and downward shift. This could be as a consequence of climate change. Similarly, based on the recruits i.e., seedlings and saplings changing patterns of species composition within the communities has been found. It can be said that species composition within the communities are changing due to the changing environmental conditions particularly climate change.

On comparing total tree density with total basal area, a significant positive correlation was found (r=0.24. p=0.05, n=69). This indicated that with the increase in tree density the total basal area also increases. It was also found highly significant for total saplings density and total seedlings density (r=0.48, p<0.001, n=69), indicating that the environmental conditions for the growth of seedlings are favourable (Fig. 3) but, altitude and trees diversity (r=0.46, p<0.001, n=69) of sites showed significant negative correlations. Which means, decrease in species diversity with the increasing altitude due to severe climatic conditions at higher elevations and inability of the various species to survive under such harsh circumstances.

CONCLUSION

Sanctuary supports high diversity of plant communities and resource exploitation, which indicates high conservation value. Due to grazing rights the sanctuary is facing severe threats. In addition, the area is sensitive to climate change and the identified communities have indicated the changing patterns. Therefore, frequent monitoring of these communities in relation to climate change is required to understand the dynamics of the vegetation. Education and awareness programmes for the local inhabitants on biodiversity conservation and management and restoration of degraded forests with the help of local communities and forest department are essential for maintaining the rich communities for posterity.

REFERENCES

Arya V, Kumar B 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.

Devi LN, Singha D 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.

Curtis JT and McIntosh RP 1950. The interrelation of certain analytic and Phytosociological characters. *Ecology* **31:** 434-455.

Dhaliwal DS and Sharma M 1999. Floristic analysis and diversity of Kullu district, Himachal Pradesh. In: M. Sivadasan and P. Matthew (eds.) *Biodiversity Taxonomy and Conservation of Flowering Plants*. Mentor Books, Calicut. pp. 49-55.

Dhar U, Rawal RS and Samant SS 1997. Structural diversity and representative ness of forest vegetation in a protected area of Kumaun Himalaya, India: Implications for conservation. *Biodiversity and Conservation* **6:** 1045 -1062.

Joshi HC and Samant SS 2004. Assessment of forest vegetation and conservation priorities of communities in part of Nanda Devi Biosphere Reserve, West Himalaya. Part I. *The International Journal of Sustainable Development & World Ecology* **11**(3): 326-336.

Joshi HC and Samant SS 2014. Change in structural and compositional diversity with altitude: A case study from Nanda Devi Biosphere Reserve, West Himalaya. *Indian Journal of Forestry* **37**(2): 121-136.

Mueller-Dombois D and Ellenberge H 1974. Aims and Methods of Vegetation Ecology. John Willey and Sons, New York.

Naidu MT, Premavani D, Suthari S and Venkaiah M 2018. Assessment of tree diversity in tropical deciduous forests of North-central Eastern Ghats, India. *Geology, Ecology and Landscapes* **2**: 216-227.

Pant S and Samant SS 2012. Diversity and regeneration status of tree species in Khokhan Wildlife Sanctuary, north-western Himalaya. *Tropical Ecology* **53**(3): 317-331.

Pant S, Samant SS and Arya SC 2009. Diversity and indigenous household remedies of the inhabitants surrounding Mornaula reserve forest in West Himalaya. *Indian Journal of Traditional Knowledge* **8**(4): 606-610.

Polunin O and Stainton A 1984. *Flowers of the Himalaya*. Oxford University Press.

Prasad C and Sharma RC 2018. Wild edible plants of Kedarnath Valley, Garhwal Himalaya, India. *Indian Journal of Ecology* **45**(3): 433-434.

Rana MS and Samant SS 2009. Prioritization of habitats and communities for conservation in the Indian Himalayan Region: a state-of-the-art approach from Manali Wildlife Sanctuary. *Current Science* **97**(3): 326-335.

Shannon CE and Weaver W 1963. The Mathematical Theory of Communications. University of Illinois Press. Urbana, IL.

Sharma A and Samant SS 2013. Diversity, Structure and composition of forest communities in Hirb and Shoja catchments of Himachal Pradesh, North West Himalaya, India. *International Journal of Botany* **9**(1): 50-54.

Sharma P, Rana JC, Devi U, Randhawa SS and Kumar R 2014. Floristic diversity and distribution pattern of plant communities along altitudinal gradient in Sangla Valley, Northwest Himalaya. *The Scientific World Journal* http://dx.doi.org/10.1155/2014/264878.

Sheng-Ji P 2001. Ethnobotanical approaches of traditional medicine studies: some experiences from Asia. *Pharmaceutical Biology* **139**(sup1): 74-79.

Singh A and Samant SS 2010. Conservation prioritization of habitats and forest communities in the Lahaul Valley of proposed Cold Desert Biosphere Reserve, North Western Himalaya, India. *Applied Ecology and Environmental Research* **2**: 101-117.

Singh DK and Hajra PK 1996. *Floristic diversity*. In: GS Gujral, V Sharma (Eds.): Changing Perspectives of Biodiversity Status in the Himalaya. New Delhi: British Council, pp. 23-38.

Singh JS and Singh SP 1992. *Forest of Himalaya: Structure, Functioning and Impact of Man*. Gyanodya Prakashan, Nainital.

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.

Thakur SD, Kapoor KS and Samant SS 2015. Conservation prioritization of habitats and communities of Tirthan Wildlife Sanctuary, District Kullu, Himachal Pradesh, India: A floristic approach based on potential distribution of vascular plant species. *Ecology Environment and Conservation* 165-173.

Whittakar RH 1977. Evolution of species diversity in land plant communities. *Evolutionary Biology* **10**: 167.

Depth Wise Assessment of Soil Fertility in Seabuckthorn in Comparison to Willow and Poplar in Cold Arid Himalayas

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Abstract: *Hippophae* L. is a multipurpose plant in the cold deserts of Himachal Pradesh. The aim of the study was to understandthe effect of seabuckthorn plantation on soil fertility and to compare it with willow and poplar at Khangsar village, soil samples were collected from three depths, i.e., 0-15 cm, 15-30 cm and 30-45 cm and analysed for pH, organic carbon, available N, P, K, S, exchangeable Ca, Mg and micronutrient cations following standard procedures. All the available nutrients, pH and organic carbon were higher in seabuckthorn plantation except available K, which was higher in wasteland. With the increase in depth, the decrease in content of available nutrient was observed in all three plantations. Soil pH was negatively correlated with available N, P, K, S, exchangeable Ca, and Mg, whereas soil organic carbon was positively correlated with available N, P, K, S, exchangeable Ca, and Mg. Comparatively the soils under seabuckthorn are more fertile and it can be recommended for the sustainability of cold arid Himalayas.

Keywords: Seabuckthorn, Macronutrients, Micronutrients, Himalayas, Soil fertility, Exchangeable Ca and Mg

The cold desert area represents the harsh climatic conditions, high wind velocity, scanty rainfall, great variation in temperature, massive snowfall and extremely xeric conditions. In India trans-Himalayan zone covers the cold deserts, lying in the rain shadow of the main Himalayan range and are usually described as high altitude Himalayas. Himachal Pradesh's two districts Lahaul-Spiti and Kinnaur represents approximately 13.45 per cent of the total area of cold desert in India (Sharma et al 2006). The various environmental challenges prevailing in the region includes the poor water management, soil erosion and degradation of soil fertility. Eco sensitive zones are in threat due to climate change which causes extreme events such as storms, land-slides, avalanches and rock falls in these mountain areas (Kohler et al 2010). The growth of human as well as livestock population, the widespread incidence of poverty and the current phase of economic and trade liberalization, is exerting heavy pressures on India's limited land resources for competing uses in forestry, agriculture, pastures, human settlements and industries. This has led to significant land degradation. Therefore, management and maintenance of soil fertility is essential for sustainability. The major reason of land degradation and loss in soil fertility in cold deserts are deforestation, indiscriminate and unscientific management practices. Due to steep slopes cultivation is confined only to the flatter portions of the valley land and with possibilities of irrigation. Very little is known about the indigenous land-use techniques and fertility status of these soils. So, to study the nutrient status of these soils is highly important and useful. Due to land degradation and increase in desertification there is a great need to have some technology or practice which can minimize the problem. Seabuckthorn can be used a solution to this problem.

Seabuckthorn is a general term given to the shrub-tree *Hippophae* L. Seabuckthorn (*Hippophae* L.) a member of the family Elaeagnaceae, is a thorny deciduous bush. Most importantly seabuckthorn is nitrogen fixing shrub/small tree of 2-6 m height, growing widely on river sides indicating that it is a water loving plant and growing at altitudes up to 5200 m. It rapidly develops an extensive root system and is therefore, an ideal plant for preventing soil erosion (Natasha 2011). The well-developed root system of this plant not only improves the soil fertility through its root nodular nitrogen fixation with the help of Frankia symbiotic association, but also adds to soil organic matter through root and litter decomposition. It has also been used in land reclamation for its ability to fix atmospheric nitrogen and conserve other essential nutrients (Akkermans et al 1983). Many investigations found seabuckthorn as a most suitable species to rehabilitate the wasteland of mining areas. Planting of seabuckthorn increases soil fertility and favours a policy of increase of vegetation and sustainable land use in the hilly and mining areas, which conserves slope farmlands into more sustainable land uses. Hence, seabuckthorn shrub and grassland is a cost efficient way to achieve soil conservation and increase in soil fertility.

Seabuckthorn is an important pioneer plant in the rehabilitation of other plant species, as it helps in the better growth and survival of other wild plants including poplar and willow growing in or near seabuckthorn stand (Quanzhong et al 1989). So it is important to study the status of nutrients under seabuckthorn plantation in comparison to willow and poplar. Considering the distinctiveness and importance of seabuckthorn in conserving soil the present investigation was planned with depth wise assessment of soil fertility in seabuckthorn in comparison to willow and poplar in cold arid Himalayas.

MATERIAL AND METHODS

The present investigation was carried out in the Khangsar village and adjacent area in district Lahaul-Spiti of Himachal Pradesh state during the year of 2015-2016. The Lahaul (31°44' 57"- 32°59' 57"N, 76°46'29"-78°41' 34"E) is situated towards western side of Lahaul-Spiti district and covers an area of 6244 sq. km and is part of the proposed Cold Desert Biosphere Reserve of Himachal Pradesh. Lahaul valley falls under dry temperate zone. The rainy season receives variable rainfall, which varies between 10 mm to 300 mm yr^{-1} depending upon the part of the valley. The winter season is comparatively a large period *i.e.*, starts from November and ends by April. The temperature shows considerable variation throughout the year from a maximum of 25°C in July and minimum of -1°C in November (Fig. 1).

Soil samples were collected from seabuckthorn (*Hippophae salicifolia*), willow (*Salix daphnoides*), poplar (*Populus nigra*) vegetation and control land/barren land at soil depths of 0-15, 15-30 and 30-45 cm from 5 different locations within 3 plots, each of 10 m × 10 m size, chosen randomly in every site and were thoroughly mixed together making 5 replicates of each samples from each soil depth weighing about 200 g. Soil samples were air dried, grinded by pestle mortar and passed through 2 mm sieve and then analysed for pH, organic carbon and nutrients by standard procedures. The organic carbon was measured using $K_2Cr_2O_7$ method (Walkley and Black 1934) and the available N was estimated by using the method of Kjeldahl extraction given by Subbiah and Asija (1956), the available P was measured by Olsen's method with spectrophotometer (Olsen et al 1954), available K was estimated by using flame photometer and micronutrients (Fe, Cu, Mn and Zn) were estimated in atomic absorption spectrophotometer by DTPA method (Lindsay and Norvell 1978).

RESULTS AND DISCUSSION

pH: The soil reaction (pH) under seabuckthorn, willow, poplar and wasteland/barren land (control) revealed that soils were
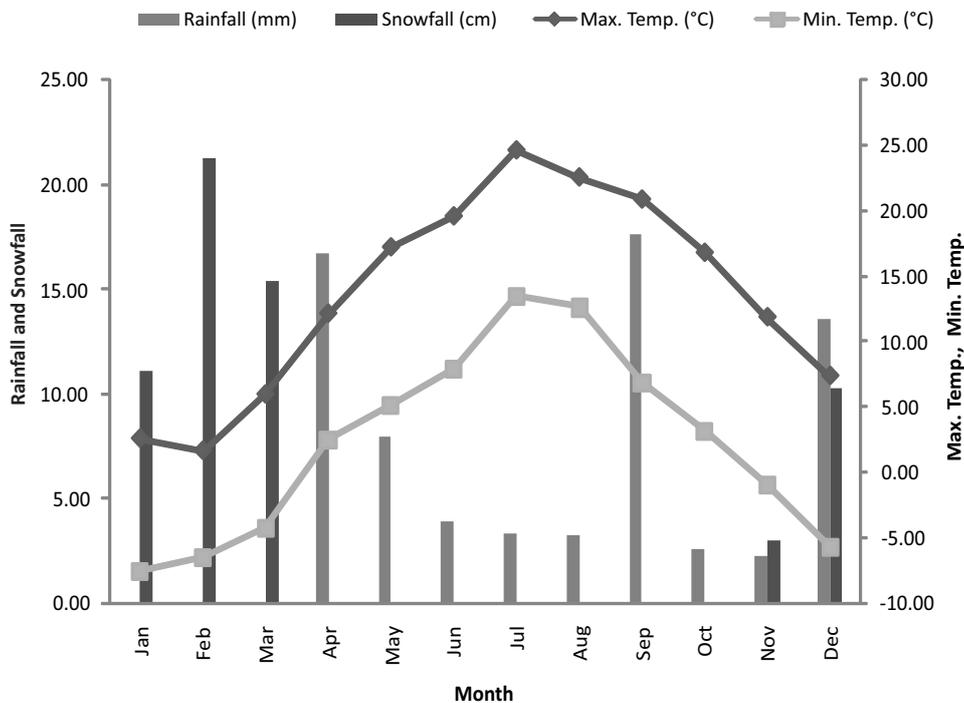

Fig. 1. Variation in the temperature, rainfall and snowfall in Lahaul ofHimachal Pradesh

alkaline in reaction (Table1). The pH under seabuckthorn plantations in Khangsar varied from 7.76-7.98 in 0-15 and 30-45 cm soil depth. This showed that pH increased with increasing soil depth. The pH at 0-15 cm and 15-30 cm depth was at par but pH at 0-15 cm was significantly higher than 30-45 cm depth. Similarly, the pH values of 15-30 and 30-45 cm soil depths were also statistically at par. Comparatively higher soil pH values in the dry temperate zone might be due to accumulation of $CaCO_3$ and other salts due to extremely low rainfall and high evaporation rate in this zone Sharma and Kanwar (2010). Ali et al (2013) also reported the higher pH with increasing depth which is possibly due to acidic parent material of soil, comparatively higher decomposition of organic residues, less percolation and leaching of organic materials to lower depths, probably due to less annual precipitation under the prevailing semi-arid climatic conditions.

In comparison to willow, poplar and wasteland, seabuckthorn had highest soil pH. The effect of different species on soil pH was not significant. Irrespective, the interaction between soil depths and species was not significant.

Organic carbon: The soil under seabuckthorn plantation, have higher values of organic carbon than under willow, poplar and wasteland. The soil organic carbon did not

differing significantly at different depth. Incorporation of seabuckthorn leaf litter, roots secretions, addition of decayed branches and roots in the upper layers and their further slow decomposition in low temperature might have resulted in the accumulation of organic carbon in the surface layers. Similar vertical distribution pattern of organic carbon have been reported by Sarkar and Sahoo (2000), Singh et al (2000), Dhale and Prasad (2009) and Sharma (2011). Gong et al (2007) in Loess Plateau, China also found the enrichment of organic matter in the soils under seabuckthorn, which ultimately increased the soil fertility. Lu (2009) also found the similar results in loess hilly region of China. The soil organic carbon significantly varied with different species. It was significantly higher in seabuckthorn (2.11 per cent) followed by willow, poplar and significantly lowest in wasteland/ barren land (Table 2). On an average in all the plantation the organic carbon of 0-15 and 15-30 cm depth was significantly at par, but organic carbon in 0-5 cm soil depth was significantly higher than 30-45 cm depth. Irrespective, the interaction between soil depths and species was not significant. Ali et al (2013) found the higher organic carbon in seabuckthorn which probably due to less or no manipulation/tillage of soil in seabuckthorn forest.

Available N: The seabuckthorn plantation has higher values of available nitrogen than under willow, poplar and

Table 1. Vertical distribution of available nutrients, soil pH and organic carbon in seabuckthorn

Depth (cm)	pH	OC (%)	N (kg ha^{-1})	P (kg ha^{-1})	K (kg ha^{-1})	S (kg ha^{-1})	Ca (cmol (p+) kg^{-1})	Mg (cmol (p+) kg^{-1})	Fe (mg kg^{-1})	Cu (mg kg^{-1})	Zn (mg kg^{-1})	Mn (mg kg^{-1})
D_1 (0-15)	7.76	2.14	293.6	23.8	140.4	27.8	9.53	2.78	5.0	1.82	1.3	3.56
D_2 (15-30)	7.86	2.11	287.2	19.2	133.4	23.8	9.49	2.62	4.7	1.52	0.9	3.14
D_3 (30-45)	7.98	2.08	281.6	15.8	128.4	20.4	9.45	2.44	4.4	1.26	0.7	2.78
CD (p=0.05)	0.12	0.08	12.38	2.54	19.15	2.94	0.18	0.24	0.3	0.22	0.2	0.24

Table 2. Comparison of soil chemical properties of the sea buckthorn, willow, poplar and wasteland

Species	pH	OC (%)	N (kg ha^{-1})	P (kg ha^{-1})	K (kg ha^{-1})	S (kg ha^{-1})	Fe (mg kg^{-1})	Cu (mg kg^{-1})	Zn (mg kg^{-1})	Mn (mg kg^{-1})	Ca (cmol (p+) kg^{-1})	Mg (cmol (p+) kg^{-1})
Seabuckthorn	7.88	2.11	287.7	19.6	134.2	24.0	4.7	1.53	1.01	3.16	9.49	2.62
Willow	7.81	1.99	215.6	19.3	234.4	23.0	3.9	1.26	1.06	2.11	9.17	2.45
Poplar	7.64	1.82	242.6	18.9	239.8	14.7	3.8	1.23	0.98	1.89	8.86	2.42
Wasteland	7.67	1.73	144.2	17.6	243.8	14.9	3.1	1.11	0.71	1.36	8.35	2.28
CD (p=0.05)	0.26	0.06	7.41	0.62	7.07	0.64	0.13	0.04	0.03	0.07	0.29	0.08
Depth (cm)												
D_1 (0-15)	7.68	1.95	227.9	21.2	218.2	22.6	4.2	1.43	1.11	2.44	9.04	2.54
D_2 (15-30)	7.73	1.91	221.8	18.9	212.4	19.1	3.9	1.27	0.95	2.11	8.95	2.45
D_3 (30-45)	7.84	1.87	217.8	16.4	208.6	15.8	3.6	1.16	0.76	1.84	8.91	2.33
CD (p=0.05)	0.22	0.05	6.42	0.53	6.12	0.56	0.11	0.04	0.03	0.06	0.25	0.07

wasteland. The available nitrogen under seabuckthorn plantations varied from 281.6 to 293.6 kg ha^{-1} at different soil depth. This showed that available N decreased with increasing depth. The content of soil available N with soil depth was not significant. The soil available N was significantly higher in seabuckthorn (287.7 kg ha^{-1}) followed by poplar, willow and wasteland/ barren land (Table 2). The soil available N of the soil varied significantly with different depths. Overall, the soil available N consistently decreased with increase in depth of the soil. On an average the difference in available N content of 0-15 cm and 15-30 cm depth was non-significant but in 0-15 cm, it was significantly higher than 30- 45 cm soil depth. Irrespective, the interaction between soil depths and species was not significant. The soils under seabuckthorn had more available N in comparison to soils of willow and control (wasteland) which might be due to addition of organic matter. These results authenticated with the findings of Kumar et al (2006) and Rajeshwar et al (2009).

Available P: The available P under seabuckthorn plantations varied from 15.8 to 23.8 kg ha^{-1}. Available P decreased significantly with increasing depth being maximum 23.8 kg ha^{-1} at soil top layer (0-15 cm), followed by 19.2 kg ha^{-1} at (15-30 cm) and a minimum of 15.8 kg ha^{-1} at (30-45 cm) soil depth. The soil available P significantly higher in seabuckthorn (19.6 kg ha^{-1}) followed by willow, and significantly lowest in wasteland/ barren land (Table 2). In Eastern Loess Plateau of China Zhang and Chen (2007) observed that *Hippophae rhamnoides* with its rich root nodules showed higher soil available P in mixed forest than in pure forest. The nutrients content decreased with increase in soil depth. Similar results were reported by Lu (2009), who showed that the content of available P was rich in 0-10 cm soil

layer and decreased as the depth of soil increased. The soil available P varied significantly with different depths being maximum in soil top layer (21.2 kg ha^{-1}), followed by 15-30 cm and a minimum at 30-45 cm soil depth. The interaction between soil depths and species was significant.

Available K: The available K under seabuckthorn plantations varied from 128.4 - 140.4 kg ha^{-1} in top soil layer 0-15 and 30-45 cm soil depth. This showed that available K decreased with increasing depth but high in all the three depth. The available K with soil depth was not significant. In China, Guo (2003) reported that K content under seabuckthorn vegetation was 90.3 per cent, which were higher than that of sandy soil. Therefore, seabuckthorn was found most suitable species to rehabilitate the wasteland of mining areas. Similar results were obtained by Gurung (2001) in Nepal.

The soil available K varied significantly with different species being significantly higher in wasteland/ barren land (243.8 kg ha^{-1}) followed by poplar, willow, and significantly lowest in seabuckthorn (Table 2). The lowest content of available K in seabuckthorn plantation may be due to its higher uptake. The soil available K content of the soil varied significantly with different depths. Overall, the soil available K content in soils consistently decreased with an increase in depth of the soil. On an average the difference in available K of 0-15 cm and 15-30 cm depth was non-significant but in 0-15 cm depth, it was significantly higher than 30- 45 cm depth. Irrespective, the interaction between soil depths and species was not significant. This decrease in content of available K with increase in depth was also reported by Zhang and Chen (2007) and Zhao et al (2013).

Available S: The available S under seabuckthorn plantations varied from 20.4 - 27.8 kg ha^{-1} in top soil layer 0-15 cm and 30-45 cm soil depth indicating that available S decreased with

Table 3. Correlation between pH, OC and other available soil nutrients with each other under sea buckthorn plantation

Correlation	pH	OC	N	P	K	S	Fe	Cu	Zn	Mn	Ca	Mg
pH	1.000											
OC	-0.545**	1.000										
N	-0.440**	0.498**	1.000									
P	-0.558**	0.578**	0.694**	1.000								
K	-0.406**	0.636**	0.682**	0.703**	1.000							
S	-0.528**	0.628**	0.730**	0.752**	0.643**	1.000						
Fe	-0.660**	0.660**	0.599**	0.747**	0.750**	0.581**	1.000					
Cu	-0.547**	0.645**	0.764**	0.902**	0.730**	0.776**	0.792**	1.000				
Zn	0.320*	-0.414**	-0.033	0.032	-0.197	0.121	-0.412**	-0.085	1.000			
Mn	0.487**	-0.567**	-0.244	-0.209	-0.419**	-0.175	-0.694**	-0.288	0.843**	1.000		
Ca	-0.544**	0.788**	0.765**	0.612**	0.740**	0.713**	0.741**	0.706**	-0.428**	-0.613**	1.000	
Mg	-0.447**	0.699**	0.813**	0.821**	0.780**	0.766**	0.753**	0.879**	-0.162	-0.349*	0.809**	1.000

* and ** Significant level : 0.05, r ≥ 0.294, 0.01, r≥0.380

increasing soil depth being maximum at at soil top layer (0-15 cm),followed by 15-30 cm and a minimum at 30-45 cm soil depth. The S content decreased with increasing depth was due to the addition of leaf litter annually and slow decomposition of organic residues under low temperature which result in the increased amount of the organic matter and increase in organic matter result in increase in S contents. Similar vertical distribution pattern of available S have been reported by Kour et al (2010).

The available S varied significantly with different species being It was significantly higher in seabuckthorn (24.0 kg ha^{-1}) followed by willow, wasteland/ barren land and significantly lowest in poplar (Table 2). The soil available S content of the soil varied significantly with different depths. Overall, the soil available S content in soils consistently decreased with an increase in depth of the soil. Soil available S at different depths was significant with maximum value 22.6 kg ha^{-1} at soil top layer (0-15 cm), followed by 19.1 kg ha^{-1} at (15-30 cm) and a minimum of 15.8 kg ha^{-1} at (30-45 cm) soil depth. The higher S content in seabuckthorn may be due to higher organic matter under seabuckthorn plantation, as also reported by Sharma (2011, 2014).

Exchangeable Ca: The soil exchangeable Ca under seabuckthorn varied from 9.45 - 9.53 c mol (p$^+$) kg^{-1} in top soil layer 0-15 cm and in 30-45 cm soil depth. This showed that exchangeable Ca decreased with increasing depth. The soil exchangeable Ca varied significantly with different species and was significantly higher in seabuckthorn (9.49 c mol (p$^+$) kg^{-1}) followed by willow, poplar and significantly lowest in wasteland/ barren land (Table 2). Also, soil exchangeable Ca at all depths was statistically same. Irrespective, the interaction between soil depths and species was not significant.

The content of exchangeable Ca in most of soil profiles decreased with increase in soil depth. Higher exchangeable Ca in the upper soil layer may be due to higher organic carbon matter in the upper soil layer and tendency to accumulate in the soil lower layer may be due to the less leaching of basic cations. In china, Xiaoning et al (2002) also reported the increase in soil fertility due to increase in the Ca content in the topsoil.

Exchangeable Mg: The soil exchangeable Mg under seabuckthorn varied from 2.44 - 2.78 cmol (p$^+$) kg^{-1} at different soil depth and decreased significantly with increasing soil depth. The soil exchangeable Mg varied significantly with different species being significantly higher in seabuckthorn (2.62 c mol (p$^+$) kg^{-1}) followed by willow, poplar, and significantly lowest in wasteland/ barren land (Table 2). Overall, the soil exchangeable Mg content in soils consistently decreased with an increase in depth of the soil.

Soil exchangeable Mg at different depths was significant with maximum value 2.54 c mol (p$^+$) kg^{-1} at soil top layer (0-15 cm). Irrespective, the interaction between soil depths and species was not significant In China, Xiaoning et al (2002) reported the increase in soil fertility in the woodland of *Hippophae rhamnoides* plantations due to exchangeable Mg.

Available Fe: The available Fe under seabuckthorn plantations varied from 4.4-5.0 mg kg^{-1} at different soil depth with significant difference and decreased with increasing depth.The soil available Fe significantly varied with different species and was significantly higher in seabuckthorn (4.7 mg kg^{-1}) followed by willow, poplar and significantly lowest in wasteland/ barren land (Table 2). The available Fe content of the soil varied significantly with different depths. Overall, the soil available Fe content in soils consistently decreased with an increase in depth of the soil. Soil available Fe at different depths was significant with maximum value 4.2 mg kg^{-1} at soil top layer (0-15 cm), followed by 15-30 and 30-45 cm soil depth. Irrespective, the interaction between soil depths and species was not significant. The decreased content of available Fe in the lower layers than the surface soils, were also reported by Vivek and Kanwar (2010) and Saeed et al (2014) in high altitude areas.

Available Cu: The soil available Cu under seabuckthorn plantation varied significantly with soil depth maximum (1.82 mg kg^{-1}) at soil top layer (0-15 cm) followed by 15-30 and 30-45 cm soil depth. Available Cu in top soil layer was significantly higher than both the underlying soil layer of depths 0-15 cm and 15-30 cm. The soil available Cu was significantly higher in seabuckthorn (1.53 mg kg^{-1}) followed by willow, poplar and significantly lowest in wasteland/ barren land (Table 2). The soil available Cu varied significantly with different depths. Overall, the soil available Cu content in soils consistently decreased with an increase in depth of the soil. Soil available Cu at different depths was significant with maximum value 1.43 mg kg^{-1} at soil top layer (0-15 cm), followed by 15-30 and 30-45 cm soil depth. The soil Cu concentration may be higher due to higher inputs of organic matter. Decrease in available micronutrients with increasing soil depth may be attributed to low temperature which, reduces the rate of mineralisation and leads to the accumulation of nutrients in the top soil layers as compared to bottom layers (Dar et al 2012).

Available Zn: The available Zn at different depths was significant being maximum 1.34 mg kg^{-1} at top soil layer (0-15 cm), followed by 15-30 cm and 30-45 cm soil depth. The soil available Zn significantly varied with different species and was significantly higher in willow (1.06 mg kg^{-1}) followed by seabuckthorn, poplar and lowest in wasteland/ barren land (Table 2). The available Zn at different depths was found to be

significant with maximum value 1.11mg kg^{-1}at soil top layer (0-15 cm), followed by 15-30 and 30-45cm soil depth. Vivek and Kanwar (2010) and Saeed et al (2014) also observed the decrease in available Zn with increase in soil depth.

Available Mn: The available Mn at different depths was significant being maximum 3.56 mg kg^{-1} in soil top layer (0-15 cm), followed by 15-30 and 30-45 cm soil depth. The soil available Mn significantly varied with different species. It was significantly higher in seabuckthorn (3.16 mg kg^{-1}) followed by willow, poplar, and significantly lowest in wasteland/ barren land (Table 2). The soil available Mn varied significantly with different depths. Overall, the soil available Mn decreased with an increase in depth of the soil. Soil available Mn at different depths was significant with maximum value 2.44 mg kg^{-1}at soil top layer (0-15 cm), followed by 15-30 and 30-45cm soil depth. Comparatively the higher content of micronutrients in seabuckthorn plantation may be due to the decomposition of leaf litter and deadroots which would increase the mineralisation and add nutrients in soil, leading to increase in the content of micronutrients (Dar 2012, He et al 2016).

Correlation Studies: The soil pH was negatively and significantly correlated with organic carbon (r = -0.545). Soil organic carbon showed significant positive correlation (r = 0.498) with available N and significant negative correlation (r = -0.545) with soil pH. Similarly, a significant positive and negative correlation of soil available N, available P, available K, available S, exchangeable Ca, exchangeable Mg, Cu and Fe was observed with organic carbon and soil pH, respectively. Zn and Mn were positively correlated with pH and negatively correlated with organic carbon. Similar correlations were reported by Sharma (2011, 2014).

CONCLUSION

The soils of Lahaul, Himachal Pradesh were alkaline in reaction (pH) and high in organic carbon. Seabuckthorn planted soil accumulated higher organic carbon, available N, available P, available S, exchangeable Ca, exchangeable Mg and micronutrient cations than the willow, poplar and wasteland. The contents of these elements decreased with the increase in soil depth. However, seabuckthorn soils had slight lesser values of available K than willow and poplar which was highest in wasteland (barren land).Soil pH was negatively correlated with available N, P, K, S, exchangeable Ca, Mg, Cu and Fe whereas, soil organic carbon was positively correlated with available N, P, K, S, exchangeable Ca, Mg and Cu and Fe. Seabuckthorn enriched the soil with nutrients as compared to willow, poplar and wasteland soil and has great potential for sustainable environmental protection in cold desert areas of Himalayas. It can be used as remedy for land degradation and escalating soil fertility of cold desert.

REFERENCES

Akkermans ADL, Roelofsen W, Blom J, Huss D and Harkink R 1983. Utilization of carbon and nitrogen compounds by *Frankia* in synthetic media and root nodules of *Alnusglutinosa*, *Hippophaerhamnoides*and *Datiscacannabina. Canadian Journal of Botany* **61**: 2793-2800.

Ali H, Razaq A, Perveen S and Khan B 2013. Nitrogen Fixation by non-leguminous plant seabuckthorn in semi arid climatic conditions of Gilgit- Baltistan. *Pakistan Journal of Weed Sciences* **19**: 305-314.

Dar MA, Wani JA, Raina SK, Bhat YM, Malik MA and Najar RG 2012.Effect of altitude and depth on available nutrients in pear orchards of Kashmir. *Agropedology* **22**: 115-118.

Dhale SA and Prasad J 2009. Characteristics and classification of sweet-orange growing soils of Jalna District, Maharashtra. *Journal of Indian Society of Soil Science* **57**: 11-17.

Gong J, Chen LD, Fu BJ and Wei W 2007. Integrated effects of slope aspect and land use on soil nutrients in a small catchment in a hilly loess area China. *International Journal of Sustainable Development and World Ecology* **14**: 307-316.

Guo ZS 2003. Seabuckthorn for the improvement of the microclimate and soil properties of mountainous waste- lands in arid and semi-arid China. In: Singh, V. 2003 (Editor-in-Chief). Seabuckthorn (*Hippophae* L.): *A Multipurpose Wonder Plant, Indus Publication Co., New Delhi* 417-432.

Gurung K 2001. *Ecology and distribution of seabuckthorn (Hippophae L.) in Mustang and Manang Districts, Nepal.* M.Sc.Thesis*, p 58. Submitted to Central Department of Botany, Tribhuvan University, Nepal.

HeX, Hou E, Liu Y and Wen D 2016. Altitudinal patterns and controlsof plant and soil nutrient concentrations and stoichiometry insubtropical China. *Scientific Reports* **6**: 24261.

Kohler T, Giger M, Hurni H, Ott C, Weismann U, Wymann S and Maselli D 2010. Mountain and climate change: A Global concern. *Mountain Research and Development* **30**:53-55.

Kour S, Arora S, Jalali VK and Mondal AK 2010. Soil sulphur forms in relation to physical and chemical properties of mid hill soils of north India. *Journal of Indian Society of Soil Science* **41**: 277-289.

Kumar P, Verma TS and Sharma PK 2006. Effect of land uses on relationship between organic carbon and available Nutrients in dry temperate zone of Himachal Pradesh. *Journal of Indian Society of Soil Science* **54**: 485-488.

Lindsay WL and Norwell WA 1978. Development of DTPA soil test for Zinc, Iron, Manganese and Copper. *Soil Science Society of American Journal* **42**: 421-428.

Lu JL 2009. Study on Ecological effect of artificial seabuckthorn forest with different ages in Loess Hilly region. M.Sc Thesis.Agricultural Sciences, China.

Natasha 2011. E*cological characteristics of some important plant species in Lahaul valley, Himachal pradesh.* M.Sc. Thesis, p 63. Department of Biology and Environmental Sciences, CSK Himachal Pradesh KrishiVishvavidyalaya, Palampur, India

Olsen SR, Cole CV, Watanave FS and Dean LA 1954. Estimation of available phosphorus in soils by extraction with sodium carbonate. *United States Department of Agriculture, Citric*. p. 939.

Quanzhong L, Peiyun L, Shaozhou C, Yuzhen B, Lixin P and Qingjie K 1989. Multiple effects of artificial common seabuckthorn (Hippophae rhamnoides) forests in western Liaoning. *Proceedings of International Workshop on Seabuckthorn*, p. 288-297, Xianf China p.415.

Rajeshwar M, Rao CS, Balaguravaiah D and Khan MA 2009. Distribution of available micronutrients in soils of Garikapadu of Krishna districts of Andhra Pradesh. *Journal of Indian Society of Soil Science* **57**: 210-213.

Saeed S, Barozai MY, Ahmad A and Shah SH 2014. Impact of

altitudeon soil physical and chemical properties in Sra Ghurgai (Takatumountain range) Quetta, Balochistan. *International Journal of Scientific and Engineering Research* **5**: 730-735.

Sarkar D and Sahoo AK 2000. Aquepts of Indo-Gangetic Plain of Bihar and their Suitability for Major crops. *Journal of Indian Society of Soil Science* **48**: 561-566.

Sharma A 2011. *Impact assessment of seabuckthorn (Hippophae L.) on soil fertility status.* M.Sc. Thesis, p 86. Department of Biology and Environmental Sciences, COBS, CSK Himachal Pradesh Krishi Vishvavidyalaya, Palampur, India.

Sharma A 2014. *Soil Fertility status under seabuckthorn (Hippophae L.) at different altitudes in Spiti.* M.Sc. Thesis, p 95. Department of Biology and Environmental Sciences, CSK Himachal Pradesh   Krishi Vishvavidyalaya, Palampur, India.

Sharma PK, Sethi GS, Sharma SK and Sharma TK 2006. Ethno-medicinal observations among the inhabitants of cold desert area of Himachal Pradesh. *Indian Journal of Traditional Knowledge* **5**: 358-361.

Sharma V and Kanwar BB 2010. Copper status and its relation with soil properties in pea growing soils of high hills dry temperate zone of the Himachal Pradesh. *Journal of Indian Society of Soil Science* **44**: 32-37.

Singh RN, Singh RNP and Diwaker DPS 2000. Characterization of old alluvial soils of Sone Basin. *Journal of Indian Society of Soil Science* **48**: 352-357.

Subbiah BV and Asija GL 1956. A rapid procedure for estimation of available nitrogen in soils. *Current Science* **25**: 259-260.

Vivek S and Kanwar BB 2010. Copper status and its relation with soil properties in pea growing soils of dry temperate zone of Himachal Pradesh. *Indian Journal of Agricultural Research* **44**: 32-37.

Walkley A and Black CA 1934. An estimation of the method for determination of soil organic matter and a proposed modification of the chromic acid titration method. *Soil Science* **37**: 29-39.

Xiaoning T, Baoli A, Xiufend W and Jing N 2002. Soil Improvement of Seabuckthorn (*Hippophae rhamnoides*) Plantations and its characteristics of the Roots in Loess Plateau. 12th ISCO conference, China.

Zhang JT and Chen T 2007. Effects of mixed *Hippophae rhamnoides* on community and soil in planted forests in the Eastern Loess Plateau, China. *Ecological Engineering* **31**: 115-121.

Zhao Z, Shahrourl, Bai Z, Fan W, Feng L and Li H 2013. Soils development in opencast coal mine spoils reclaimed for 1-13 years in the West-Northern Loess Plateau of China. *European Journal of Soil Biology* **55**: 40-46.

Dynamics in Biomass Expansion Factor, Root-to-Shoot Ratio and Wood Quality Parameters in Different Girth Class of *Gmelina arborea* Roxb.

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Abstract: Trees of different diameter classes were harvested to assess the dynamics in biomass, root: shoot ration and some wood characteristics. A perusal of data showed that in the 20-30 cm girthclass, the proportion of stem (53.67%) and root (25.61%) in total biomass was far more than the branch (12.56 %) and leaf (8.16 %) but with increase in girth class, the mean proportion of stem and root increased further i.e., 67.22% and 19.13%, respectively than branch (8.86%) and leaves (4.79%) in 120-130cm girthclass. The values of Biomass expansion factor (BEF) ranged from 1.36 to 1.17, showing decreasing trend as the range of the girth classes increased. Root: shoot ratio varied from 0.18 to 0.36 and per cent wood shrinkage decreased as the girth class increased.

Keywords: *Gmelina arborea*, BEF, Biomass, Root : shoot ratio, Shrinkage, Specific

Knowledge of timber quality as well as quantity is important for processing of timber and financial assessment of afforestation programme. Inspite of large number of commercial species in the forests, very few short rotation trees are used for commercial purpose. The biomass partitioning on component basis prediction is lacking, which makes it difficult to assess the complete value of tree. Each and every tree component is saleable including the residue, provided there is proper assessment for the same. Wood quality and quantity cannot be treated independently for marketing. Quantity through is important but for end uses quality itself is given due weightage. The general pattern of variation in wood elemental dimensions is not only found within a species and between trees but also within a tree as well (Pandey et al 1995). These variations though are governed by the genetic potential but environment including management plays a significant role rather interaction of genotype and environment decides the end product. These properties ultimately govern the end use of the wood.

Gmelina arborea, a native of Australia, southeast Asia, Malaysia and the Philippines is an important commercial short rotation tree, timber is mainly used in plywood industry (Tenorio et al 2011). It tolerates a wide range of climatic conditions. In Indian north-western states, it may find a suitable alternative place in farming system to diversify the narrow tree base in agroforestry/farm forestry plantations. However, at present very few trees are available in Punjab, Haryana, Uttrakhand, western UP, etc. but its plantations by

state forest department initially would certainly attract the attention of the farmers. Additionally, industry needs to promote the tree for processing to add value and open up market for the farmers. The proportion of the wood in tree/stem, wood specific gravity, shrinkage, etc. are some of the reliable indicators of wood quality, which would be desired by the industry for processing. Therefore, the aim of the present study was to observe the extent of wood variation w.r.t. wood quality parameters at differential girth classes.

MATERIAL AND METHODS

The present investigation on biomass distribution and wood quality in *Gmelina arborea* (Roxb.) was carried out at the University Seed Farm, Ladhowal, Punjab Agricultural University (PAU), Ludhiana on pre-planted trees of variable girth classes.

Forty one *Gmelina arborea* (Roxb.) trees of different girth classes were harvested at PAU Seed Farm, Ladhowal to recorded the actual component wise biomass and wood quality parameters at variable heights. Trees were selected from eleven girth classes ranging from 20-30 cm to 120-130 cm. Trees equally represented in different girth classes with minimum girth tree of 20.3 cm and maximum girth of 122 cm. All the trees were used for making assessment of different variables. Trees from eleven girth classes were subjected to destructive sampling for estimation of tree component biomass. Roots were excavated completely to record the below ground biomass. Each and every component through

has market value but additionally these components have environmental value as well. Therefore, component wise carbon sequestration values were also worked out as per the procedure adopted by Chauhan et al (2015).

Biomass expansion factor (BEF): Biomass expansion factor was calculated using the formula given by FAO (1997) i.e. the ratio of above-ground (dry weight of stem + leaf + shoots) oven-dry biomass of trees to oven-dry biomass of stem. BEF was calculated using the following equation:

$$BEF = \frac{ADB}{DSW}$$

BEF = Biomass expansion factor (dimension less), ADB = Above-ground dry biomass, DSW = Dry stem weight

Root-to-shoot ratio (R): Root-to-shoot ratio was calculated using the formula of IPCC (2006), which defines R as the ratio of belowground (root) to aboveground biomass (dry weight of stem + leaf + branches), the equation used to calculate R value as follows:

$$R = \frac{W_{root}}{W_{aboveground}}$$

R = root-to-shoot ratio (dimension less), W_{root} = tree-root dry weight (kg), $W_{aboveground}$ = aboveground total dry weight (kg)

Quality Parameters

Specific gravity: The representative samples (1cm^3) from stem of each tree were collected at three different heights [at collar region (disc$_1$), mid height of tree (disc$_2$) and from top portion of tree (disc$_3$)] and immersed in water for 48 hours and maximum moisture weight was recorded. Samples were dried in the oven (103±2^{0}C) till the constant weight was achieved. Specific gravity was calculated by using Okon (2014) formula:

$$Specific\ gravity = \frac{1}{\frac{Mm - Mo}{Mo} + \frac{1}{GS}}$$

Mm = Weight of sample having maximum moisture, Mo = Weight of oven dried sample, GS = Constant = 1.53

Moisture content (%): Moisture content in wood samples was calculated on the basis of total fresh weight and oven dry weight of wood by using formula given by Kollman and Cote (1968):

$$Moisture\ content\ (\%)\ \mu = \frac{W_\mu - W_0}{W_\mu} \times 100$$

μ = Moisture content (%), Wμ = Weight of the wood sample with moisture content μ or original fresh weight, Wo = Weight of the oven dried wood sample

Shrinkage (%): All the wood samples that have been taken from forty one selected trees were used for determining the wood shrinkage. Percentage shrinkages along the two

planes of wood (radial and tangential) were measured after dischad been oven-dried using Okon (2014) and Malami et al (2015) formula:

$$S\ (\%) = \frac{D_s - D_o}{D_s} \times 100$$

S = Shrinkage (%), D_s = Dimensions of fresh sample, D_o = Dimensions of oven dried sample

Radial shrinkage (%): Radial shrinkage was recorded from each disc (without bark) with measuring scale by using four points at the margins of approx.1cm thick disc at equal distance. Measurements were done in the field on fresh wood samples and then after oven drying at 100± 2°C in the wood sample. Percentage shrinkages were measured by using Okon (2014) formula:

$$RDS\ (\%) = \frac{Dr - dr}{Dr} \times 100$$

RDS = Radial shrinkage (%), D_r = Initial dimensions along the radial axis on fresh wood samples, d_r = Final dimensions along the radial axis on oven dry wood samples

Tangential shrinkage (%): Tangential shrinkage was measured at tangential axis on same four points on the disc (without bark) from where radial shrinkage was taken both on the fresh wood samples and on oven dried wood samples at 100± 2°C. Percentage shrinkages were measured by using Okon (2014) formula:

$$TGS\ (\%) = \frac{D_t - d_t}{D_t} \times 100$$

TGS = Tangential shrinkage (%), D_t = Initial dimensions along the tangential axis on fresh wood samples, d_r = Final dimensions along the tangential axis on oven dried wood samples

Average shrinkage (radial and tangential) was calculated by adding percentage shrinkage of all the three discs taken at collar region (disc$_1$), mid height of tree (disc$_2$) and from top portion of tree (disc$_3$) and then divided by three for average. So both average radial shrinkage and average tangential shrinkage was added to get total volumetric shrinkage in the wood.

RESULTS AND DISCUSSION

Proportion of tree components in different girth classes: A perusal of data presented in Fig.1 shows that in the lowest girth class (20-30 cm), the proportion of stem (53.67 %) and root (25.61 %) was far more than the branch (12.56 %) and leaf (8.16 %). With the increase in the girthclass, the mean proportion of stem and root further increased and the proportion of branch and leaves in the total biomass decreased accordingly. The maximum value of 67.22% of stem and 19.13% of root proportion was recorded in highest girthclass. Study conducted by Singh (1998) on partitioning of biomass recorded that stem wood alone constituted almost 55% of the tree biomass, the branch + twig measured
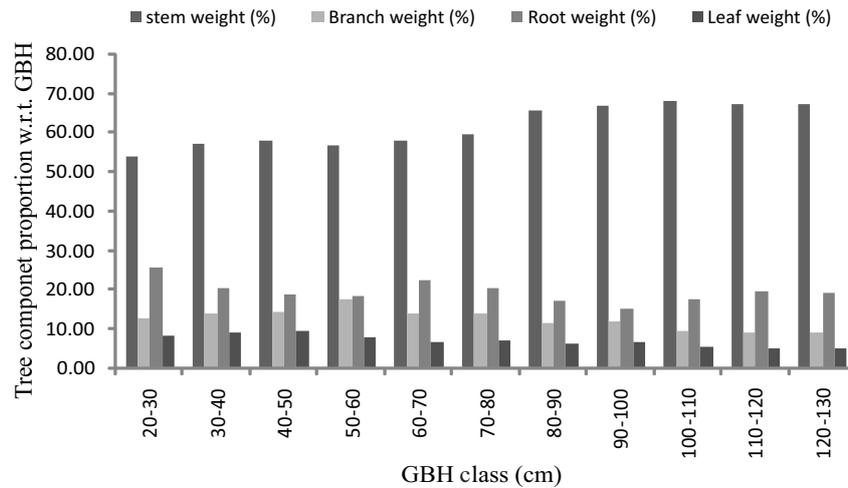
Fig. 1. Tree component proportion with respect to girth classes

about 22%, root 17% and leaf 6-8%, which are almost similar to the present study. Havreljuk et al (2013) found 40% of tree value was in the first log, 25% was in the second log and 17% in the third log. Value increased with increasing dbh (diameter at the breast height) and decreasing age after maturity age. Value per tree was significantly related to tree dbh regardless of the clone. The carbon contribution of different tree components are presented in Table 1, which shows significant environmental contribution in terms of carbon storage in trees from 17.03 to 248.29 kg for lowest to highest girth class in *Gmelina arborea*. The biomass expansion factor and shoor: root ratio are important parameters for quantification of biomass carbon stocks (Sanquetta et al 2011, Giri et al 2014).

Biomass expansion factor (BEF) and root-to-shoot ratio (R): BEF showed decreasing trend as the range of the girth classes increased. The maximum value of BEF (1.42) was recorded in GBH class 50-60 cm followed by very closer value of BEF (1.41) in GBH class 40-50 cm and the minimum value of BEF (1.17) was found in the highest girth- class 120-130 cm (Table 2). There was a decreasing trend in the values of BEF w.r.t. to increment in girth class. The BEF reduction with increasing girth class indicates that the proportion of the stem in comparison to other parameters increased in total tree biomass. The root-to-shoot ratio irrespective of girth class remained almost static. The highest value 0.36 was found in lowest girth class 20-30 cm, which may be due to less developed root system and proportionately low biomass of the stem at initial stage of growth. Rawat et al (2015) reported that the BEF and R values vary according to the age of the trees in *Eucalyptus* hybrid*, Dalbergia sissoo, Acacia catechu* and *Populus deltoides*. The results presented here agreed with them in an another tree species of *Gmelina arborea* where both the parameters showed differential value

with changing girth classes.

Quality parameters of trees in different girth classes
radial and tangential shrinkage (%): Mean data for shrinkage presented in table 3, clearly depicts maximum shrinkage in the top region in *Gmelina arborea* and it decreased with increase in girthclass. Maximum radial and tangential shrinkage of 3.81% and 4.82%, respectively was recorded in the lowest girth class, whereas, the respective minimum value of 1.25% and 2.28% was recorded in the highest girth class (120-130 cm). Likewise, the shrinkage decreased gradually from top portion to the lower portion in all the respective girth classes. The increase in both the radial as well as tangential shrinkage towards the top region of the tree from the collar region was due to the increase in the wood immaturity and variation in orientation of cell wall constituents especially cellulose and hemicelluloses molecules from collar to top region. The results presented here on radial and tangential shrinkage agreed with Okon (2014), where increased shrinkage was recorded from base to top region in *Gmelina arborea*. The pooled average trend showed in fig. 2 clearly depicts that the radial and tangential shrinkage decreased with increase in the range of girth class. Rigatto (2004), Onyekwelu et al (2006), Poku et al (2001) also recorded increase in both the shrinkage from butt log to Crown Point. Higher tangential shrinkage is also in agreement with the findings of Okon (2014), where almost double tangential shrinkage was observed than radial shrinkage due to physiological activities, cell structure and cellulose molecules within cell wall, etc. Armstrong et al (2007) also recorded more tangential shrinkage than radial shrinkage in African mahogany in Australia. The shrinkage values are comparable to the values reported by Shanavas and Kumar (2006) for four tree species (*Acacia auriculiformis, Acacia mangium, Greville arobusta* and*Tectona grandis*).

Specific gravity: Mean data of specific gravity at variable heights of trees is presented in Table 4, which clearly depicted that minimum specific gravity in *Gmelina arborea* was found in top region of wood samples in the lowest girth class 20-30 cm in the tree with minimum value of 0.47. The values increased with increase in girth class with maximum value of 0.57 in the highest girth class i.e. in 120-130 cm for samples collected from top portion. Accordingly the specific gravity increased from top portion to collar region with similar trend of increase in specific gravity with increase in girthclass. The decrease in the specific gravity towards the top region of the tree from the collar region was due to the decrease in the maturity of the wood from collar to top region. This change is due to the cell wall thickness and cell size, which varies with increasing age and maturity of cambium. The results presented here on specific gravity agreed with Okon (2014), who reported that the specific gravity decreased from base to top region in *Gmelina arborea*. The trend showed in Fig. 3 clearly depicted that the pooled average specific gravity increased with increase in the range of girth class. Pandey et al (1995), Chauhan et al (2001) and Pandey (2007) recorded impact of height on specific gravity due to differential sapwood and heartwood ratio at different tree heights. Panshin and de

Table 3. Mean data of radial and tangential shrinkage (%) on top, middle and collar region of tree w.r.t. to girth classes

Girth class	Avg. radial shrinkage (%) on top region	Avg. radial shrinkage (%) on mid region	Avg. radial shrinkage (%) on collar region
20-30	3.81 (4.82)	2.92 (3.95)	1.96 (2.99)
30-40	3.61 (4.76)	2.66 (3.69)	1.30 (2.33)
40-50	3.16 (4.66)	2.10 (3.53)	1.20 (2.23)
50-60	2.75 (3.98)	1.69 (3.45)	1.22 (2.25)
60-70	2.27 (3.81)	1.31 (2.94)	1.15 (2.18)
70-80	2.01 (3.73)	1.17 (2.60)	1.03 (2.06)
80-90	1.26 (2.89)	1.01 (2.44)	0.98 (1.97)
90-100	1.29 (2.85)	0.88 (1.91)	0.83 (1.76)
100-110	1.31 (2.64)	0.71 (1.74)	0.59 (1.52)
110-120	1.29 (2.52)	0.88 (1.91)	0.45 (1.48)
120-130	1.25 (2.28)	0.56 (1.59)	0.33 (1.36)

* Tangential shrinkage (%) values in parentheses

Zeeuw (1980); Grabner and Wimmer (2006) also reported vertical variation along the main axis of the stem.

The observations of the present study requires further establishment of juvenile and mature wood relationship so that the quality of mature wood could be assessed at the initial stage of development.

Table 1. Carbon content (kg) in different tree component w.r.t. girth classes

Girth class	Avg. carbon content in stem (kg)	Avg. carbon content in branch (kg)	Avg. carbon content in roots (kg)	Avg. carbon content in leaves (kg)	Avg. carbon content in bark (kg)	Total carbon content (kg)
20-30	9.48	2.25	4.04	1.26	1.15	17.03
30-40	11.77	2.93	4.78	1.63	1.24	21.10
40-50	15.81	4.26	4.90	2.38	2.13	27.35
50-60	26.74	7.98	8.08	3.28	4.34	46.09
60-70	43.99	10.20	15.15	4.20	4.84	73.54
70-80	46.81	11.84	15.03	4.87	4.85	78.55
80-90	91.42	17.12	22.66	7.91	9.09	139.11
90-100	103.47	21.13	23.59	9.78	8.86	157.97
100-110	144.89	21.77	35.55	10.08	9.54	212.29
110-120	157.31	24.29	47.79	11.29	10.25	240.68
120-130	161.27	25.94	49.07	12.01	11.40	248.29

Table 2. Mean data of biomass expansion factor (BEF) and root-to-shoot ratio (R) w.r.t. girth classes

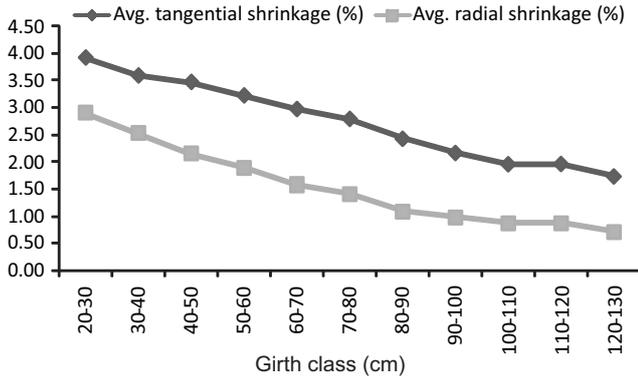| Girth class (cm)	Biomass expansion factor (BEF)	Root-to-shoot ratio (R)	Girth class (cm)	Biomass expansion factor (BEF)	Root-to-shoot ratio (R)
20-30	1.36	0.36	80-90	1.27	0.20
30-40	1.39	0.24	90-100	1.30	0.18
40-50	1.41	0.22	100-110	1.22	0.20
50-60	1.42	0.22	110-120	1.21	0.25
60-70	1.33	0.21	120-130	1.17	0.25
70-80	1.36	0.24	CD (p=0.05)	0.06	0.04

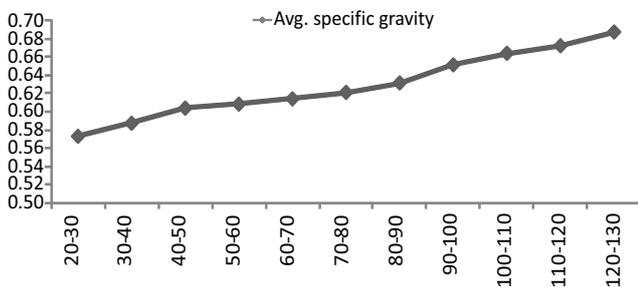**Fig. 2.** Trend in radial and tangential w.r.t. girth classes

Fig. 3. Increasing trend in pooled average specific gravity w.r.t. girth classes

Table 4. Mean values of specific gravity on top, middle and collar region of tree w.r.t. to girth classes

Girth class	Top portion specific gravity	Middle portion specific gravity	Collar region specific gravity
20-30	0.47	0.55	0.69
30-40	0.48	0.57	0.71
40-50	0.50	0.59	0.73
50-60	0.50	0.59	0.74
60-70	0.50	0.60	0.74
70-80	0.50	0.60	0.76
80-90	0.51	0.63	0.76
90-100	0.53	0.66	0.77
100-110	0.55	0.67	0.77
110-120	0.55	0.68	0.79
120-130	0.57	0.69	0.80

CONCLUSION

The wood proportion in tree in comparison to other components (leaf, bark, root, etc.) keep increasing with age, which is related in the decreasing values of BEF with increasing age. Also wood shrinkage reduces with maturity of wood.

REFERENCES

Armstrong M, Reilly DF, Lelievre T, Hopewell G, Redman A, Francis L and Robertson RM 2007. African mahogany grown in Australia-wood quality and potential uses. A report for the RIRDC/L&WA/FWPRDC/MDBC Joint Venture Agroforestry Program. RIRDC Contact Details Rural Industries Research and Development Corporation Level 2, 15 National Circuit BARTON ACT, 94p.

Chauhan L, Gupta S, Madhwal RC, Pandey R and Pal M 2001. Inter-clonal, Intra-clonal and within tree variation in wood parameters of different clones of *Populus deltoides. Indian Forester* **127**: 777-784.

Chauhan SK, Sharma R, Singh B and Sharma SC 2015. Biomass production, carbon sequestration and economics in on-farm poplar plantations in Punjab, India. *Journal of Applied and Natural Science* **7**: 452-458.

FAO 1997. *State of the world's forests.* Food and agricultural organisation of the United Nations; 1997, 200.

Giri N, Kumar R, Rawat L and Kumar P 2014. Development of biomass expansion factor (BEF) and estimation of carbon pool in *Ailanthus excelsa Roxb* plantation. *Journal of Chemical Engineering Process and Technology* **5**: 210. doi: 10.4172/2157-7048.1000210.

Gomez KA and Gomez AA 1984. *Statistical Procedures for Agricultural Research* 2nd edn., pp. 680. John Willey and Sons, New York.

Grabner M and Wimmer R 2006. Variation of different tree ring parameters as present in a complete Norway spruce stem. *Dendrochronologia* **23**:111-120.

Havreljuk F, Achim A and Pothier D 2013. Regional variation in the proportion of red heartwood in sugar maple and yellow birch. *Canadian Journal of Forestry Research* **43**(3): 278-287.

IPCC 2006. Intergovernmental panel on climate change. *Guidelines for National Greenhouse Gas Inventories* [http://www.ipcc.ch].

Kollmann FFP and Cote WA 1968. Principles of wood science technology. 1. Solid wood. Springer-Verlag, New York.

Malami AA, Zubairu YG and Nafiu AK 2015. Variation in density and shrinkage between sawmill and hand processed *Khaya senegalensis* wood in sokoto, Northwestern Nigeria. *International Journal of Sustainable Agricultural Research* **2**(3): 77-85.

Okon KE 2014. Variations in specific gravity and shrinkage in wood of a 25-year-old *Gmelina arborea* in Oluwa forest reserve, south west Nigeria. *Archies Applied Science and Research* **6**: 271-276.

Onyekwelu JC, Mosandl R and Stimm B 2006. Productivity, site evaluation and state of nutrition of *Gmelina arborea* plantations in Oluwa and Omo forest reserves, Nigeria. *Forest Ecology and Management* **229**: 214-227.

Pandey PK, Rao RU, Agrawal SP and Singh M 1995. Variations in the dimensions of tracheid elements of *Pinus caribaea* var. *bahamensis. Journal of Tropical Forest Products* **1**:117-123.

Pandey PK 2007. Intra-tree variations in wood anatomical properties of *Dalbergia sissoo* Roxb. *Annals of Forestry* **15**: 335-342.

Panshin AJ and de Zeeuw C 1980. Textbook of wood technology. McGraw-Hill, New York.

Petersson H, Holm S, Ståhl G, Alger D, Fridman J, Lehtonen A, Lundström and Mäkipää R 2012. Individual tree biomass equations or biomass expansion factors for assessment of carbon stock changes in living biomass-A comparative study. *Forest Ecology and Management* **270**: 78-84.

Poku K, Wu Q and Viosky R 2001. Wood properties and their variation within the tree stem f lesser used species of tropical hardwood from Ghana. *Wood Fiber Science Journal* **33:** 284-291.

Rawat L, Kamboj SK and Kandwal A 2015. Biomass expansion factor and root-to-shoot ratio of some tree species of Punjab ,India. *Indian Forester* **141**:146-153.

Rigatto AT 2004. Tangential shrinkage, radial shrinkage and volumetric shrinkage in *Gmelina arborea. South African Journal of Science* **59**: 653-683.

Carbon Sequestration and Tree Diversity of Thimmalapura Reserve Forest, Tumakuru, Karnataka

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Abstract: Present study was conducted to determine the carbon sequestration capacity of Thimmalapura Reserve Forest, one of the dry forests of Karnataka. Average carbon sink of the study area is around 3015g of carbon per tree with a total carbon assimilation of 1658550g. *Chloroxylon swietenia* has the highest amount of carbon assimilation (88420 g/sp) as compared to other species. *Careya arborea* with lone individual in the sampled area has carbon stock of 12701g/tree/sp. Above ground biomass constitutes major part of the biomass. Average aerial biomass of the sampled area is 4645 g/sp and the total aerial biomass of 25550 g/sp. Pearson's correlation studies on total number of individuals and carbon stock in each species shows a positive correlation. Diversity study shows that the vegetation has a very high index value indicating the richness of species. Conservation and afforestation measures would enhance the capacity of the Thimmalapura forest to sink more carbon.

Keywords: Carbon sequestration, Thimmalapura forest, Afforestation, Diversity index, Total biomass

UN-REDD is a collaborative programme of FAO, UNDP and UNEP with 64 member countries to reduce emission from deforestation and forest degradation. In their latest blog (3 October 2018), mentioned that forest is a natural solution to climate change and crucial for sustainable future. It emphasizes the need to enhance carbon sink by afforestation and reforestation to reduce increasing global warming. It is estimated that in the last 2 decades, land use changes including deforestation and forest degradation accounts for 12 to 29% green house gases. India being a tropical and developing country and rich in biodiversity needs special emphasis on such studies which help in proper planning and protection strategies. Forest plays an important role in the global carbon cycle. They are the store house of large quantities of carbon and could sequester 60 to 70 Pg of carbon globally. The carbon dioxide was about 200 ppm during pre-industrial period and rose to 390 ppm during post industrial period. This escalation in CO_2 can be ameliorated by the forest ecosystem which assimilates carbon and produce biomass. There is a linear relationship between carbon fixation and plant diversity and also species richness. Loosing of biodiversity would result catastrophic effect. There are several studies on carbon sequestration of urban areas and forests of both tropical and subtropical region. Rai and Procter (1986) have carried out the study in the Western ghat region and have stimated the biomass based on dry weight of large number of tree. Kaul (2010), Chauhan et al

(2015) and Sharma et al (2016) emphasized on the reforestation and sustainable afforestation which would minimize the accumulation of carbon dioxide in the atmosphere. Rangaswamy et al (2007) have studied on the estimation of leaf area index and above ground biomass in deciduous forests of western Ghat of Karnataka. Gavali and Shaikh (2013) have estimated the carbon storage in the trees of the Solapur University Campus. Concludes thatthe well managed vegetation likely to have greater impact of tree canopies. Nadia Castro Izagutre et al (2016) showed the increase in carbon stock with the increase in plant diversity but not with leaf area index. According to her, the Indian forests have the potential to create an additional carbon sinks by using marginal lands. The present study is on Thimmalapura reserve forest, a tropical dry deciduous forest of the Tumkur District, Karnataka to understand the role of tree diversity, richness and carbon assimilation. The area sites selected for enumeration of species for their biovolume, biomass, and carbon assimilation is based on rich biodiversity of the areas and will be the representative of the total forest area.

MATERIAL AND METHODS

Study area: Thimmalapura of Madhugiri taluk is 55 km from Tumakuru. It has a protected area officially known as 'Thimmalapura wildlife sanctuary and Thimmalapura Conserved Area, which falls under Madhugiri Reserve range of forest. The wildlife sanctuary is spread at 50.86 sq. km. and

protected area of 17.38 sq.km. Two hundreds hectares have been identified as medicinal plant rich area and conserved under Medicinal Plant Conservation Area scheme. The study area is located 23 km to the north east of Madhugiri town (Karnataka) and about 20 km to the west of Hindupur town (Andhra Pradesh). The geographical co-ordinates of the forest watch tower inside this area are 13° 44' 20" N and 7°19' 41" E. Survey of 2.5 hectares across the total forest area for the present study was undertaken to document the floristic richness, abundance, density, biovolume and carbon sequestration of the forest.

Climate and vegetation: The temperature varies from 8^{0}C in winter to a maximum of 43 ^{0}C in summer. The rainy season is from late June to mid-October with an average rainfall of 680 mm and about 65 rainy days in a year. Vegetation is dry deciduous type dominated by *Chloroxylon*, *Terminalia* and *Tamarindus*. Herbaceous flora becomes more prominent during rainy season and many species make their sporadic appearance. Climbers constitute about 7% of the total flora and predominantly obstructing the growth of many trees Seetharam et al (2018).

Sampling technique: 10 quadrats of 50 X 50m size were laid randomly covering about 2.5 hectares of the total 1700 hectares (17.38 sq. km.) protected area considering the richness of the flora to estimate the relative frequency, relative abundance, relative density of tree species. All the species located in 10 quadrats were recorded. The following parameters were calculated to estimate biomass such as aerial biomass, underground biomass, total biomass and also carbon content.

Tree height and diameter at breast height (DBH): To estimate biomass of different trees, non-destructive method was used. The biomass of trees was estimated on the basis of DBH and tree height by measuring tree girth at breast height (GBH), 1.3 meter from the ground. The GBHs of trees having diameter greater than 10 cm were measured directly by measuring tape. The height of the trees was measured by using Baumhoehenmesser an android application version 1.4.

Above the ground biomass (AGB): Above ground was calculated by multiplying the volume of biomass and wood density. The volume was calculated based on diameter and height. The wood density for the species was obtained from world agro forestry database (2016). Wherever the wood density of tree species was unavailable, the standard average value of 0.6 gm/cm^{3} was taken.

AGB (g) = volume of biomass (cm^{3}) × wood density (g/ cm^{3})

Below the ground biomass (BGB): This includes all biomass of live roots excluding fine roots having, less than 2 mm diameter. The below ground biomass (BGB) was calculated as:

BGB (g) = 0.26 × above ground biomass (ton)

Total Biomass (TB): Total biomass is the sum of the above and below ground biomass (AGB + BGB)

Carbon storage: It is calculated by dividing the biomass by 2 i.e. Biomass × 50% or Biomass/2

Soil analysis: Soil samples were collected from 5 different sites representing different types of vegetation. Collected samples were shade dried and evaluated for both micro and macro nutrients at Horticultural Station, Bengaluru and other soil profile studies were carried out in the Vriksha Vijnan Pvt. Ltd. by standard method (Kanwar and Chopra 1982). Soil samples were made to free from organic matters by treating with hydrogen peroxide to oxidize all organic matters. The obtained soil was used to separate coarse sand, fine sand and silt and clay.

Separation of coarse sand: To soil sample, known quantity of 0.2N HCl and 1% CaCO$_3$ were added and make the volume to 250 ml by adding distilled water. After few minutes of incubation, the solution was filtered using Whatman filter paper No 1. Treated soil sample was air dried. The dried soil was sieved using a mesh size of 0.2mm to separate coarse sand. Thus obtained coarse sand was weighted and the values were recorded.

Separation of fine sand: The soil suspension is diluted by adding 1000 ml of distilled water and 10mL of NaOH. The suspension was vigorously shaken and left over night for sedimentation. The sediment was taken and diluted with water and allowed it to sediment. The sediment was taken and dried at 100 $^{\circ}$C and weigh was recorded.

Separation of clay and silt: The turbid soil suspension contains clay and silt, which is filtered and dried at 100^{0}C to obtain a known weight of clay and silt was recorded.

Soil pH: A known quantity of soil from a depth of 1 foot below the surface of the earth was dissolved in known quantity of water and stirred well. Field pH meter was used to determine the pH of the soil.

Relative Humidity (RH) of the forest: Digital RH meter (Hygrometer) was used to know the RH of the study area and recorded.

Water holding capacity of soil: It was estimated by using earthen pot filled with known amount of soil sample and pouring water to saturation and the pot was allowed to drain out excess water. Weight of the pot with soil and water was recorded. The same is dried in an oven for overnight at 70 $^{\circ}$C and the dry weight was recorded. The difference of pot with wet soil and pot with dry soil was taken. Difference would give the water holding capacity of the soil.

Qualitative determination of carbonates: Test for carbonates was conducted by treating the soil samples from

5 different sites by using HCl. The intensity of effervescences as the determinants of carbonates was noted.

Quantitative estimation of mineral nutrients: Estimation of mineral nutrients such as Na_2CO_3, N P K and Zn, Cu, Mn, and Fe was carried out at Biotechnology center at Hulimavu, Bengaluru.

Frequency: The frequency of a species in a given area is studied by quadrat method and is calculated as:

$$Frequency = \frac{Number\ of\ quadrats\ in\ which\ species\ occurred}{Total\ number\ of\ quadrats\ studied} \times 100$$

Density: Density is expressed as trees per hectare

Density =Total number of individuals of each species/Total area studied

Relative Density: The density for each species was expressed:

$$Relative\ density = \frac{Total\ number\ of\ individuals\ of\ the\ species}{Total\ number\ of\ individuals\ of\ all\ the\ species} \times 100$$

Abundance: It is also calculated like density but in this case, only those quadrants are considered for calculation where a species actually occurs.

$$Abundance = \frac{Total\ number\ of\ individuals\ of\ a\ species}{Total\ number\ of\ quadrats\ in\ which\ species\ occurred}$$

Dominance: Basal area: 0.005454xDBH

Diversity: Diversity is a mathematical measures of species richness and evenness (sometimes known as equitability) and it shows how equally abundant the species are.

Diversity Index: Two indices were calculated for estimating the plant diversity. Simpson and Shannon Weiner indices. Natural log was calculated using the online log calculator. The vegetation data were analyzed for frequency (F), density (D) and abundance (A). The Importance Value Index (IVI) was computed for all the tree species by adding the relative values of frequency, density and dominance (basal area).

Shannon Diversity Index: It assumes that individuals are randomly sampled from an indefinitely large population and the index also assumes that all species are represented in the sample and estimated as:

H' = - Pi ln Pi, Where Pi is the proportional abundance of ith species = (ni/N), ni = the number of individuals in the i species and N = the total number of individuals.

Simpson's Index: gave the probability of any two individuals drawn at random from an indefinitely large community belonging to different species. This index is referred to as dominance index since it weighted towards the abundance of the commonest species rather than providing a measure of species richness (Simpson 1949).

$$1-D = \frac{n\ (ni-1)}{N\ (N-1)}$$

Importance Value Index (IVI): The IVI is statistical measure, which gives an overall picture of the importance of the species in the vegetation community.

IVI = Relative density + Relative frequency + Relative dominance

RESULTS AND DISCUSSION

Carbon assimilation: There are 286 individuals belonging to 56 tree species and 44 genera in the sample (Table 1). The average carbon assimilation of the study area is around 3015 g of carbon per tree with a total carbon assimilation of 1658550 g. *Chloroxylon swietenia* has the highest amount of carbon assimilation (88420 g/sp) as compared to other species. *Cassia fistula* accumulates lowest carbon of 399 g/tree. Above groung biomass constitutes major part of the biomass. Among the 56 species studied *Terminalia bellerica* has 21600g/tree of aerial biomass as compared to other species. Average aerial biomass of the sampled area is 4645g/tree and the total aerial biomass of the study area is 255501 g/tree. Below ground biomass is mainly comprises root system. Of the species studied *Terminalia bellerica* has the maximum below ground biomass of 5616 g/tree. Minimum below ground biomass with 179.71g/tree iwas produced by a small tree of *Mundelea sericea*. Total underground biomass produced in the sampled plot is 72358 g/tree with an average of 1315 g/tree . Total biomass of the area is 328812 g with average biomass of 5978 g/tree. *Terminalia bellerica* has the highest amount of total biomass of 21600 g and. *Mundelea sericea* the lowest total biomass (498g). Pearson's correlation studies on total number of individuals and carbon stock in each species showed a positive correlation. Similarly the correlation of carbon stock and wood density of species also shows positive correlation so also and total biomass and carbon assimilation also indicated the same trend (Fig. 6).

There are 17 species in the study area (Table 2) whose carbon stock ranges from 12,666g/sp. to 88, 420g/sp. *C. swietenia* with 57 individuals has this large carbon stock of 88,420 g but the individually it has only 1551g/tree. *C. arborea* with lone individual in the sampled area has carbon stock of 12701g/tree/sp. It indicates that as an individual *C. arborea* has ability to assimilate more of carbon than other species. Similarly *S. urens* with 2 individuals has total carbon stock of 21772g/sp. individually it has 10886g/tree. Like *C. arborea* it has high assimilation ability too. Afforestation with such high assimilation ability species such as *C. arborea* and *S. urens* would reduce carbon dioxide in the atmosphere.

pH of the study area: pH is acidic in 4 of 5 quadrats, neutral pH was in the 5th quadrat. According to Songbai et al (2018) soil pH regulates biogeochemical process and also has an effect on ecosystem. Similar observations are made in
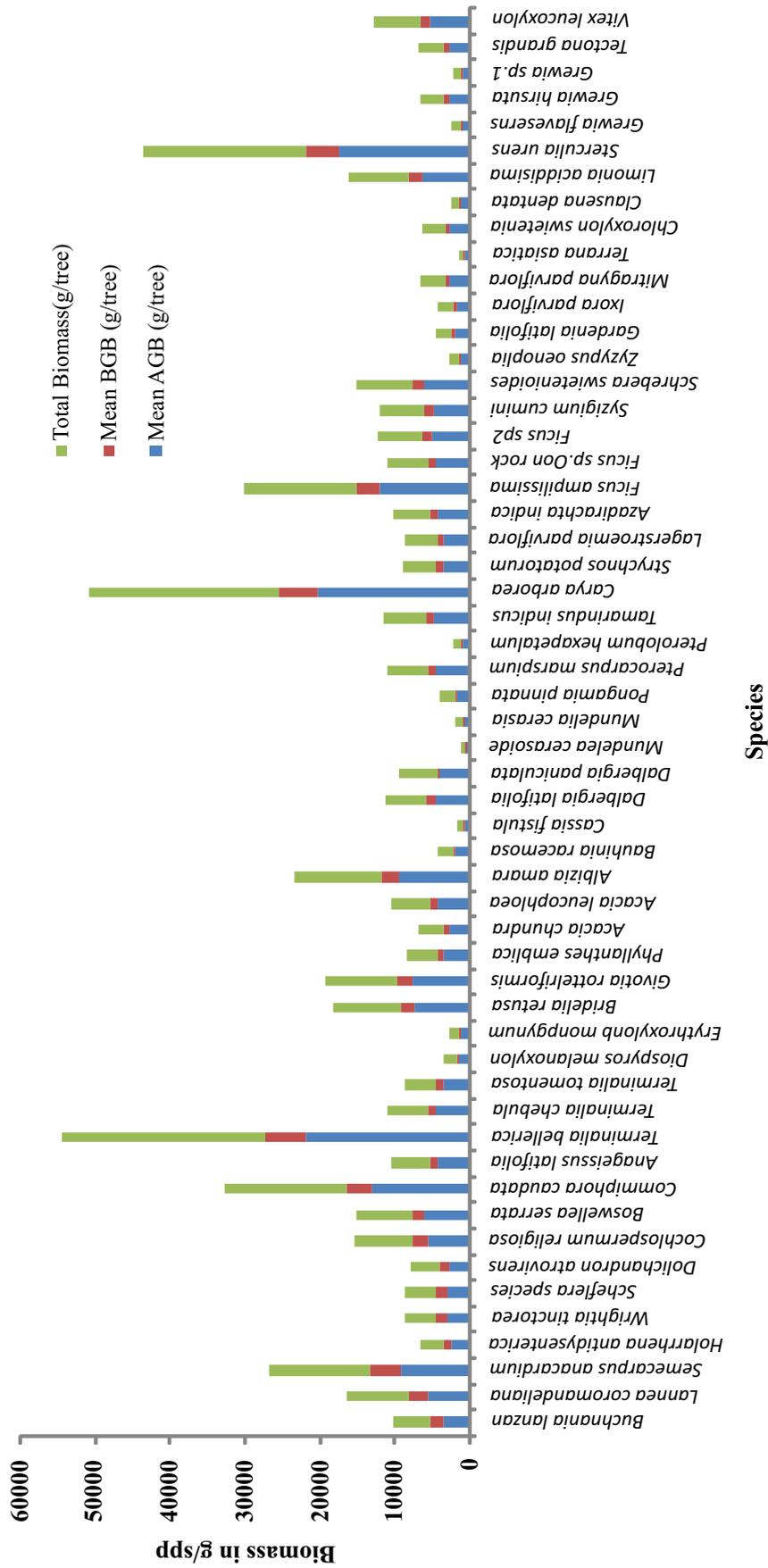
Fig. 1. Mean below ground, above ground and total biomass of the species of Thimmalapura Reserve Forest
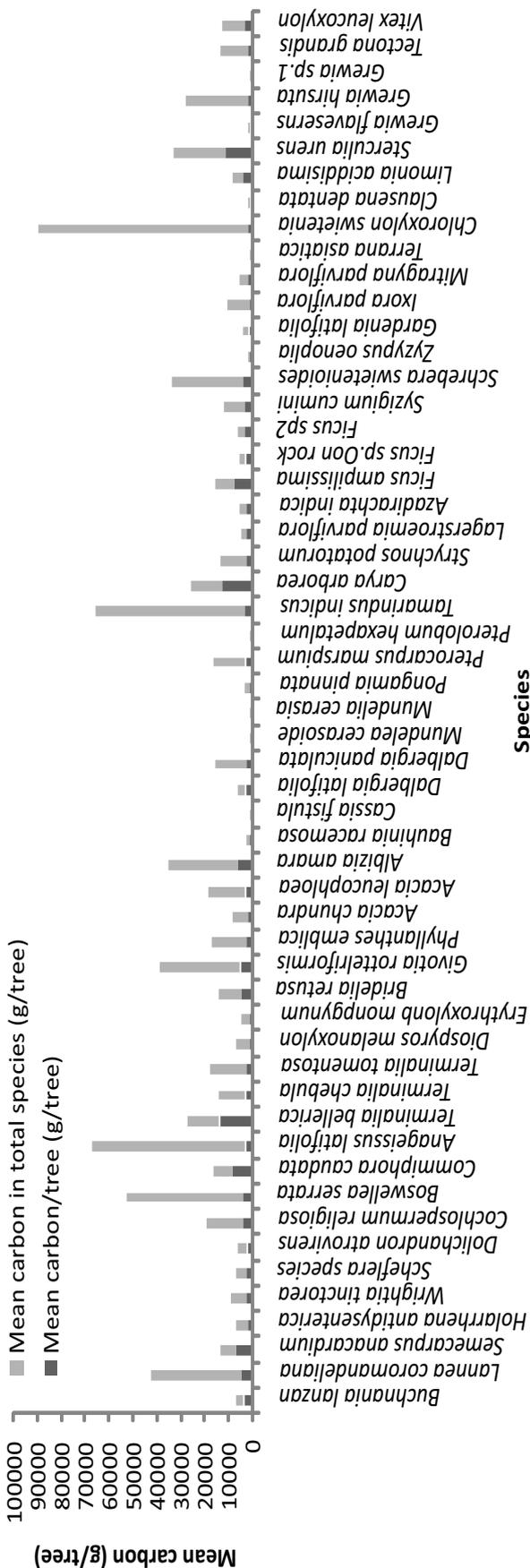
Fig. 2. Mean carbon in total species and mean carbon per tree in Thimmalapura reserve forest

Karpakapalli (Bidar) and Sandur (Bellary) forests of Karnataka.

Soil analysis: Soil of Thimmalapura is red clay with 92g of coarse sand, 2g of fine sand and 6g of clay silt. The pH of soil was 6.84 to 7.13.

Water holding capacity of the soil: The water holding capacity of the soil of Thimmalapura forest at different altitude (900m to 925m) ranged from 0.05 to 11%.

Organic nutrients: Out of 5 samples tested for foam, 4 samples showed less foam indicating lower amounts of carbonates where as sample 4 indicated the rich carbonates. NPK was 0.52, 21.0 and 141.0 kg acre^{-1} respectively. Sodium carbonate was 0.08 kg acre^{-1}, zinc 1.02, copper 0.16, manganese 2.16 and ferrous 3.48 ppm respectively.

There are nine different girth classes could be recognized viz. 1-10, 11-20, 21-30,31-40, 41-50, 51-60, 61-70, 71-80 and >80cm. Among these classes, 11-20cm girt class included maximum (66) individuals and class 1-10 cm minimum (22) individuals. The girth class 21 to 30 cm girth includes most of the dominant species such as *A. latifolia* and *C. swietenia*. They also come under the girth classes of 31-40 and 41 to 50 cm. Another dominant species *T. indica* comes under the girth class 41 to 50 and 51-60cm. A few of the individuals of *T. indica* with maximum girth of 138cm, 240cm and 400cm were observed in few plots. *C. caudata* is one of the dominant species often as pure community in some part of the forest has a girth more than 150 cm. Similarly, *B. serrata* another dominant member has few stands reaching the girth of 125 to 130cm. A few stands of *T. bellerica*, reaching the girth of 150cm are seen sporadically in the forest (Fig. 3)

Family importance value (FVI): There 42 families and 107 species were identified in 10 quadrats. However, there are few more species not encountered in the sampled area. In terms of number of species, there are top 10 families with high importance value (HIV). They are Fabaceae with 18 species with HIV of 75.29, Poaceae with 7 species and family importance value of 39.29, Combretaceae with 4 species and FIV of 18.79 followed by Euphorbiaceae, Burseraceae, Rubiaceae, Asclepiadaceae Anacardiaceae and Verbenaceae .

Diversity study showed that the vegetation has a Simpson index of 0.045. It is a very high index value indicating the richness of species. 45 pairs of species out of 100 are considered for diversity, composed of different species. The richness of species and domination of few species such as *C. swietenia*, *T. indica* and *A. latifolia* was onserved. Shannon Weiner diversity index also shows the richness of the vegetation with H value of 3.45 and H max value of 4.71. Equitability also shows 0.73 indicating even/

Table 1. Species number, carbon sequestration, aerial, underground and total biomass and by trees of Thimmalapura protected forest area, Tumakuru

Species Name	No. of individual	Mean AGB (g tree^{-1})	Mean BGB (g tree^{-1})	Total biomass (g tree^{-1})	Mean carbon (g tree^{-1})	Mean carbon in total species (g/species)
Acacia chundra	4	2637.00	685.62	3322.62	1661.31	6645.24
A. leucophloea	6	4137.60	1075.77	5213.37	2606.68	15640.12
Albizia amara	5	9227.52	2399.15	11626.7	5813.34	29066.74
Anageissus latifolia	25	4117.2	1070.47	5187.67	2593.83	64845.90
Azadirachta indica	1	4032.00	1048.32	5080.32	2540.16	2540.16
Bauhinia racemosa	1	1692.00	439.92	2131.92	1065.96	1065.96
Boswellia serrata	13	5975.07	1553.52	7528.59	3764.29	48935.87
Bridelia retusa	2	7200.00	1872.00	9072.00	4536.00	9072.00
Buchnania lanzan	1	3456.00	1613.00	5069.00	3341.00	3341.00
Careya arborea	1	20160.00	5241.60	25401.60	12701.00	12701.00
Cassia fistula	1	633.60	164.74	798.34	399.17	399.17
Chloroxylon swietenia	57	2462.17	640.21	3102.42	1551.23	88420.03
Clausena dentata	1	972.00	252.72	1224.72	612.36	612.36
Cochlospermum religiosa	4	5310.00	2310.35	7620.35	3810.05	15240.20
Commiphora caudata	1	12960.00	3369.60	16329.60	8164.80	8164.80
Dalbergia latifolia	1	4435.20	1153.15	5588.35	2794.18	2794.18
D. paniculata	5	4021.20	104.51	5066.71	2533.35	12666.78
Diospyros melanoxylon	7	1286.74	332.12	1621.30	810.64	5674.52
Doliochandron atrovirens	2	2664.00	1243.00	3907.00	1953.00	3906.00
Erythroxylon monogynum	5	1069.92	278.17	1348.09	674.04	3370.24
Ficus ampilissima	1	11880.00	3088.80	14968.80	7484.40	7484.40
Ficus spp.	1	4860.00	1263.60	6123.60	3061.80	3061.80
Ficus sp.(On rock)	1	4320.00	1123.20	5443.20	2721.60	2721.60
Gardenia latifolia	2	1764.00	458.64	2222.64	1111.32	2222.64
Givotia rotteliformis	7	7620.68	1981.37	9602.06	4801.03	33607.21
Grewia flaveserns	1	921.60	239.61	1161.21	580.60	580.60
G. hirsute	16	2596.72	675.15	3271.88	1635.96	26175.44
Grewia spp.	1	828.00	215.28	1043.28	521.64	521.64
Holarrhena antidysenterica	3	2232.00	1041.33	3273.33	1636.66	4910.00
Ixora parviflora	9	1661.64	432.11	2093.81	1046.91	9422.23
Lagerstroemia parviflora	1	3384.00	880.00	4264.00	2132.00	2132.00
Lannea coromandeliana	8	5537.25	2581.50	8121.27	4699.67	37597.36
Limonia aciddisima	1	6336.00	1647.36	7983.36	3991.68	3991.68
Mitragyna parviflora	2	2520.00	655.20	3175.20	1587.88	3157.76
Mundelea cerasoide	2	396.00	102.96	498.96	249.48	498.96
M. sericea	1	691.20	179.71	871.00	435.50	435.50
Phyllanthes emblica	7	3322.97	857.54	4186.94	2093.47	14652.30
Pongamia pinnata	2	1530.00	397.80	1927.84	963.92	1927.84
Pterocarpus marsupium	5	4337.28	1127.69	5464.97	2732.48	13662.44
Pterolobium hexapetalum	1	792.00	206.00	998.00	499.00	499.00
Scheflera spp.	2	2916.00	1360.50	4276.50	2138.00	4276.00
Schrebera swietenioides	8	5976.00	1553.76	7529.76	3764.88	30119.04
Semecarpus anacardium	1	9072.00	4233.00	13305.00	6652.00	6652.00
Sterculia urens	2	17280.00	4492.80	21772.80	10886.40	21772.80
Strychnos potatorum	5	3463.20	900.43	4363.63	2181.81	10909.08
Syzigium cumini	3	4752.00	1235.52	5987.52	2993.76	8981.28
Tamarindus indicus	22	4548.92	1182.72	5731.65	2865.89	63049.66
Tectona grandis	7	2621.31	681.54	3302.85	1651.42	11559.99
Terminalia bellerica	1	21600.00	5616.00	27216.00	13608.00	13608.00
T. chebula	4	4320.00	1123.20	5443.20	2721.60	10886.40
T. tomentosa	7	3424.11	890.26	4314.38	2157.19	15100.34
Terrana asiatica	2	544.50	141.60	686.10	343.05	686.10
Vitex leucoxylon	3	5043.60	1311.33	6354.93	3177.46	9532.34
Wrightia tinctorea	3	2922.00	1363.33	4285.33	2142.66	6428.00
Zyzypus oenoplia	1	1036.80	270.00	1306.80	653.40	653.40

Table 2. Species of Thimmalapura reserve forest with high carbon stock

| Species	Individuals	Total carbon/sp	Carbon/tree
Chloroxylon swietenia	57	88420	1551
Anogeissus latifolia	25	64845	2593
Tamarindus indica	22	63049	2865
Boswellia serrata	13	48975	3764
Lannae coramendeliana	8	37597	4699
Givotia rottleriformis	7	33607	4801
Schrebera swieteniodes	8	30119	3764
Albzia amara	5	29066	5813
Grewia hirsuta	16	26175	1635
Sterculia urens	2	21772	10886
Acacia leucophloea	6	15640	2606
Cochlospermum religiosum	4	15240	3810
Terminalia paniculata	7	15100	2157
Pterocarpus marsupium	5	13662	2732
Careya arborea	1	12701	12701
Dalbergia paniculata	5	12666	2533
Strychnos potatorum	5	10909	2181
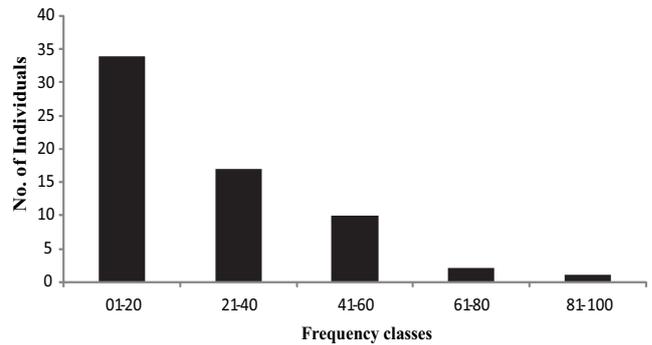
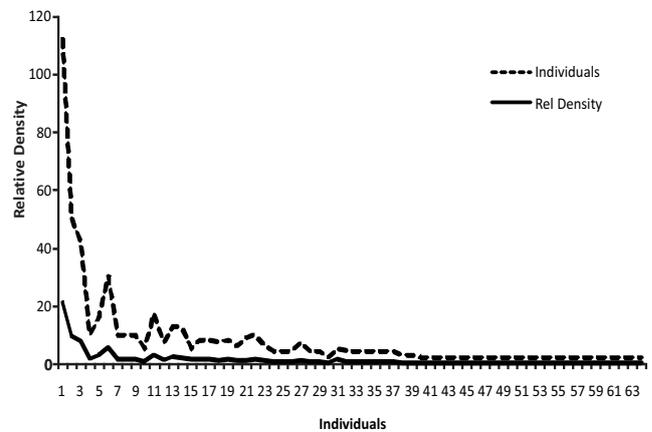**Fig. 5.** Frequency classes and total number of individuals

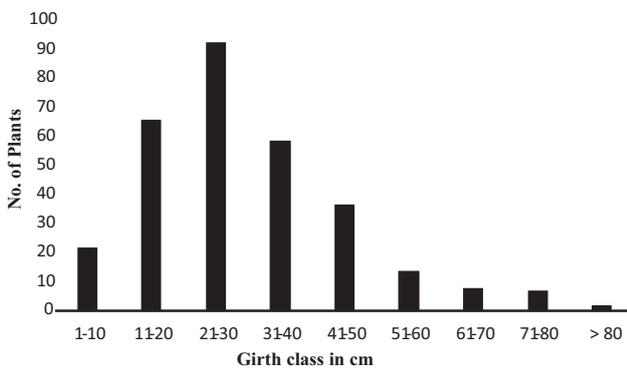**Fig. 6.** Pearson's correlation coefficient (0.998)

Fig. 3. Plants belonging to different girth class
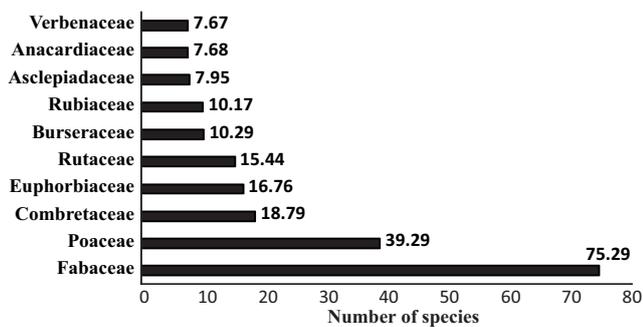

Fig. 4. Importance value of the species

equitable distribution of species. An average number of individuals per species is 22.5 unit and an average area occupied by a species is 409 m^2 (Fig. 4).

Frequency and relative frequency: There are 64 woody species recorded from the sampled area, spread across six Rauknier frequency classes A-E. Out of 64 species and 524 individuals, 34 species are in the lowest frequency class of 1-20%. They are reported from 2 out of 10 quadrats studied with 106 individuals. Whereas, 17 species comes in the second category with 21-40 % frequency occur in 4 quadrats of 10 with 106 individuals. There are 10 species occurring in third frequency class ranging from 41 to 60 % frequency has 183 individuals. There are only two species in the frequency range of 61 to 80 % represented by *A. amara* and *G. latifolia*. Last frequency range 81-100% frequency has a lone species namely *C. swietenia* with 112 individuals occurring in all the 10 quadrats studied. Among the woody species, *Chloroxylon*, *Anogeissus* and *Tamarindus* constitute the dominant genera and form an association in the forest of Thimmalapura (Fig. 5).

Correlation studies on individuals and relative density: Pearson's Correlation studies showed a very strong positive correlation exists between the number of individuals and the relative density of species (Fig. 6).

Table 3. Relative density, relative dominance and relative frequency of tree species and species importance value

Species	No of individuals	Quadrats	Frequency	Rauknier	Density	Abundance	Relative density	Relative frequency	Relative dominance	SIV
Acacia chundra	4	2	40	B	0.4	2.0	1.17	1.88	0.016	3.06
A. leucophloea	6	3	60	C	0.6	3.0	1.76	2.70	0.024	4.48
Aegle marmelos	1	1	20	A	0.1	1.0	0.29	0.90	0.004	1.19
Albizia amara	5	4	80	D	0.5	1.2	4.41	3.60	0.020	8.03
Angeissus latifolia	25	3	60	C	2.5	83.0	7.35	2.70	0.100	10.10
Azadirachta +T. indica	1	1	20	A	0.1	1.0	0.29	0.90	0.004	1.19
Bauhinia racemosa	1	1	20	A	0.1	1.0	0.29	0.90	0.004	1.19
Boswellia serrata	13	2	40	B	1.3	6.1	3.82	1.88	0.052	5.75
Bridelia retusa	2	2	40	B	0.2	1.0	0.50	1.88	0.008	2.38
Buchnania lanzan	10	1	20	A	1.0	10.0	2.94	0.90	0.019	3.85
Careya arborea	1	1	20	A	0.1	1.0	0.29	0.90	0.004	1.19
Cassia fistula	1	1	20	A	0.1	1.0	0.29	0.90	0.004	1.19
Chloroxylon swietenia	56	5	100	E	5.6	11.5	16.40	4.50	0.224	21.10
Clausena dentata	1	1	20	A	0.1	1.0	0.29	0.90	0.004	1.19
Cochlospermum religiosa	4	2	40	B	0.4	1.0	1.17	1.88	0.016	3.06
Commiphora caudata	1	1	20	A	0.1	1.0	0.29	0.90	0.004	1.19
Dalbergia latifolia	1	1	20	A	0.1	1.0	0.29	0.90	0.004	1.19
D. paniculata	5	1	20	A	0.5	5.0	1.47	0.90	0.020	2.39
Diospyros melanoxylon	7	1	20	A	7.0	7.0	2.00	0.90	0.028	2.92
D. montana	1	1	20	A	0.1	1.0	0.29	0.90	0.004	1.19
Dodonea viscosa	2	2	40	B	0.2	1.0	0.50	1.80	0.008	2.30
Doliochandron atrovirens	2	2	40	B	0.2	1.0	0.50	1.80	0.008	2.30
Erythroxylum monogynum	5	2	40	B	0.5	2.5	4.40	1.80	0.020	6.22
F. ampilissima	5	1	20	A	0.5	5.0	4.40	0.90	0.020	5.32
F. arnotiana	2	1	20	A	0.2	2.0	0.50	0.90	0.008	1.40
Ficus spp.On rock	1	1	20	A	0.1	1.0	0.29	0.90	0.004	0.29
Ficus spp.	1	1	20	A	0.1	1.0	0.29	0.90	0.004	1.19
Gardenia latifolia	2	1	20	A	0.2	2.0	0.50	0.90	0.008	1.40
G. resinifera	4	4	80	D	0.3	1.0	0.88	3.60	0.016	4.49
Givotia rotteliformis	8	3	60	C	0.8	2.6	2.35	2.70	0.032	5.08
Gmelina asiatica	2	1	20	A	0.2	2.0	0.50	0.90	0.008	1.40
Grewia flaveserns	17	1	20	A	1.7	17.0	5.00	0.90	0.068	5.96
G. hirsuta	15	3	60	C	1.5	5.0	4.40	2.70	0.060	7.16
Grewia spp.	1	1	20	A	0.1	1.0	0.29	0.90	0.004	1.19
Holarrhena antidysenterica	3	2	40	B	0.3	1.5	0.80	1.80	0.012	2.61
Ixora parviflora	9	2	40	B	0.9	4.5	2.64	1.80	0.036	4.47
Lagerstroemia parviflora	1	1	20	A	0.1	1.0	0.29	0.90	0.004	0.29
Lannea coromandeliana	8	3	60	C	0.8	2.5	2.35	2.70	0.032	5.08
Limonia aciddisima	1	1	20	A	0.1	1.0	0.29	0.90	0.004	1.19
Mitragyna parviflora	2	1	20	A	0.2	2.0	0.50	0.90	0.008	1.40
Mundelia cerasia	12	2	40	B	1.2	6.0	3.50	1.80	0.048	5.34
Ochna obtusa	1	1	20	A	0.1	1.0	0.29	0.90	0.004	1.19
Phyllanthus emblica	7	3	60	C	0.7	2.5	2.00	2.70	0.028	4.72
Pongamia pinnata	2	1	20	A	0.2	2.0	1.50	0.90	0.008	2.40
Premna tomentosa	3	1	20	A	0.3	3.0	0.88	0.90	0.012	1.79
Pterocarpus marspium	5	2	40	B	0.5	2.4	4.40	1.80	0.020	6.22

Cont...

P. hexapetalum	2	2	40	B	0.2	1.0	0.50	1.80	0.008	2.30
Scheflera species	2	1	20	A	0.2	2.0	0.50	0.90	0.008	1.40
Schrebera swietenioides	4	1	20	A	0.4	4.0	1.17	0.90	0.016	2.08
Securniga virosa	1	1	20	A	0.1	1.0	0.29	0.90	0.004	1.19
Semecarpus anacardium	1	1	20	A	0.1	1.0	0.29	0.90	0.004	1.19
Sterculai urens	2	2	40	B	0.2	1.0	0.50	1.80	0.008	2.30
Strychnos potatorum	5	2	40	B	0.5	2.5	4.40	1.80	0.020	6.22
Syzigium cumini	3	2	40	B	0.3	1.5	0.88	1.80	0.012	2.69
Tamarindus indicus	21	3	60	C	2.1	7.0	6.17	2.70	0.084	8.95
Tectona grandis	5	3	60	C	0.5	1.5	4.40	2.70	0.020	7.12
Terminalia bellerica	1	1	20	A	0.1	1.0	0.29	0.90	0.004	1.19
T. chebula	4	2	40	B	0.4	2.0	1.17	1.80	0.016	2.98
T. tomentosa	7	2	40	B	0.7	3.5	2.00	1.80	2.050	5.85
Terrana asiatica	1	1	20	A	0.1	1.0	0.29	0.90	0.290	1.48
Vitex leucoxylon	3	1	20	A	0.1	3.0	0.88	0.90	0.012	1.79
Wrightia tinctorea	8	3	60	C	0.3	2.6	2.35	2.70	2.340	7.39
Ziziphus nummularia	1	1	20	A	0.1	1.0	0.29	0.90	0.290	1.48
Zyzypus oenoplia	3	3	60	C	0.3	1.0	0.88	2.70	0.012	3.59

Total density= 1.36 plants/m^2 and total frequency = 11.1 plants sp/quadrat

Table 4. Floristic diversity and diversity indices

Area m^2	No. of species S (G>15 cm)	No. of individuals N(N-1)	Number of Individual/species	An average area occupied by a species	Simpson's index 1-D	Shanon weiner index
25,000	64	331	22.5	409 m^2	0.045	H= 3.45546 H max 4.71849 E= 0.73232

Total 525 individuals of 64 species can be grouped in 5 categories based on the number of individuals: 1-10, 11-20 21- 30, 41 - 50 and 112. The very strong positive correlation exists between them. Higher relative density value corresponds with large number of individuals.

Species value index (SIV): There are 64 woody species in the study area with 525 individuals. Of which, *C. swietenia* was the most dominant species with more number of individuals (56) and high relative dominance, relative density and relative frequency and also species Index value of 26. Other dominant species are *Anogeissus latifolia* with SIV of 12 followed by *Tamarindus indica* (SIV 10) *W. tinctoria* (SIV 08) and *G. hirsuta* (SIV 08) *A. amara* with SIV 05. These species with relatively large number of individuals makes the dominant components of the vegetation. Remaining species have the SIV ranging from 0.3 to 4. Of the tree species under study, 29 species with compound leaf and 25 with simple leaf. There exists a positive correlation with more of carbon stock in plants with compound leaves than with simple leaves. Since the total leaf area of compound leaf is more than the leaf area of simple leaves.

Jithili and Prasadan (2018) have shown an average carbon sequestration of trees of Wayanaad region is 50,319 t/tree and the total carbon assimilation is 138367 t yr^{-1} and highest of 33709 kg yr^{-1} in *Artocarpus heterophyllus* and lowest in *Spondias pinnata*. *Melia azadirach* has the highest potential of carbon assimilation. They have seen the positive correlation of number of individuals, DBH and carbon assimilation. In Thimmalapur forest, *Carya arborea* with a lone representative in the sampled area has high carbon assimilation potential of 12701 g tree^{-1}. The average carbon assimilation of the sampled area of the forest is 1658550 g. More (57) number of individuals of *Chloroxylon swietenia* contribute to assimilation of carbon 88420.02g/sp., followed by *Tamarindus indica* (63049.65 g/sp.) and others. There exists a positive correlation of number of individuals, DBH and carbon assimilation in Thimmalapur forest also like in Wayanaad region.

CONCLUSION

The forest of Thimmalapura is one of rich plant diversity areas of Tumkur district. It has 17 species which can sequester more of carbon from the atmosphere. Species like *Chloroxylon swietenia*, *Anogeissus latifolia*, *Tamarindus indica* and *Boswellia serrata*. should be propagated in large number so that they can sink more carbon from their surrounding areas. In addition to carbon assimilation they can hold good amount of soil water and thus prevent soil

erosion. Further conservation and afforestation measures would enhance the capacity of the Thimmalapura forest to sink more carbon. Hence, these remedies will enhance good quality of atmosphere and mitigate ascending climate change for good. Conservation of documented plants of Thimmalapura Reserve forest will also help in maintaining true structural and functional architecture of the natural area.

REFERENCES

Chauhan SK, Sharma R, Singh B and Sharma SC 2015. Biomass production, carbon sequestration and economics of on-farm poplar plantations in Punjab, India. *Journal of Applied and Natural Science* **7**(1): 452-458.

Gavali RS and Shaikh HMY 2013. Estimation of carbon storage in the tree growth of Solapur University campus, Maharashtra, India. *International Journal of Science and Research* **5**(4): 2365-2367.

Jithila PJ and Prasadan PK 2018. Carbon sequestration by trees – A study in the Western Ghats, Wayanad region. *Indian Journal of Ecology* **45**(3): 479-482.

Mani S and Parthasarathy N 2007. Above-ground biomass estimation in ten tropical dry evergreen forest sites of peninsular India. *Biomass and Bioenergy* **31**: 284-290.

Kaul M 2010. *Carbon budgets and carbon sequestration potential of Indian forests.* Ph. D. dissertation, Wageningen University, Wageningen, NL.

Nadia Castro-Izaguirre, Xiulian Chi, Martin Baruffol, Zhiyao Tang, Keping Ma, Bernhard Schmid and Pascal A Niklaus 2016. Tree diversity enhances stand carbon storage but not leaf area in a subtropical forest. https://doi.org/10.1371/ journal. pone.0167771

Rai SN and Proctor J 1986. Ecological studies on four rainforests in Karnataka, India I. environment, structure, floristic and biomass. *Journal of Ecology* **74:** 439-454.

Rangaswamy M, Vyjayanthi N and Chandrashekar Jha 2007. Estimations of LAI and above ground biomass in deciduous forests: Western Ghats of Karnataka, India. *International Journal of Applied Earth Observations and Geoinformations* **10**: 211-219.

Seetharam YN, Kotresha K, Vijay Danapur, Mouna S and Ramalinge Gowda 2018. *Plants of Siddarabhetta and Thimalapura forests Tumkur District, Karnataka*. Published by Karnataka Forest Department, Tumakur Division, Tumkur, pp. 100.

Sharma R, Chauhan SK and Tripathi AM 2016. Carbon sequestration potential in agroforestrey system in India: An analysis for carbon project. *Agroforestry Systems* **90:** 631-644.

Songbai Hong, Shilong Piao, Anping Chen, Yongwen Liu , Lingli Liu, Shushi Peng, Jordi Sardans, Yan Sun Josep Peñuelas and Hui Zeng 2018. A*fforestation neutralizes soil pH. Nature Communications* **9**: 520.

UNFCCC Fact sheet: Reducing emissions from deforestation in developing countries: approaches to stimulate action http://unfccc.int/files/press/backgrounders/application/ pdf/fact_sheet_reducing_emissions_from_deforestation.pdf (Date of access: 09/05/2017) (2011).

Machine Learning Based Modelling of Human Panther Interactions in Aravalli Hills of Southern Rajasthan

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Abstract: Conserving keystone species of any ecosystem requires scientific knowledge of their habitat and interaction amongst wildlife especially the top predators. The wildlife managers are facing problems in the protection and conservation of the Indian Panthers due to continuous habitat loss and reduction in prey base. Modelling their habitat with certain parameters may provide better chances to protect and conserve Indian panthers in their natural habitat. In present study, habitat model is developed for Udaipur Wildlife (UW), Udaipur North UN) and Udaipur South (US) protected forest areas which include three wildlife sanctuaries to study different parameters related to habitat. It was observed that Random Forest Regression (RFR) is suitable where it is desired to predict the number of conflicts in a specific region given the type of conflict and other data (R^2 = 0.888). Only for US region, Decision Tree Regression (DTR) proved to be better predictor (R^2=0.897). The performance is derived from R^2 value between the actual and predicted value. Similarly, where it is desired to identify the number of major and minor mining leases given respective mining area and other data DTR outperforms RFR with better R^2 value (0.980). Machine learning is a branch of Artificial Intelligence (AI) which is used to study and develop system behaviour model. Machine learning modelling techniques used to design models which can be further predict vital system parameters with regards to Indian panther ecosystem. Present study supports further modelling of habitats of same kind of species via sample data management.

Keywords: Machine learning, Decision tree regression, Random forest regression, Indian panther, Wildlife conflicts.

Best conservation practices involve protecting the habitat of threatened species which requires habitat identification and species distribution in that particular region depending on its economic stability and future human needs. Protecting and conserving keystone predator species definitely helps in wildlife management and maintaining species diversity. (Gavashelishvili and Lukarevskiy 2008). Species survival in suitable areas is a function of fulfilment of their requirements (Nazeri et al 2010). Habitat suitability models are the basis of population viability analyses, restoration of ecosystems specifically broken food chains, re-introduction of species and analysing and reducing frequent conflicts of human with wildlife (Hirzel et al 2001). These models help in assessing ecological impacts of pollution and climate change, management of threatened species and spatial distribution of species (Guisanand and Thuiller 2005). Supervised learning for example by showing machines correct pairs of inputs and outputs it can be trained for collection and analysis of various data sets (Mohri et al 2012). Deep learning (LeCun et al 2015) allows computers to automatically extract multiple levels of abstraction from raw data which is inspired by the mammalian visual cortex (Hu et al 2015), deep convolutional neural networks (deep CNNs) are a class of feed forward DNs (LeCun et al 2015) in which each layer of neurons (to be "deep," three or more layers)

uses convolutional operations to extract information from overlapping small regions coming from the previous layers (Goodfellow et al 2016). DNNs have dramatically improved the state of the art in many challenging problems (Goodfellow et al 2016), including speech recognition (Deng et al 2013 and Bahdanau et al 2016), machine translation (Cho et al 2014 and Sutskever et al 2014) and image recognition (He 2016, Simonyan and Zisserman 2014).

Presence of various environmental parameters, wild habitat and wild species is predicted by an SVM (Support Vector Machine) classifier which is trained for different weighted values of all tags (Jeawak et al 2017, 2018) which exploited weighted values of all tags to train an SVM (support vector machine) classifier to predict the presence of various environmental phenomena including species. In looking at species distribution no distinction was made in (Jeawak et al 2017) between whether the species name was present or not and the focus was on the additional value that Flickr tags provide relative to scientific data such as climate and land cover. Machine learning enables analysis of large data which generally shows non-linear results in between various diverse and complex multiple variables, failing to stand up to the mark of common statistical methods and their assumptions (Valletta et al 2017). Machine learning modelling has been utilized to study anthropogenic stresses

and their combined spatio-temporal effects on wildlife. Machine learning technique Deep Convolution Neural Networks (DCNN) is utilized for the recognition of Snow Leopards, from a data set of photos taken in the wild with the use of Rectified Liner Units (ReLU) activation function in the fully connected layers and softmax function for classification showing an overall 91% accuracy, along with sensitivity of 0.90 and specificity of 0.88 for Snow Leopard class identification (Tariq et al 2018). Machine learning performance is very sensitive to positive data augmentation which involves careful augmentation of positive data by expert's thereby increasing positive performance prediction (Gurumurthy et al 2018). Work done related to wildlife conflicts (Sharma and Chishty 2018) acted as the base work for the present study which focuses to generate a machine learning model which can predict with more accuracy for sampling areas and areas outside sampling areas based on essential factors for survival of Indian panthers.

MATERIAL AND METHODS

Schematic system under observation consists of ecological components, stakeholders in the system such as villagers, farmers, miners, forest officials, and most importantly the panthers for the present study. The dotted line represents the ideal separation between the areas of operation of different stakeholders. The primary reason for the conflicts happening between different entities of the system is the violation of hypothetical separation boundary. While this is natural for panthers or other wildlife creatures to roam around for food and other necessities, the same is not true for miners, villagers etc. Because of excessive pressure to make profitable earnings, this boundary is violated repeatedly by both these entities. However, villagers or farmers have long been in harmony with the ecological system, the main source of conflicts seems to be the mining activity.

The present study focuses on AI modelling of the system on the basis of different temporal data. System data is collected over a period of time, and for different attributes (Fig. 2). This data is divided into 2 groups: a smaller data group for testing the model and a bigger data group for training the model. This ensures that model is not biased by any of the data attributes.

The training data is used to train the model with numerous iterations. Once all the iterations are performed, it gives a classifier in the form of a digital file (generally xml or hdf5 format). Before applying this classifier for further prediction or analysis, it is tested for its accuracy with the help of test data. If it performs well against some set threshold value, it is accepted.

There are various techniques in AI modelling based on the objectives. The whole modelling objective is divided into 2
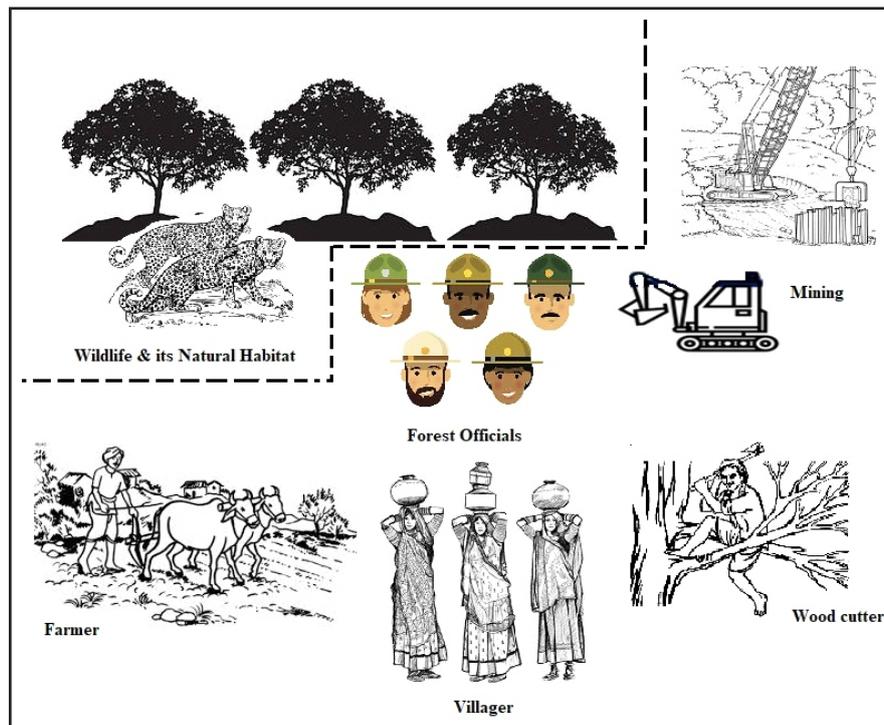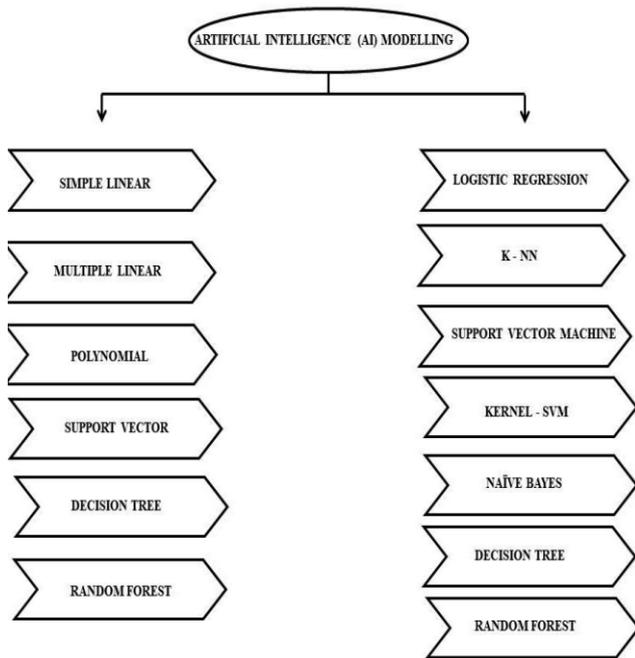

Fig. 1. System under observation

Fig. 3. AI Modelling techniques

types: regression and classification (Fig. 3). Based on the type of prediction, appropriate technique is selected. Regression models are used where it is required to predict some numerical value of a parameter. Classification models are used where the prediction is a label or class.

For the present analysis, regression-based modelling has been performed for prediction of key system parameter values and various data pre-processing tasks have to be performed before initiating the learning (training) process. These primarily include handling categorical data and feature scaling. Categorical data consists of categories or labels as input variables for regression rather than numerical values. This is taken care with the help of encoding. Feature scaling is yet another important operation which is performed when the Input/output variables have higher range differences in their respective values. Features value range is made uniform by eliminating mean and scaling to unit variance. By

Table 1. Dataset 1 (regional conflict)

Timeline (years) (2006-18)	Type	UN	US	UW	Total
4th	PCID	1	0	0	1
4th	PRO	0	0	0	0
5th	LUDIN	0	5	0	5
5th	HCID	0	3	1	4
5th	PCID	3	0	0	3
5th	PRO	0	0	0	0
6th	LUDIN	1	4	2	7
6th	HCID	0	1	3	4
6th	PCID	3	0	3	6
6th	PRO	0	0	0	0
7th	LUDIN	6	18	21	45
7th	HCID	1	2	15	18
7th	PCID	0	2	1	3
7th	PRO	0	1	0	1
8th	LUDIN	6	13	31	50
8th	HCID	0	2	0	2
8th	PCID	4	5	5	14
8th	PRO	0	1	0	1
9th	LUDIN	19	17	56	92
9th	HCID	1	2	0	3
9th	PCID	0	7	4	11
9th	PRO	1	1	0	2
10th	LUDIN	32	41	44	117
10th	HCID	1	7	0	8
10th	PCID	6	4	14	24
10th	PRO	4	1	0	5
11th	LUDIN	54	29	15	98
11th	HCID	1	4	0	5
11th	PCID	9	7	4	20
11th	PRO	0	0	0	0
12th	HCID	0	1	0	1
12th	LUDIN	5	2	0	7
12th	PCID	5	1	0	6
12th	PRO	2	2	0	4

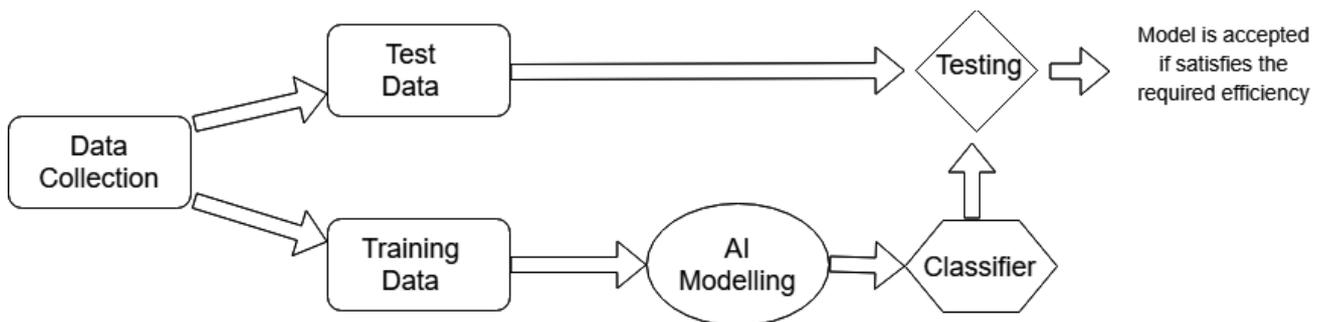There was no conflict for first 4 timelines

Fig. 2. AI modelling approach

computing relevant statistics for training data, average and variance are then applied on data. Also, decision tree and random forest regression are used here due to their better suitability in the present context. The software tools used for this analysis include python coding in Anaconda IDE, scikit-learn library, panda library. The simulation was performed on a GPU enabled laptop with Intel core i7 (7th gen) CPU, Windows 10.

RESULTS AND DISCUSSION

Model was developed after analysing dependence of output variable on remaining input variables. The variables are conflict type (categorical), regional conflicts number (numerical data) for Udaipur North (UN), Udaipur South (US) and Udaipur Wildlife (UW).Category nomenclature is: LUDIN (livestock uplifting/death/injury), HCID (human casualty/injury/death), PCID (panther casualty/injury/ death), and PRO (Panther Rescue Operation). This categorical data is taken care with the help of one-hot encoding. The output variable is chosen one at a time, and analysed with respect to remaining variables treating them as input variable. For considering number of conflicts happening in UN region as an output variable, and remaining variable as input variables (conflict type, US, UW, total conflicts), analysis is performed

Table 2. Dataset 2 (number and area of mining leases)

Timeline (in years) (2006- 2018)	Number of mining leases			Area of mining leases (in hectare)		
	Major mining number (a)	Minor mining number (b)	Total mining lease numbers (TN) (a) + (b)	Major mining area (c)	Minor mining area (d)	Total area (TA) (c)+(d)
1st	171	441	612	13793.79	475.1	14268.89
2nd	158	478	636	13240.36	529.61	13769.97
3rd	155	455	610	11852.84	522.35	12375.19
4th	161	463	624	11882.95	547.713	12430.66
5th	160	472	632	12341.62	585.285	12926.91
6th	169	480	649	12351.07	585.723	12936.8
7th	171	488	659	12154.06	603.54	12757.6
8th	189	543	732	12327.52	597.25	12924.77
9th	237	522	759	12635.58	618.25	13253.83
10th	11	715	726	6283.68	6151.85	12435.53
11th	10	698	708	6284.58	3677.998	9962.578
12th	19	701	720	7084.58	4677.998	11762.58

Table 3. Dataset-1 regression results (Feature scaling = YES, Test size = 25%)

Output variable	Input variables	Actual value	Predicted value		R^2 value	
			DTR	RFR	DTR	RFR
UN	US, UW, Conflict type	6	6	10	0.473	0.888
		0	0	0		
		0	1	1		
		32	54	41		
		5	4	3		
US	UN, UW, Conflict type	18	13	10	0.897	0.696
		0	0	0		
		3	2	2		
		41	29	20		
		1	1	1		
UW	US, UN, Conflict type	21	31	31	0.528	0.851
		0	0	0		
		1	0	1		
		44	15	30		
		0	3	2		

Table 4. Dataset-2 regression results (Feature Scaling = YES, Test size = 25%)

Output variable	Input variables	Actual	Predicted value		R^2 value	
			DTR	RFR	DTR	RFR
Major mining number	Minor mining number, major & minor mining area	160	171	170	0.980	0.330
		158	171	174		
		11	10	108		
Minor mining number	Major mining number, major & minor mining area	472	463	480	0.980	0.630
		478	463	467		
		715	698	598		

using Decision Tree (DT) regression and Random Forest (RF) regression. Similar is done for other 2 variables US and UW conflict numbers. Each of the three analysis so performed would yield a performance parameter based on how many correct predictions are made.

The variables for mining lease number for 2 mining categories (major/minor) on the basis of type of minerals, and their respective area in hectare. Major mining lease number (column a) was taken as an output and analysed with respect to data in column (b), (c), (d) & (TN). Similar is done in second iteration considering minor mining lease number (column b) as an output variable and column (a), (TN), (c), (d) as an input variable (Table 2).

CONCLUSION

Random Forest Regression (RFR) is suitable to predict the number of conflicts in a specific region given, the type of conflict and other data. Only for US region, Decision Tree Regression (DTR) proved to be better predictor. The performance is derived from R^2 value between the actual and predicted value. Similarly, for desired to identify the number of major and minor mining leases given respective mining area and other data, DTR outperforms RFR with better R^2 value. Such analysis could significantly help to track number of illegal mines also. This modelling is extremely useful in resource management as required by the agencies to mitigate the causes and effects of human wildlife conflicts and effective conservation of wildlife.

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REFERENCES

Bahdanau D, Chorowski J, Serdyuk D, Brakel P and Bengio Y 2016. End-to-end attentionbased large vocabulary speech recognition. *IEEE International Conference on Acoustics, Speech and Signal Processing* (ICASSP) (IEEE, New York).

Cho K, Bahdanau D, Bougares F, Schwenk H and Bengio Y 2014. Learning phrase representations using RNN encoder-decoder for statistical machine translation.*arXiv*:1406.1078

Deng L, Hinton G and Kingsbury B 2013. New types of deep neural network learning for speech recognition and related applications. Proceedings: *IEEE International Conference on Acoustics, Speech and Signal Processing* (ICASSP) (IEEE, New York).

Gavashelishvili A and Lukarevskiy V 2008. Modeling the habitat requirements of leopard *Panthera pardus* in west and central Asia. *Journal of Applied Ecology* **45**: 579-588.

Goodfellow I, Bengio Y and Courville A 2016. Deep Learning, *MIT Press*, Cambridge, MA.

Guisan A and Thuiller W 2005. Predicting species distribution: Offering more than simple habitat models. *Ecological Letter* **8**: 993–1009.

Gurumurthy S, Yu L, Zhang C, Jin Y, Li W, Zhang H and Fang F 2018. COMPASS '18, June 20–22, 2018, Menlo Park and San Jose, CA, USA

He K, Zhang X, Ren S and Sun J 2016. Deep residual learning for image recognition. Proceedings:*IEEE Conference on Computer Vision and Pattern Recognition* (CVPR) (IEEE, New York).

Hinton G, Deng L, Yu D, Dahl G, Mohamed AR, Jaitly N, Senior A, Vanhoucke V, Nguyen P, Sainath T and Kingsbury B 2012. Deep neural networks for acoustic modeling in speech recognition: The shared views of four research groups. *IEEE Signal Processing Magazine* **29**: 82-97.

Hirzel AH, Helfer V and Metral F 2001.Assessing habitat-suitability models with a virtual species. *Ecological Modeling* **145**: 111-121.

Hu W, Huang Y, Wei L, Zhang F and Li H 2015. Deep convolutional neural networks forhyper spectral image classification. *Journal of Sensors* **2015**: 1-10

Jeawak S S, Jones C B and Schockaert S 2017. Using Flickr for characterizing the environment: An exploratory analysis. In 13th International Conference on Spatial Information Theory, *COSIT 2017*, September 4-8, 2017, *L'Aquila*, Italy, pages **21**:1–21:13.

Jeawak SS, Jones CB and Schockaert S 2018.10th International Conference on Geographic Information Science (GIScience 2018). *Leibniz International Proceedings in Informatics Schloss Dagstuhl – Leibniz-Zentrum für Informatik*, *Dagstuhl Publishing*, Germany. Article No. **45**: pp. 45: 1–45:6

LeCun Y, Bengio Y and Hinton G 2015. Deep learning. *Nature* **521**: 436-444.

Mohri M, Rostamizadeh A and Talwalkar A 2012. *Foundations of Machine Learning, Series: Adaptive computation and machine learning. The MIT Press*, Cambridge, Massachusetts London, England.

Nazeri M, Jusoff K and Madani N 2010. Habitat models as a research gap in biodiversity conservation in tropical rain forest of Southeast Asia, Proceedings *International Congress on Environmental Modelling and Software Modelling for Environment's Sake*.

Sharma P and Chishty N 2018. Human-panther conflicts in the Aravalli hills of Southern Rajasthan-A case study. *Indian Journal of Ecology* **45**: 489-493.

Simonyan K and Zisserman A 2014. Very deep convolutional networks for large-scale image recognition.*arXiv*: 1409.1556.

Stock A, Haupt AJ, Mach ME and Michelid F 2018. Mapping ecological indicators of human impact with statistical and machine learning methods: Tests on the California coast. *Ecological Informatics* **48**: 37-47.

Sutskever I, Vinyals O and Le QV 2014. Sequence to sequence learning with neural networks. Proceedings: *Advances in Neural Information Processing Systems* (NIPS), Neural Information Processing Systems Foundation, La Jolla, CA.

Tariq N, Saleem K, Mushtaq M and Nawaz MA 2018. Snow Leopard Recognition Using Deep Convolution Neural Network. ICISDM '18 Proceedings of the 2nd *International Conference on Information System and Data Mining*, Lakeland, FL, pp. 29-33.

Valletta JJ, Torneya C, Kingsb M, Thorntonb A and Madden J 2017. Applications of machine learning in animal behaviour studies. *Animal Behaviour* **124**: 203-220.

Shift in Phenology of Some Dominant Tree species due to Climate Change in Mizoram, North-East India

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Abstract: Phenology (leaf fall, leaf emergence, flowering and fruiting) of six dominant tree species in semi-evergreen forest of Mizoram University Campus in Aizawl district of Mizoram, Northeast India were observed. The selected deciduous and evergreen tree species have exhibited marked phenological variations. Evergreen trees shed old leaves throughout the year and flush new leaves multiple times with peak period towards the end of dry season. However, the deciduous trees flush new shoots in the wet season after rain. Evergreen species observed flowering mostly after leaf flushing except for *Schima wallichii* where new shoots emerge simultaneously during flowering, while the deciduous species exhibited flowering soon after the leaf flushing. Most of the species exhibited a lengthy fruit maturation period extending up to five months except for *Callicarpa arborea* with brief and rapid fruit maturation. The flowering and fruiting time of the selected species were observed either advanced or delayed as compared to phenological status recorded in the flora of Lushai Hills in 1938. Hence, tree phenological observations with response to climate change are important to predict future impacts. Phenological observations from the present study would be significant towards *in-situ* and *ex-situ* conservation of the studied tree species.

Keywords: Phenology, Climate change, Deciduous, Evergreen, Northeast India

Tree phenology observations comprised of bud growth, leaf emergence, flowering, fruiting and leaf fall activities in relation to seasons with variations in environmental and climatic factors like temperature and precipitation (Moza and Bhatnagar 2005). Anthropogenic carbon emission into the atmosphere has been held responsible for the rise of global temperature by 0.7°C over the last century (Smith et al 2007). Variation in temperature and rainfall greatly influence phenophases of tree species with variations according to types (Stirnemann et al 2008 and Thakur et al 2008). Irregular trends of precipitations and fluctuating temperature regimes (increased) have greatly affected the leaf-flush and leaf-fall activities of trees at varying extent (Singh and Kushwaha 2005). Phenological changes following climate change have consequential effects on the production, distribution, composition and their life cycles with serious economic and social implications (Sparks and Menzel 2002 and Badeck et al 2004). A number of studies have been carried out in many parts of India to understand the phenological behaviour during the last few decades. However, the phenological pattern studies in tropical semi-evergreen forest of Mizoram, Northeast India had received less attention. The present study was carried out to observe the phenological pattern of some dominant tree species and understand the response of tree species to climatic change.

MATERIAL AND METHODS

Study area: The study was conducted for a period of one year during March 2017 to February 2018 in Mizoram University Campus (23°43'37" to 23°45'25" N latitudes and 92°38'39" to 92°40'23" E longitudes) in Aizawl district of Mizoram, Northeast India. Highest temperature in the study area was during March-April and the lowest during December-January. Rainfall is from the south-west monsoon with heavy precipitation in summer (May-September) continuing till late October (Fig. 1). Climatic conditions of the study area are broadly characterized by three seasons: cold or winter (November-February), warm or spring (March-May), and rainy or summer (June-October) seasons (Pachuau 1994). The vegetation and forest type of the study area is tropical semi-evergreen forests.

Phenological observations: Density, basal area cover and importance value index (IVI) of trees in tropical semi-evergreen forest in the study area was quantified using standard quantitative techniques from 200 quadrats (10 m × 10 m) laid randomly and six dominant tree species (*Schima wallichii, Castanopsis tribuloides, Castanopsis indica, Albizia chinensis, Callicarpa arborea* and *Albizia procera)* were selected being IVI greater than 10 for phenological observations (Table 1). Five individuals of each 6 species were randomly marked and tagged for recording phenological observations (leaf fall, leaf emergence, flowering and fruiting) at monthly intervals for a period of one year (Dutta and Devi 2015). The tree species are either evergreen or deciduous, where evergreen trees produce leaves continuously without heavy leaf fall while deciduous

trees have a marked leaf fall with complete leafless for a period during the year. Duration of the phenological activities can be either brief (extends for 2 weeks or less) or extended (more than 2 weeks). Flowering activities can be either synchronous or asynchronous. Fruit maturation activities can be either rapid (fruit maturation ≤ 4 months) or lengthy (> 4 months). Phenological pattern of the trees was compared with records earlier in the flora of Lushai Hills (Fischer 1938) to obtain the trend in behavioral pattern changes.

RESULTS AND DISCUSSION

Leaf fall: The leaf fall of *A. chinensis* and *C. arborea* begin in December and continued until February. *A. procera* also shed their leaves from January until April. All the deciduous trees studies observed a complete leafless period for one to two months (during March and April). However, the evergreen tree species shed old leaves while retaining a stable population of functional leaves throughout the year. The species observed highest leaf fall during the dry and cold period (January and February) as an effect of water stress on the morpho-physiological activities where plants adapt through leaf fall to reduce the effect of water shortage (Borchert et al 2002 and Tesfaye et al 2011). Similar pattern of leaf fall was reported from different species of several subtropical forests of Manipur and Balafort reserve forest in Rajasthan (Kikim and Yadava 2001, Yadav and Yadav 2008).

Leaf initiation: End of dry season is characterized by leaf initiation of the studied evergreen trees where rising temperature and increased photoperiod may be the triggering effect as reported by several workers (Singh and Singh 1992, Singh and Kushwaha 2006). Rivera et al (2002) reported an increase in photoperiod of 30 minutes or less induce spring flushing and also suggest optimum synthetic gain due to new foliage production shortly before the rainy season. On the other hand, deciduous trees flush new leaves in the wet season after rains in conformity to reports observed in earlier studies (Elliot et al 2006). However, *S. wallichi, C. tribuloides* and *C. indica* showed flushing of leaves more than once in a year. Water is very essential for leaf initiation and the production of new leaves by the evergreen trees during the dry season depend on water stored in the tree stem or water remaining in the subsoil (Sayer and Newbery 2003).

Flowering: Flowering of the tree species continued at different seasons in the year. *S. wallichii* and *A. chinensis* recorded flowering in April-May while *C. tribuloisdes, A. procera* and *C. indica* exhibited flowering in August-September (rainy season). However, *C. arborea* started flowering in June just with the onset of monsoon. Flowering
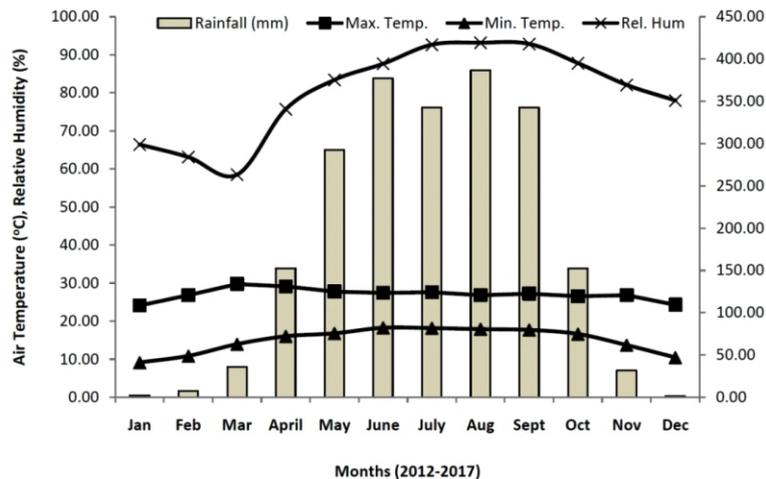

Fig. 1. Ombrothermic diagram of the study area (2012-2017)

Table 1. Phytosociology of selected tree species in semi-evergreen forest in the study area

Tree species	Local name	Family	D	BA	**IVI**
Schima wallichi	Khiang	Theaceae	181	22.32	51.07
Castanopsis tribuloides	Thingsia	Fagaceae	120.5	13.39	33.99
Albizia chinensis	Vang	Mimosaceae	55	9.17	21.17
Callicarpa arborea	Hnahkiah	Verbenaceae	48	3.62	13.53
Albizia procera	Kangtek	Mimosaceae	41	4.77	13.27
Castanopsis indica	Sehawr	Fagaceae	34	3.8	10.86

D- Density (ha^{-1}); BA- Basal area (m^2 ha^{-1}); IVI- Importance Value Index

during the dry season indicate the availability of water from different sources, such as sporadic winter rains, absorption from soil and water stored in stem (Singh and Kushwaha 2006). Extended asynchronous flowering activity was observed in all tree species under observation. Flowering in evergreen species were observed mostly after leaf flushing except for *S. wallichii* where new shoots emerge simultaneously during flowering. However, the deciduous species exhibited flowering soon after the leaf flushing.

Fruiting: The selected tree species showed a marked seasonal variation in fruiting behaviour. *S. wallichii* exhibited fruiting during the rainy season to onset of autumn (May to October), whereas, the other tree species studied bear fruit during late autumn that extended up to the winter season (October to February). These observations are similar to reports from other subtropical forest of the region at high altitude (Kikim and Yadava 2001). The observed tree species

exhibited lengthy fruit maturation period extending up to five months except for *C. arborea* with brief and rapid fruit maturation recorded during October to December. In *S.*

Table 2. Phenological pattern of selected tree species in the study area

Tree species	Behavioral pattern			
	Leaf drop	Leaf flushing	Flowering	Fruiting
Schima wallichi	PE	Pe	PeA	PeL
Castanopsis tribuloides	PE	Pe	PeA	PeL
Albizia chinensis	PD	Pe	PeA	PeL
Callicarpa arborea	PD	Pe	PeA	Pbr
Albizia procera	PD	Pe	PeA	PeL
Castanopsis indica	PE	Pe	PeA	PeL

P=Periodic, D=Deciduous, E=Evergreen, e=Extended periods > 2 weeks per episode, A=Asynchronous, r=Rapid fruit maturation ≤ 4 months, L=Lengthy fruit maturation >4 months

PA- Phenological Activities; S- Leaf fall; E- Leaf emergence ; Fl- Flowering; Fr- Fruiting

Fig. 2. Phenology of selected tree species recorded in the study area

Table 3. Phenological changes of the selected tree species in the study area

Tree species	(Fischer,1938)		Present Study		Phenological Change	
	Flowering	Fruiting	Flowering	Fruiting	Flowering	Fruiting
Schima wallichi	March	-	April	May- October	Advanced	-
Castanopsis tribuloides	-	December	August-September	September-January	-	Advanced
Albizia chinensis	April	-	May-June	October-February	Delayed	-
Callicarpa arborea	August	-	June-September	October-December	Advanced	-
Albizia procera	-	October	September-October	October-February	-	Delayed
Castanopsis indica	-	December	August-October	September-January	-	Advanced

wallichii, initiation of fruiting was with flowering, while the other tree species studied recorded fruiting after completion of flowering phase. The timing and period of flowering mostly influenced the initiation of fruiting rather than climatic parameters like rainfall and temperature (Singh and Kushwaha 2006). However, temperature and photo-period greatly determine the fruit ripening and the length of fruiting period (Pandey et al 2002). Fruit dehiscence of tree species fruiting during September to December coincides with the ensuing spring and onset of monsoon to allow optimal germination after a brief period of dormancy (Singh and Kushwaha 2006).

Phenological shifts: The observed shifts in phenophases of the selected tree species as a result of comparisons with phenological status recorded in the flora of Lushai Hills in 1938 are presented in Table 3. The flowering and fruiting time of the selected species were either advanced or delayed by a period ranging from one to three months. The flowering of *S. wallichii* and *C. arborea* has been advanced, whereas, delayed in *A. chinensis*. Advanced fruiting occurred in *C. tribuloides* and *C. indica*, whereas, fruiting was delayed in *A. procera*. Climate change brings about significant variation (advanced or delayed) in onset dates of flowering (Fitter and Fitter 2002) and fruiting responses (Chapman et al 2005) in tree species. Studies from Western Himalayas reported advanced flower initiation and leaf emergence phase as a result of climate change in terms of rising temperature (increased by 3.7°C within eight years) and reduced rainfall (Thakur et al 2008). These changes in the phenological pattern serves as an effective indicator of the climate change (Chmielewski and Rotzer 2001). The long-term phenological records analysis provide an effective means to examine phenological shifts with time, understand how vegetation responded to climate change and predict plants response to future climate change (Moza and Bhatnagar 2005, Luo et al 2007).

CONCLUSION

The phenological pattern of the tree species vary in seasonality based on functional types either being deciduous or evergreen. Spatial and temporal variations in the phenology of tree species throughout the year maintain a dynamic and productive forest ecosystem. The phenological behaviour observations of the species will be useful for both *in-situ* and *ex-situ* conservation through proper understanding of seed maturity, dormancy, germination and collection timings. The study findings about phenological shifts (either advanced or delayed) with climate change indicate the importance and directly evaluate the extent how recent climatic trends have influenced phenological events, and make decisions well in advance to adapt future climate change. Tree phenology emerged out to be an effective indicator of climate change owing to its responsive, earliest and easily visible traits with variations in the annual course of weather elements.

REFERENCES

Badeck FW, Bondeau A, Böttcher K, Doktor D, Lucht W, Schaber J and Sitch S 2004. Responses of spring phenology to climate change. *New Phytologist* **162:** 295-309.

Borchert R, Rivera G and Hagnauer W 2002. Modification of vegetative phenology in a tropical semi-deciduous forest by abnormal drought and rain.*Biotropica* **34:** 381-393.

Chapman CA, Chapman LJ, Struhsaker TT, Zanne AE, Clark CJ and Poulson JR 2005. A long-term evaluation of fruiting phenology: importance of climate change. *Journal of Tropical Ecology* **21**: 31–45.

Chmielewski FM and Rotzer T 2001.Response of tree phenology to climate change across Europe. *Agricultural and Forest Meterology* **108**: 101-112.

Dutta G and Devi A 2015. Phenology and population study of six tree species in tropical forest of Assam, northeast India. *Tropical Ecology* **56**(3): 393-399.

Elliott S, Baker PJ and Borchert R 2006. Leaf flushing during the dry season: The paradox of Asian monsoon forests. *Global Ecology and Biogeography* **15:** 248-257.

Fischer CEC 1938. The flora of Lushai Hills. *Records of the Botanical Survey of India* **12**(2): 75-161.

Fitter AH and Fitter SR 2002. Rapid change in flowering time in British plants. *Science* **296**: 1689-1692.

Kikim A and Yadava PS 2001. Phenology of tree species in subtropical forests of Manipur in Northeast India. *Tropical Ecology* **42**: 269-276.

Luo Z, Sun OJ, Xu QGW and Zheng J 2007. Phenological responses of plants to climate change in an urban environment. *Ecological Research* **22**: 507-514.

Moza MK and Bhatnagar AK 2005. Phenology and climate change. *Current Science* **9**: 243-244.

Pachuau R 1994. *Geography of Mizoram*. R T Enterprise, Venghlui, Mizoram, p 153.

Pandey AK, Solanki KR and Gupta VK 2002. Periodical growth and phenology of 4-year-old Neem in semi-arid region. *Range Management and Agroforestry* **23:** 122-126.

Rivera G, Elliott S, Caldas LS, Nicolossi G, Coradin VTR and Borchert R 2002. Increasing day length induces spring flushing of tropical dry forest trees in the absence of rain. *Trees* **16**: 445-456.

Sayer EJ and Newbery DM 2003. The role of tree size in the leafing phenology of a seasonally dry tropical forest in Belize, Central America. *Journal of Tropical Ecology* **19:** 539-548.

Singh JS and Singh VK 1992. Phenology of seasonally dry tropical forest. *Current Science* **63:** 684-688.

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. *Annals of Botany* **97:** 265-276.

Smith P, Martino D, Cai Z, Gwary D, Janzen H, Kumar P, McCarl B, Ogle S, O'Mara F, Rice C, Scholes B and Sirotenko O 2007. Agriculture. In: Metz B, Davidson OR, Bosch PR, Dave R and Meyer LA (eds). *Climate Change 2007: Mitigation. Contribution of Working Group III to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change*. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA.

Sparks TH and Menzel A 2002. Observed changes In seasons: An overview. *International Journal of Climatology* **22:** 1715-1725.

Stirnemann R, Pletsers A, Proctor H, Cooney T, Caffarra A, O'Halloran J, Jones M and Donnelly A 2008. Climate change impacts on phenology: Implications for terrestrial ecosystems. Presented at the *Climate Change and Systematics conference at Trinity College, Dublin, Ireland*.

Tesfaye G, Teketay D, Fetene M and Beck E 2011. Phenology of seven indigenous tree species in a dry Afromontane forest, southern Ethiopia. *Tropical Ecology* **52:** 229-241.

Thakur PS, Dutt V and Thakur A 2008. Impact of inter-annual climate variability on the phenology of eleven multipurpose tree species. *Current Science* **94**(8):1053-1058.

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.

Impact of the Aridity Gradient on the Physico-chemical Parameters of the Needles of *Pinus halepensis* Mill. in the Western Algeria

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Abstract: In Algeria, pinewoods are mainly concentrated in arid and semi-arid areas where climatic and edaphic conditions have an effect on the phenology, physiognomy and growth of trees. The objective of this study is to see whether the aridity gradient has an effect on the needles of Aleppo pine. For realized this work, some characteristics of 50 samples of Aleppo pine needles collected from five stations in two areas of western Algeria (semi arid and arid) were studied. Analysis of the results showed a significant difference in the specific characteristics of needles in each zone, namely morphology, water content, chlorophyll rate and yield, which are more important in the semi-arid zone.On the other hand organic and mineral content, the pH and conductivity remain homogeneous between the two zones. The principal component analysis (PCA) confirmed the significant differences between the parameters measured in the two study areas, highlighting the imprint of the bioclimatic stage on the *Pinus halepensis* Mill in each zone.

Keywords: *Pinus halepensis* Mill., Needles, Drought, Physico-chemical parameters

In the mediterranean region, currently the main climatic constraint on ecosystems is the summer drought characterized by high temperatures associated with low rainfall in summer (Le Houérou 2005). High-intensity drought can cause water stress to trees and results in decrease in productivity and survival, thus can have significant deleterious consequences for ecosystem services. Water stress may alter the functioning of plantations over the long term by decreasing production and leaf area, resulting in a decrease in photosynthesis and therefore growth (Breda et al 2006). Trees, with very long life cycles, appear to be particularly vulnerable, whether for survival or for the services they provide, to the effects of climate change that can be rapid. This vulnerability may, among other things, affect the goods and services that humans derive from it wood production, carbon storage, water cycle operation (Lindner et al 2010). On the other hand, associated with these climate changes, other factors such as land use changes or the use of biomass as renewable energy can affect the forest ecosystem. They can act independently or in combination with climate change (Hendrik 2016). Mediterranean forests are a fragile natural environment already deeply disturbed by multiple uses, the origins of which date back to the early neolithic period. The

aggressions they underwent, however, varied considerably in frequency and intensity over the ages as a function of human demography, which determined phases of regression or progression of their surface (Marien and Billand 2009, Guénon 2010). Aleppo pine is the most common resinous essence in the Mediterranean basin and especially in Algeria, as it is the most rustic and able to adapt to several types of soil and the most varied climates, there are almost 881 000 ha of Aleppo pine in Algeria from a reforestation or in the natural state (DGF 2007). Aleppo pine is characterized by leaves in the form of very fine needles (less than 1 mm), soft 5 to 10 cm long. The aim of present study is to understand some physico-chemical characteristics of needles of the *Pinus halepensis* species between the semi-arid and arid bioclimatic stage represented by the mountain of Sid Ahmed Zaggai (Saida) and Antar (Naàma) forestansd to assess the impact of the main regional climatic conditions on the adaptation of the needles of Aleppo pine in the face of extreme conditions.

MATERIAL AND METHODS

Semi-arid area: The semi-arid area is represented by the forest of Sid Ahmed Zaggai (34° 50' 12.7" N, 00° 05' 14.2" E, Altitude: 1126 m), 4.5 km west of wilaya of Saida upstream of

bourg "OuledHennoun". The forest Sid Ahmed Zaggai is part of the mountains of Saida, an oriental extension of the Dhaya Mountains (Atlas Tellian) (Fig. 1). *Pinus halepensis* and *Pistacia lentiscus* are the two dominant plant species of the stand on calcareous brown and brown soils. According to the climatic data of the Rebahiametrological station (34 ° 52 ' N; 00 ° 10 ' E), this zone has an average of 361.77 mm yr^{-1} with a seasonal diet of type HAPE (winter, autumn, spring, summer), where precipitation is more abundant in winter and fall (ONM 2015). January is the coldest month of the year with an average of 8.6 °C while the July is the hottest month with an average of 27.2 °C. It has a dry period from May to October and 38 days of jelly on average per year.

Arid area: The arid zone is represented by the Djebel Antar Forest (33° 32'24.1" N, 00° 18'24.9" W, Altitude: 1141m), 30 km east of the wilaya of Naàma. From a soil point of view have found calcimagnesic rocks formed from brown calcium soils with gypsum crusting. Aleppo pine is the dominant species (Fig. 1). Monthly analysis of meteorological precipitation and temperature data collected at nearby Mécheria (33 ° 31 ' N; 00 ° 17 ' W) weather stations shows that this arid zone receives an average of 222.06 mm/year with a seasonal diet of type APHE (ONM 2015) and more abundant in autumn and spring. January is the coldest month with an average of 5,6 °C while July is the hottest with an average of 28.7 °C. The arid zone has 8 months of drought with a period of jelly that averages over 40 days.

Selection of stations and sampling: In each of these two zones, 25 samples collected from five sampling sites of 400 m^2 selected with a similar exposure, a mean slope, a similar

geological facies and a common presence of Aleppo pine. For morphological observations five trees were selected from each site, 20 needles were selected from the well-developed shoots of each tree (Tiwari et al 2013). The collected samples were stored at (4 °C) for chemical analyses (Borsali et al 2017).

Physio-chemical analysis: Standard protocol used by Garnier et al (2001) and Vile et al (2005) was followed to characterize the morphology of the needles. 20 needles of each sample were scanned, the length is determined by the Mesurim software and the width is by Motic microscopy after a cross section in the needle. The water content is given by the gravimetric method (determination of weight loss by desiccation at 100°C to a constant weight to determine the water content). Some of the plant material was allowed to dry in the shade at room temperature in a ventilated room for a period of 10 to 15 days. After drying this plant material was ground in powder with the aid of an electric mill. The determination of ash content and organic matter content was done by the calcination technique at 550 °C. Part of the samples was crushed and left macerate for 24 hours to prepare the ethanoic extracts (Harbore1998). The pH measurement and salinity of a solid sample were performed on a sample suspension (10 g) in distilled water (100 ml) (Aouidi 2012). The yield of Aleppo pine needles in dry extract was estimated according to the method of Hadri (2015). The quantitative determination of chlorophyll was done spectroscopy (UVVIS), one gram of finely cut fresh leaves were taken and ground with 20 – 40ml of 80% acetone. After the preparation of the acetonic extracts it was then
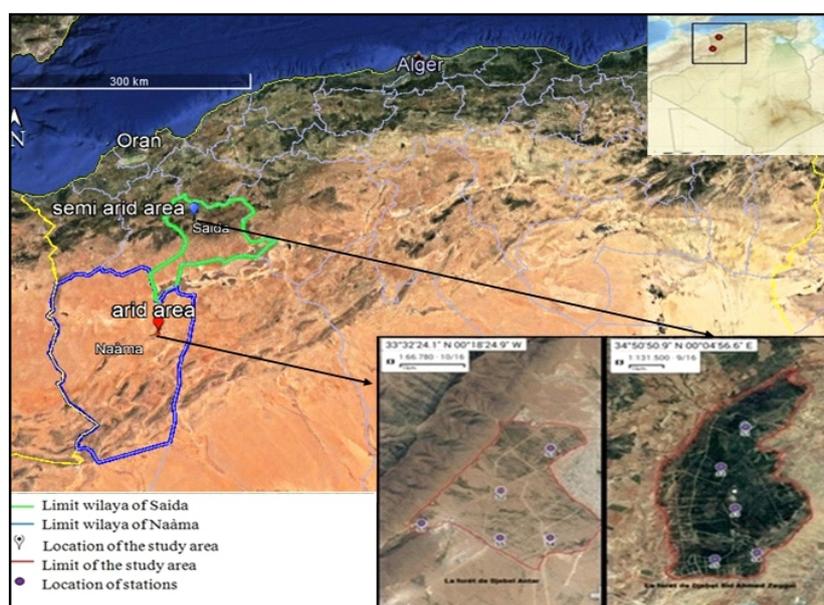

Fig. 1. Geographical location of study areas

centrifuged at 5000-10000 rpm for 5mins. The absorbance of the solution was at 645nm and 663nm against the solvent (acetone) blank, then the chlorophyll content was determined by using the following formula Arnon's (1949) equations:

Total chlorophyll (μg/ml) = 20.2 A663 + 8.02 A645

Where, A: Absorbance at respective wave length

Statistical analysis: The statistical study of the results, was carried out using software Statistica 8 to compare the averages of the results of the analyses carried out according to the variability of the zones using a student t-test, then a principal component analysis (PCA) was performed for the correlation of samples of each area in function parameters study.

RESULTS AND DISCUSSION

The needles of Aleppo pine shows that the length (95.7 mm) and width (0.848 mm) are more in the zone of the semi-arid) compared to the arid zone (80.5 and 0.516 mm for length and width). There was significant difference between the two zones for the length or width of the needles. Moisture measurements underline the footprint of the climatic stage on each zone and shows a very highly significant difference, where the highest proportion was recorded in the semi-arid zone (47.61%) compared to arid zone (28.85%). Aleppo pine needles are acidic and have no salinity, for both zones no significant difference was recorded. The organic matter varies between 97.34 and 98.34% for the needles of the semi-arid and between 96 and 96.67% for arid station. The mineral varied between 1.66 and 2% for the semi-arid zone and 3.33 and 4% for the arid station. The differences were not significant for organic and mineral contents between the arid and semi-arid zone. The chlorophyllien pigment content of the needles of Aleppo pine in the semi-arid was higher (36.91 and 47.01 μg/ml) than in arid zone (24.03 and 31.81 μg/ml) and differences were significant. The yield of the needle extract of the semi-arid zone is high (between 15.4 and 16.9%) compared to the extract of needles of Aleppo pine from the arid zone (13.4 and 14.2%). The comparison of the two mean shows a highly significant difference between the needle extracts of the two zones (Fig. 2).

The principal component analysis(PCA) for the 50 samples analyzed contrasts two groups of homogeneous samples (Fig. 3), the first group (1-25) represents the samples of our semi-arid zone and the second group (26-50) represents samples from the arid zone. According to the correlation circle, the first group representing samples of the semi-arid zone is characterized by long needles and a little wide with more moisture, yield, and chlorophyll than in the arid zone samples that are mainly correlated with the pH, ash content and conductivity that are not very elevate. This (PCA)

confirms the footprint of the bioclimatic stage on the characteristics of the needles of Aleppo pine in each zone.

In general, morphological and anatomical characteristics of needles of the *Pinus* genus also depend on abiotic factors (Schoettle and Rochelle 2000). Physical factors such as elevation, atmospheric air temperature decrease, pressure, increased precipitation, and wind velocity affect plant growth (Körner 2007 and Gonzalez et al 2010). The water content in the Aleppo pine needles is probably related to humidity and precipitation in each zone, which influences the variability of evapotranspiration and the conservation of water in needles at the level of each region. Bensaid (2007) observed that the decrease in the humidity of the air and the dryness exerted in this zone, due to the effect of the high temperatures, which increase the evaporation at soil and plant evapotranspiration. Comparing the results obtained with the salinity scale, the Aleppo pine needles do not represent any salinity for the two study areas. This was confirmed by the analysis of variance, which shows that there is no significant difference between the two pinewoods. This can be explained by the nature of the unsalted limestone soil in the semi-arid zone of Djebel Sid Ahmed Zaggai (Zouidi and Borsali 2017) and in the pinewoods of our arid zone (Bensaid 2007 and Zouidi et al 2018). The organic matter was very high compared to the mineral matter. Lehner (2014) observed the mineral composition of plants on dry residue after incineration. The elements considered organic and which represents by mass more than 90% of the dry residue. This variation in the rate of organic and mineral matter is due to the physiological state of the species in its natural environment where it has specific physical and chemical characteristics. Some environmental factors such as climatic conditions or chemical characteristics exert a direct influence on plants. On the other hand the altitude or the depth of the soil have an indirect influence on the plants through the changes of temperature, pressure or light that they can cause. Inarid zone water and soil are limiting and stressful factors that can alter the functioning of trees in the long term by decreasing the production of organic matter (Breda et al 2006). Abiotic factors, climatic and edaphic (chemical composition and soil structure) affected the leaf pigment content (chlorophyll), which is one of the main signatures of the physiological state of the plants mainly by their central role in photosynthesis (Kalaji et al 2016).

The measurement of chlorophyll rate showed significant difference between the two zones. This can be explained by the bioclimatic factors in the first place (temperature and light). The distribution of chloroplasts in the leaf also results from an adaptation of plants to light conditions. Loggini et al (1999) showed that the reduction of chlorophyll pigments is due to the photosynthetic system which can be damaged by
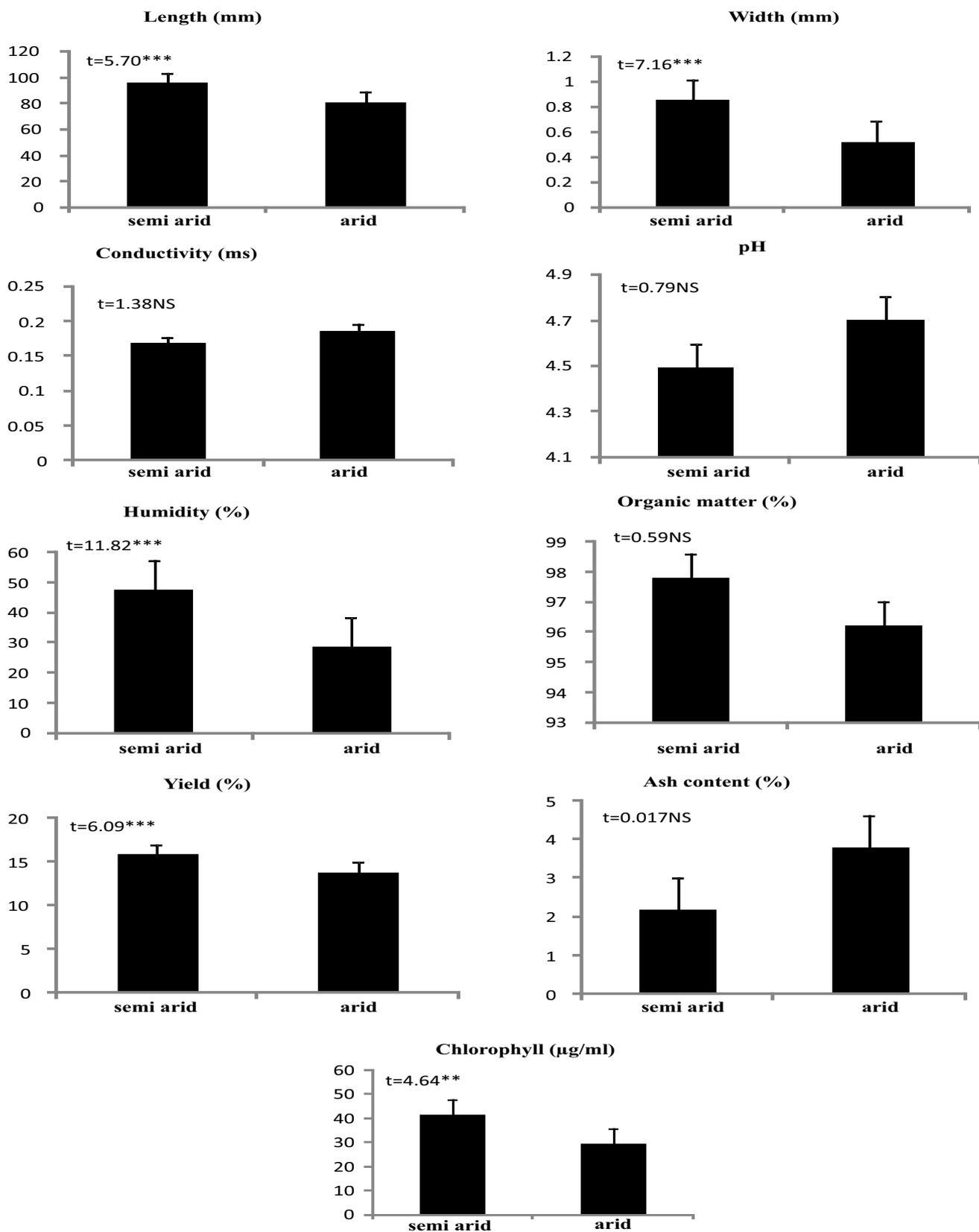
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Fig. 2. Physico-chemical parameters of the needles of *Pinus halepensis* Mill between the semi arid and the arid zone (: P < 0.05; **: P < 0.01; ***: P < 0.001 - NS: not significant)
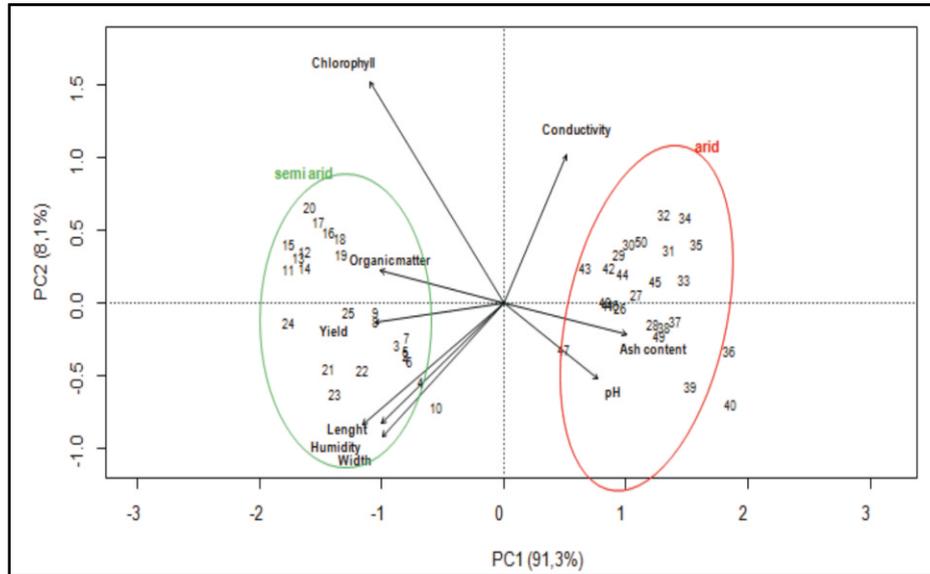
Fig. 3. Principal component analysis (PCA) of samples based on analysis results

the stressful temperatures that cause a lowering of the thylacoïdal protein content associated with the chlorophyll which can be denatured under the effect of high temperatures. Féret (2009) also showed that too intense a light causes a photo-inhibition that results in a significant reduction in photosynthetic activity and sometimes the destruction of photosynthetic pigment (chlorophyll), also the lack of elements nutrients can be considered as limiting factors of photosynthesis (C, N). Water stress in arid areas also reduces stomatal conductance to limit the loss of moisture. This regulation of gas exchange causes a decrease in the availability of CO_2 which becomes a limiting element for photosynthesis. The imbalance caused by these two parameters leads to the shift from chlorophyll to an excited state that can lead to the production of free radicals that damage the pigments. In addition to the water deficit observed in the arid zone, air pollution can be added, resulting in browning, discoloration and necrosis of foliar tissues, resulting from the destruction of chlorophyll pigments. This pollution is caused by the limestone quarry at the Djebel Antar have a negative impact on the vegetation present at the level of this area (Emberson et al 2003 and Karacan 2006). The difference in yield between the two zones can be explained by several factors, namely: difference of provenance of the species, climate, nature of the soil and edaphic conditions. Rodríguez-Calcerrasa et al (2014) show that under xeric conditions the plant closes its stomata, which induces a decrease in CO_2 entry, a decrease in the yield of photosynthesis, and a decrease in primary production. However, the demand for carbohydrates, via respiration, remains positive to ensure the metabolism of the plant even if water stress can also cause a decrease in respiration. Drought can also lead to a decrease in photosynthetic yield by acting on the mortality of organs including leaves or by acting on turgor mechanisms. The shortage of carbon can also facilitate the attack of pathogens as this will weaken the individual who will be less able to withstand the various attacks (Hendrik 2016).

CONCLUSION

The study of the physico-chemical parameters of needles of the species *Pinus halepnesis* at the level of the semi arid and arid zones of the western Algeria showed a significant difference between the two zones. This shows a form of adaptation of the tree with these xeric conditions by changing the morphology of the needles in the first place and consequently this will influence the other leaf characteristics. The high water content in the needles harvested in the semi-arid zone this is due to the humidity of the air and the higher precipitation in this area which significantly decrease the evapotranspiration and allow the conservation of the water needed for photosynthesis. The stressful effect of high temperatures in the xeric areas (arid zone) causes the lowering of chlorophyll and consequently plant productivity. The pH of the needles is acidic (< 5) this acidity is a character of the conifers and in particular the Aleppo pine, the conductivity and the ash content remains slightly more important in the arid zone without having a significant difference between the two zones.This differentiation is confirmed by the principal component analysis (PCA) and explains the existence of a bioclimatic stage imprint on the characteristics of the Aleppo pine needles, mainly the drought

which plays a crucial and limiting role in the different types of morphological and physiological adaptation of *Pinus halepensis* has different spatial scales in the Mediterranean environment.

REFERENCES

Aouidi F 2012. *Study and valorisation of Olive leaf "Olea europaea" in the Agro-food industry*. Ph.D. Dissertation, University of Carthage, Tunisia, 213p.

Arnon DI 1949. Copper enzymes in isolated chloroplasts, polyphenoxidase in *beta vulgaris*. *Plant physiology* **24**: 1-15.

Bensaid A 2007. *GIS and remote sensing for the study of silting in an arid zone: the case of the wilaya of Naàma (Algeria)*. Ph.D Dissertation, Joseph-Fourier University, Grenoble I, France, 319p.

Borsali AH, Dahmani R, Zouidi M and Gros R 2017. Chemical properties and leaf traits of *Pistacia lentiscus* in link with the age of the leaves and exposure to stress. *PONTE International Journal of Sciences and Research* **73**(3): 11.

Bréda N, Huc R, Granier A and Dreyer E 2006. Temperate forest trees and stands under severe drought: a review of ecophysiological responses, adaptation processes and long-term consequences. *Annals of Forest Science* **63**(6): 625-644.

DGF 2007. *Report on forest policy and strategic planning and sustainable development of forest and alfatières resources.* General Directorate of Forests. 32p

Emberson L, Ashmore MR and Murray F 2003. *Air pollution impacts on crops and forests*: *A global Assessment.* Air Pollution Reviews 4, World Scientific Publishing Company. 367p.

Feret JB 2009. *Contribution of modeling for the estimation of the content of foliar pigments by remote sensing.* Ph.D. Dissertation,Pierre and Marie University, Curie, 214p.

Garnier E, Shipley B, Roumet C and Laurent G 2001. A standardized protocol for the determination of specific leaf area and leaf dry matter content. *Functional Ecology* **15**(5): 688-695.

Gonzalez P, Neilson RP, Lenihan JM and Drapek RJ 2010. Global patterns in the vulnerability of ecosystems to vegetation shifts due to climate change. *Global Ecology and Biogeography* **19**(6): 755-768.

Guenon R 2010.*Vulnerability of Mediterranean soils to recurrent fires and restoration of their chemical and microbiological qualities through contributions of Compostes*. Ph.D. Dissertation. Aix-Marseille University. 248 p.

Hadri N 2015. *Photochemical study and antioxidant activity of plant extracts Sedum villosum L. (Orpin.) and Anabasis articulata Moq (Forsk.)*. Ph.D. Dissertation. University Abou BekrBelkaid Tlemcen Algeria, 148p.

Harborne JB 1998. Phytochemical Methods - A Guide to Modern Techniques of Plant Analysis, pp 182- 190. Chapman and Hall, London.

Hendrik D 2016. *Vulnerability and adaptation of forest ecosystems in a context of climate change: Observation, modeling and epistemic reflection*. Ph.D. Dissertation Aix Marseille University, France, 85p.

Kalaji HM, Jajoo A, Oukarroum A, Brestic M, Zivcak M, Samborska I,

Cetner M,Łukasik I, Goltsev V and Ladle R J 2016. Chlorophyll a fluorescence as a tool to monitor physiological status of plants under abiotic stress conditions. *Acta Physiologiae Plantarum* **38**(4): 102.

Karacan MS 2006. Monitoring of changing chlorophyll content of *Buxu sempervirens* and *Euonymus japonica* leaves affected with air pollutants in Ankara, *World Journal of Agricultural Science* **2**(2): 213-216.

Körner C 2007. The use of 'altitude' in ecological research. *Trends in Ecology & Evolution* **22**(11): 569-574.

Lehner A 2014. *Water and mineral nutrition in plants. Part 1, Laboratory of Glycobiology and Plant Extracellular Matrix*; University of Rouen. 118p.

Le Houérou HN 2005. *The isoclimatic Mediterranean biomes : Bioclimatology, diversity and phytogeography.* Montpellier, Copymania Publication, 2 vol , 760 p.

Lindner M, Maroschek M, Netherer S, Kremer A, Barbati A, Gordi-Gonzalo J, Seidl R, Delzon S, Corona P, Kolström M, Lexer MJ and Marchetti M 2010. Climate change impacts, adaptative capacity, and vulnerability of european forest ecosystems. *Forest Ecology and Management* **259**(4): 698-709.

Loggini B, Scartazza A, Brugnoli E and Navari-Izzo F 1999. Antioxidative defense system, pigment composition, and photosynthetic efficiency in two wheat cultivars subjected to drought, *Plant Physiology* **119**(3): 1091-1100.

Marien JN and Billand A 2009. Mediterranean socio-ecological forest systems facing global changes some questions raised by the wood energy sector in Morocco. *Mediterranean Forest* **4**: 297-300.

ONM 2015. Weather Center Algeria, weather archive wilaya of Saida and wilaya of Naàma. Available: http://www.meteo.dz/climatenalgerie.php.

Rodríguez-Calcerrada J, Martin-StPaul NK, Lempereur M, Ourcival JM, del Rey MDC, Joffre R and Rambal S 2014. Stem CO2 efflux and its contribution to ecosystem CO2 efflux decrease with drought in a Mediterranean forest stand. *Agricultural and Forest Meteorology* **195**: 61-72.

Schoettle AW and Rochelle SG 2000. Morphological variation of *Pinus flexilis* (Pinaceae), a bird-dispersed pine, across a range of elevations. *American Journal of Botany* **87**(12): 1797-1806.

Tiwari SP, Kumar P, Yadav D and Chauhan D 2013.Comparative morphological, epidermal, and anatomical studies of *Pinusroxburghii* needles at different altitudes in the North-West Indian Himalayas. *Turkish Journal of Botany* **37**(1): 65-73.

Vile D, Garnier E, Shipley B, Laurent G, Navas ML and Roumet C 2005. Specific leaf area and dry matter content estimate thickness in laminar leaves. *Annals of Botany* **96**(6): 1129-1136.

Zouidi M and Borsali AH 2017. Contribution to the study of physico-chemical and microbiological characteristics of forest soils under the species "*Pistacia lentiscus* L" in the semi-arid Djebe lSidi Ahmed Zeggai, Saida, Algérie. *Genetics and Biodiversity Journal* **1**(2) 54-55.

Zouidi M, Borsali AH, Allam A and Raphael G 2018.Physicochemical proprieties of soils in the arid areas of western Algeria. Proceedings of *International conference on soil sciences ICOSS2018,* Remote sensing for sustainable soil management March, 17-19, 2018 Hammamet, Tunisie, pp. 19-20.

Growth and Development of Seedlings in Relation to Container Size and Potting Media under Nursery conditions in *Oroxylum indicum*- A Multipurpose Medicinal Plant

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Abstract: The current study investigated the effect of container size and potting media on growth and development of *Oroxylum indicum.* The treatments consisted of four container sizes: root trainer 250 cc, root trainer 300 cc, polybag 16 cm x 24 cm (1500 cc) and polybag 23 cm x 28 cm (4200 cc) and three potting media: soil only, soil: sand: farmyard manure, 1:1:1 and soil: sand: vermicompost, 1:1:1. The container size, potting media and the interaction of container size x potting media exhibited significant effect on the growth and development of all the studied parameters- seedling height, collar diameter, number of leaves, shoot weight, length of primary root, number of secondary roots, root weight, total fresh weight of seedling, total dry weight of seedling, root: shoot ratio, sturdiness quotient and seedling quality index. The effect of potting media on seed germination percentage was significant. The study implies that large sized containers (polybag 23 cm x 28 cm) and potting medium soil:sand:vc (1:1:1) should be used to get better growth of *Oroxylum indicum* seedlings.

Keywords: *Oroxylum indicum*, Growth, Root trainer, Polybags, Seedlings

Forests and trees provides many benefits like fuelwood, fodder, fruits, fibre, timber, minor forest products, maintains the oxygen/CO_2 balance in the atmosphere and provides other ecosystem services. Forests play an important role in climate change mitigation and adaptation, and reduction of noise pollution (Dwivedi 2006). Forests are repository of floral and faunal biodiversity, and many of plants and animal species are becoming extinct due to their over exploitation. There has been a loss of global forest land from 31.6 per cent (4128 m ha) to 30.6 per cent in 2010-2015. The forest has been deforested at net annual rate of 0.08 per cent during 2010-2015 (FAO 2015). This has led to many concomitant adverse effects like decrease in supply of tree products and ecosystems services and reduction in biodiversity including that of medicinal plants. It is estimated that about 8 per cent of the scientifically known plants species on the earth are presently on the brink of extinction (Chapin et al 2000). This situation has caused concern not only for loss of species diversity but also for the availability of raw material for their use in various medicines. Medicinal plants play a vital role in traditional healthcare the world over (Kala 2017). It is estimated that about 80 per cent of the world population residing in the vast rural areas of the developing and under developed countries still rely mainly on the medicinal plants (WHO 2002). The medicinal plants also find application in

pharmaceutical, cosmetic, agricultural and food industry. The demand for medicinal plant-based raw materials is growing at the rate of 15 to 25% annually and it is estimated that the demand of medicinal plants is likely to be approximately worth US $ 5 billion in 2050 (Sharma 2004). Unchecked extraction of medicinal plants or their parts for various uses from natural habitats coupled with various other reasons like increasing human population, expanding agriculture, rapid urbanization, pressure on land due to industrial and other uses, has led to extinction of many medicinal plant species (Chadha and Gupta 1995).*Oroxylum indicum* is one of such medicinal plants which is being over exploited owing its multiple medicinal uses and is listed as endangered species (Gokhle et al 2006).

Oroxylum indicum is used in many Ayurvedic preparations. The stem bark paste is applied for the cure of scabies and to treat arthritis. The root bark is sweet, astringent, acrid, refrigerant, expectorant, digestive, carminative, febrifuge, diuretic, diaphoretic, antimutagenic constituent and tonic (Ramankutty et al 1995). The young shoot and unripe fruits are eaten as vegetables. The tree is also frequently lopped for fodder (Shah et al 2007).Seeds yield non-drying oil used in perfume industry. It is also used as one of the important ingredients in commonly used many Ayurvedic medicines and preparations (Parle and Bansal

2006). The natural regeneration of *Oroxylum indicum* is adversely affected owing to its over-exploitation for its various medicinal uses. In such a situation, the artificial regeneration of species would be quite useful to enable large scale plantation and its conservation. Quality of planting stock greatly influences the out-planting performance of seedlings in the field (Chauhan and Sharma 1997, Annapurna et al 2004). Therefore, present investigation was carried out to standardize the container size and potting medium under nursery conditions to produce good seedling quality of the species.

MATERIAL AND METHODS

Study area: The present study was carried out in open conditions at Sher-e-Kashmir University of Agricultural Sciences and Technology-Jammu (SKUAST-Jammu). The experimental site located at 32°40` N latitude and 74° 58` E longitude and at an altitude of 332 m above mean sea level. The study site has a subtropical climate. The average annual rainfall at the study site is 1200mm.

Experimental layout: The study was conducted in open nursery with four container sizes, root trainer 250 and 300 cc, polybag 1500 (16cm x 24cm) and 4200cc (23cm x 28cm) and three media types (soil only, soil:sand:fym-1:1:1 and soil:sand:vc-1:1:1). There were 12 treatment combinations in factorial(complete randomization design. Each root trainer block had 12 cells. Each treatment was replicated thrice. In single treatment there were 36 plants (12 per replication) and observations were recorded on 9 randomly (three per replication) selected plants per treatment. The soil of study site was sandy loam (Rana and Sood 2012). The unwanted material like plant parts, stones and weeds were removed from the soil. These ingredients-soil, farm yard manure (FYM) and vermicompost (vc) were mixed in proper proportions to get the requite media- soil, soil:sand:fym-1:1:1 and oil:sand:vc-1:1:1.

Potting media analysis: The samples were analyzed for available nitrogen using alkaline permanganate method (Subbiah and Asijia 1956), available phosphorus (Olsen et al l954) and available potassium by (Jackson 1973) on flame photometer after extraction with neutral normal ammonium acetate solution. The pH of the potting media was determined using pH meter (Jackson 1973).

Seed collection and sowing: Three trees were marked and pods were collected from these trees in first week of March. The seeds were extracted from these pods and sowing of seeds in containers filled up with requisite media was done in March. Before the sowing of seeds, soil was treated with Dithane M-45 (1%) to avoid fungal damage to tender seedlings. After sowing seeds, the light irrigation was

Table 1. Nutrient status of different potting media

Potting medium	pH	N	P	K
Soil	7.02	209.05	10.03	157.24
Soil: Sand: fym (1:1:1)	7.41	279.15	17.02	178.41
Soil: Sand: vc (1:1:1)	7.65	291.87	21.50	197.93

provided. Weeding and hoeing was done until the harvesting of seedlings. Watering of containers was done as per requirement. The germination per cent was recorded after 18 days of sowing of seeds. The observations on seedling height, collar diameter, number of leaves, length of primary root, number of secondary roots, shoot and root weight, total seedlings weight, root:shoot ratio, sturdiness quotient and seedling quality index were recorded after six months of sowing of seeds. The fresh shoot and roots were dried in hot air oven at 65°C in the paper bags for 48 hours to get the dry shoot and root weight of the seedling respectively. The root:shoot ratio (dry weight basis) was calculated. Sturdiness quotient was estimated (Roller 1977) and seed quality index were estimated (Dickson et al 1960) using the formulae:

$$\text{Sturdiness Quotient (S.Q.)} = \frac{\text{Seedling height (cm)}}{\text{Collar diameter (mm)}}$$

$$\text{Seedling Quality Index} = \frac{\text{Seedling dry weight (g)}}{\dfrac{\text{Height of seedling (cm)}}{\text{Collar diameter of seedling (mm)}} + \dfrac{\text{Shoot dry weight (g)}}{\text{Root dry weight (g)}}}$$

RESULTS AND DISCUSSION

Germination: Effect of container size and container size x media on seed germination was non-significant (Table 2). Seed germination started 11 days after sowing of seeds and it completed in 18 days. The maximum germination percentage (77.54%) was in potting medium:sand:vc (1:1:1) which was significantly higher than that of soil:sand:fym (1:1:1) and pure soil.

Aboveground parameters: Seedling height (SH), collar diameter (CD), number of leaves (NL), fresh shoot weight (FSW) and dry shoot weight (DSW) were significantly influenced by container size, potting media and interaction container size x potting media (Table 3).

The maximum seedling height (41.35 cm), collar diameter (8.66 mm), number of leaves (29.13), fresh shoot weight (25.29 g) and dry shoot weight (6.04 g) was in polybags (23 cm x 28 cm) which was statistically superior to other container sizes. The maximum shoot height (35.31), collar diameter (7.22 mm) and number leaves (23.88), fresh shoot weight (19.18 g) and dry shoot weight (4.59 g) were observed in media soil:sand:vc, 1:1:1 and were statistically superior to remaining media (Table 3). The interaction

polybag (23 cm x 28 cm) x soil:sand:vc, 1:1:1 showed highest seedling height (45.91 cm), collar diameter (9.65 mm), number of leaves (32.77), fresh shoot weight (32.32 g) and dry weight (7.94 g) which was significantly superior to the remaining interactions(Table 4).

Belowground parameters: The container size, media and interaction thereof had significant influence on length of primary root (LPR), number of secondary roots (NSR), fresh root weight (FRW) and dry root weight (DRW)(Table 4). The longest primary root (31.07 cm), maximum number of secondary roots (100.72),fresh root weight (17.55 g) and dry root weight (4.09 g) was in the 4200 CC container (polybag 23 cm x 28 cm) which was statistically superior to remaining container sizes.

The primary root length (21.43), number of secondary roots (80.22), fresh root weight (12.83 g) and dry root weight (2.99 g) was highest in media of soil:sand:fym (1:1:1) which were statistically higher than their respective values in other media. The highest length of primary root (35.10 cm) and number of secondary roots (112.66) was observed in interaction polybag (23 cm x 28 cm) x soil:sand:fym (1:1:1) and were statistically higher than remaining media. However, the highest fresh and dry root weight) was recorded in interaction of polybag (23 cmx28 cm) x soil:sand:vc (1:1:1) which were statistically superior to remaining interactions.

Seedling total fresh and dry weight, root: shoot ratio, sturdiness quotient and seedling quality index: The container size, media and interaction container size x media significantly influenced the total seedling fresh (TFWS) and dry weight (TDWS), root: shoot ratio (R:S), sturdiness quotient (SQ) and seedling quality index (SQI) (Table 5).

The highest seedling fresh weight (42.84 g), total seedling dry weight (10.13g) and seedling quality index (1.62) was in polybag (23 cm x 28 cm) which were statistically higher than remaining container sizes. However, the maximum root:shoot ratio (0.72) was in root trainer (300 cc) which was also significantly higher than that in the remaining container sizes. The highest root:shoot ratio in root trainer

300 cc during current study could be attributed to the reason that root trainers enable self-pruning of roots resulting in more fibrous root system and provide deep root runs, root free of deformities and free of coiling. This, consequently, results in vigorous plants with higher root:shoot ratio as compared to others. The present findings are in conformity with that of Annapurna et al (2007) who reported root:shoot ratio was higher in root trainers in comparison to polybags during an experiment on growth and development of *Santalum album* seedlings. In contrast to other parameters, there was an increase in sturdiness quotient with decrease in container size. The lowest container size (root trainer-250 cc) had the highest sturdiness quotient of 5.40 which was statistically at par with root trainer (300 cc). The sturdiness quotient of these container sizes (root trainer-250 ccand 300 cc) was statistically higher than large sized containers (polybags), respectively (Table 5). The lowest sturdiness quotient was obtained in largest sized containers *i.e.* polybags (23 cm x 28 cm) and vice-versa. A small quotient indicates a sturdy plant with a higher expected chance of out-planting success (Anonymous 2013). The lower sturdiness quotient in polybag (23 cm x 28 cm) could be attributed to better photosynthetic active radiation reaching in lower portion of the plants owing to lower stocking density (less number of plant per unit area) than that of other container sizes. Gera et al (2000) also reported similar findings in *Albizia procera* seedlings.

The maximum seedling fresh weight (32.01 g) and seedling quality index (1.18) was in media of soil:sand:vc (1:1:1) which were higher than soil:sand:fym (1:1:1) and soil only. Seedling quality index increased with increase in container size. The total dry weight of seedlings (7.59 g) and root: shoot ratio (0.72) was higher in soil:sand:fym (1:1:1) and were statistically higher than in media of soil:sand:vc (1:1:1) and soil only. However, the sturdiness quotient was highest (5.38) in soil only and was statistically superior to soil:sand:fym (1:1:1) and soil:sand:vc (1:1:1).The interaction polybag (23 cm x 28 cm) x soil:sand:vc (1:1:1) had the

Table 2. Effect of plant container size and potting media on germination percentage

Media	Container size				Mean
	Root trainer 250 cc	Root trainer 300cc	Polybag16cmx24cm	Polybag23cm x 28cm	
Soil only	64.01 (53.11)	65.51 (54.01)	64.71 (53.53)	64.44 (53.37)	64.66 (53.50)
Soil: Sand: Fym (1:1:1)	74.11 (59.39)	75.01 (59.98)	76.06 (60.68)	76.44 (60.93)	75.40 (60.24)
Soil: Sand: VC (1:1:1)	76.08 (60.69)	77.11 (61.39)	77.51 (61.66)	79.48 (63.16)	77.54 (61.73)
Mean	71.40	72.57	72.76	73.45	

Figures in parenthesis are transformed (angular) values, fym: Farm Yard Manure, vc: Vermicompost
CD (p=0.05)- Container size = N S, media= 0.93, container size x media = N S

Table 3. Effect of plant container size and potting media on above ground parameters of the seedlings

Media	Characteristic	Container size				Mean
		Root trainer 250 cc	Root trainer 300 cc	Polybag 16cm x 24cm	Polybag 23cm x 28cm	
Soil only	SH	20.20	24.23	32.23	35.04	27.92
	CD	3.33	4.13	6.73	7.23	5.35
	NL	12.47	17.29	21.77	25.22	19.18
	FSW	5.35	7.18	14.25	18.18	11.24
	DSW	0.97	2.21	3.27	4.08	2.46
Soil: Sand: Fym (1:1:1)	SH	24.11	28.20	37.30	43.10	33.17
	CD	4.34	5.26	7.36	9.10	6.51
	NL	14.40	18.39	23.66	29.40	21.46
	FSW	8.30	10.20	18.02	25.37	15.47
	DSW	1.87	2.21	4.51	6.10	3.67
Soil: Sand: VC (1:1:1)	SH	25.66	30.26	39.44	45.91	35.31
	CD	5.30	6.10	7.85	9.65	7.22
	NL	15.77	20.66	26.33	32.77	23.88
	FSW	10.52	12.37	21.52	32.32	19.18
	DSW	2.26	3.14	5.05	7.94	4.59
Mean	SH	23.32	27.56	36.32	41.35	
	CD	4.32	5.16	7.31	8.66	
	NL	14.21	18.78	23.92	29.13	
	FSW	8.05	9.91	17.93	25.29	
	DSW	1.70	2.29	4.27	6.04	

SH: Shoot height (cm), CD: Collar Diameter (mm), NL: Number of leaves, FSH- Fresh shoot weight (g), DSW- Dry shoot weight (g)

CD (p=0.05):
SH   : Container size= 0.12, Media= 0.10, Container size x Media= 0.21
CD   : Container size= 0.12, Media= 0.10, Container size x Media= 0.20
NL   : Container size= 0.10, Media= 0.09, Container size x Media= 0.18
FSW   : Container size= 0.16, Media= 0.14, Container size x Media= 0.28
DSW   : Container size= 0.10, Media= 0.09, Container size x Media= 0.18

Table 4. Effect of plant container size and potting media on belowground parameters of seedlings

Media	Characteristic	Container size				Mean
		Root trainer 250 cc	Root trainer 300 cc	Polybag 16cm x 24cm	Polybag 23cm x 28cm	
Soil only	LPR	10.23	16.14	23.52	30.39	20.07
	NSR	45.46	56.79	75.99	83.18	65.35
	FRW	2.54	4.66	8.50	11.38	6.77
	DRW	0.55	0.95	1.96	2.73	1.54
Soil: Sand: Fym (1:1:1)	LPR	13.11	20.10	30.29	35.10	24.65
	NSR	57.21	65.25	91.77	112.66	81.72
	FRW	5.02	9.30	14.01	20.08	12.10
	DRW	1.01	2.06	3.19	4.51	2.69
Soil: Sand: VC (1:1:1)	LPR	11.07	18.77	28.17	27.73	21.43
	NSR	55.19	63.05	96.33	106.33	80.22
	FRW	6.51	9.11	14.52	21.20	12.83
	DRW	1.45	1.95	3.56	5.03	2.99
Mean	LPR	11.47	18.33	27.32	31.07	
	NSR	52.62	61.69	88.03	100.72	
	FRW	4.69	7.69	12.34	17.55	
	DRW	1.00	1.65	2.90	4.09	

LPR: Length of primary root (cm), NSR: Number of secondary roots, FRW: Fresh root weight (g), DRW- Dry root weight (g), fym: Farm Yard Manure, vc: Vermicompost,

CD (p=0.05)
LPR   : Container size=0.09, Media=0.08, Container size x Media= 0.15
NSR   : Container size=0.18, Media=0.16, Container size x Media= 0.31
FRW   : Container size=0.04, Media=0.04 , Container size x Media= 0.07
DRW   : Container size= 0.13, Media=0.11, Container size x Media= 0.23

highest fresh(53.52 g), dry weight of seedling (12.97 g) and seedling quality index (2.05) which was statistically superior to all other interactions. However, the root:shoot ratio was highest (0.93) in interaction root trainer (300 cc) x soil:sand:fym (1:1:1) which was followed by polybag (23 cm x 28 cm) x soil:sand:fym (1:1:1) (Table 5). The highest sturdiness quotient (6.06) in root trainer (250 cc) x soil interaction was significantly higher than the remaining combinations.

The increase (except root:shoot ration and sturdiness quotient)in growth parameters with increase in container size in the current study could be attributed to more growing media and space for root development, more water retention and availability of more quantity of nutrients. Ferdousee et al (2011) also reported an increase in seed germination percentage, seedling height, collar diameter, leaf number, root length, seedling fresh and dry weight and seedling quality index with increase in container size in *Leucaena leucocephala*. Tian et al (2017) also reported higher seedling height, collar diameter, length of total root and seedling biomass in large sized containers in *Cyclocarya paliurus* under open-sided sheds with shading net in China. With respect to media, the studied parameters (seed germination percentage, seedling height, collar diameter, number of leaves, shoot and root weight and seedling quality index) followed a decreasing trend in the present study: soil:sand:VC, 1:1:1 >soil:sand: FYM,1:1:1>soil only. Devaranavadgi et al (2010) and Mugloo et al (2015) also reported similar findings in case of *Acacia nilotica* seedlings and *Picea smithiana* in their experiments in India at University of Agricultural Sciences, Karnataka and Sher-e-Kashmir University of Agricultural Sciences and Technology, Kashsmir, respectively. The possible reason could that vermicompost possess higher nutrient content than FYM (Sahrawat et al 2004; Sivasankari et al 2010). The analysis of these media in current study also revealed higher contents of available N, P and K in soil:sand:vc (1:1:1) than soil:sand:fym (1:1:1) and soil only, respectively (Table 1). However, length of primary root, number of secondary roots and root:shoot ratio first increased from soil only to soil:sand:fym (1:1:1) and subsequently decreased in soil:sand:vc (1:1:1). This may be possibly due to the fact that media containing soil:sand:fym (1:1:1) could have higher aeration porosity leading to longer primary root and more number of secondary roots. The sturdiness quotient was highest in soil only than in soil:sand:fym (1:1:1) and soil:sand:vc (1:1:1). Similar results were observed by Annapurna et al (2004) in *Santalum album* seedlings under nursery conditions at Division of Tree

Table 5. Effect of plant container size and potting media on various underground parts

Media	Characteristic	Container Size				Mean
		Root trainer 250 cc	Root trainer 300 cc	Polybag 16cm x 24cm	Polybag 23cm x 28cm	
Soil only	TFWS	7.89	11.84	22.75	29.56	18.01
	TDWS	1.52	2.48	5.23	6.81	4.01
	R:S	0.56	0.62	0.59	0.66	0.60
	SQ	6.06	5.86	4.78	4.84	5.38
	SQI	0.19	0.33	0.81	1.07	0.60
Soil: Sand: Fym (1:1:1)	TFWS	13.32	19.50	32.03	45.45	27.57
	TDWS	2.88	4.27	7.70	10.61	7.59
	R:S	0.54	0.93	0.70	0.73	0.72
	SQ	5.31	5.36	5.06	4.73	5.11
	SQI	0.40	0.66	1.45	1.74	0.99
Soil: Sand: VC (1:1:1)	TFWS	17.03	21.48	36.04	53.52	32.01
	TDWS	3.71	5.09	8.61	12.97	6.36
	R:S	0.64	0.62	0.70	0.63	0.64
	SQ	4.84	4.96	5.02	4.75	4.89
	SQI	0.58	0.77	1.33	2.05	1.18
Mean	TFWS	12.74	17.60	30.27	42.84	
	TDWS	2.70	3.94	7.18	10.13	
	R:S	0.58	0.72	0.66	0.67	
	SQ	5.40	5.39	4.95	4.77	
	SQI	0.39	0.58	1.11	1.62	

TFWS: Total fresh weight of seedling (g), TDWS-Total dry weight of seedling (g), R:S- Root:shoot ratio, SQ: Sturdiness quotient , SQI: Seedling quality index, fym: Farm Yard Manure, vc: Vermicompost

CD (p=0.05)
TFWS : Container size= 0.18, Media=0.15 , Container size x Media= 0.30
TDWS : Container size=0.02, Media= 0.02, Container size x Media= 0.04
R:S : Container size=0.02, Media= 0.01, Container size x Media= 0.03
SQ : Container size=0.05, Media= 0.04, Container size x Media= 0.08
SQI : Container size=0.02, Media= 0.02, Container size x Media= 0.03

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CONCLUSION

The container size, potting media and interaction influenced a majority of growth parameters. Plantable quality seedlings of *Oroxylum indicum* can be obtained in six months of sowing in large sized containers i.e. polybags (23cm x 28 cm) and potting media of soil:sand: VC (1:1:1). Further studies needs to be done to analyse the physico-chemical properties of the media to justify whether media soil:sand: vc (1:1:1) in polybags (23cm x 28 cm) have better physico-chemical properties and nutrient content that the remaining.

REFERENCES

Agarwal S 1999. *Study of Vermicomposting of Domestic Waste and Effects of Vermicompost on Growth of Some Vegetable Crops.* Ph.D. Thesis, University of Rajasthan, Jaipur, India.

Annapurna D, Rathore, TS and Joshi, G 2007. Effect of potting medium ingredients and sieve size on the growth of seedlings of Sandal wood (*Santalum album* L.) in root trainers. *Indian Forester* **130**(3): 323-332.

Annapurna D, Rathore TS and Joshi G 2004. Effect of container type and size on the growth and quality of seedlings of Indian sandal wood (*Santalum album* L.). *Australian Journal of Forestry* **67**(2): 310-312.

Anonymous 2013. Seedling quality. www.worldagroforestrycentre. org/NurseryManuals/ Community/SeedQuality.pdf. (accessed on 04.03.2018).

Chadha KL and Rajender G 1995. *Advances in Horticulture: Medicinal and Aromatic Plants*. Vol 11, Malhotra Publishing House, Delhi, India.

Chapin FS, Zaveleta ES, Eviner VT, Naylor RL, Vitousek PM and Lavorel S 2000. Consequences of changing biotic diversity. *Nature* **405**(3): 234-242.

Chauhan SK and Sharma R 1997. Seedling quality evaluation: Importance in afforestation. *Advances in Forestry Research in India* **17:** 59-72.

Devaranavadgi SB, Patil SB, Jambagi MB, Wali SY and Kambrekar DN. 2010. Influence of various potting mixtures on germination and root length of three species in vertisols of northern Karnataka. *Karnataka Journal of Agricultural Sciences* **23**(4): 663-664.

Dickson A, Leaf AL and Hosner JF 1960. Quality appraisal of white spruce and white pine seedling stock in nurseries. *Forestry Chronicle* **36**(4): 10-13.

Dwivedi AP 2006. *A Text Book of Silviculture*. Prashant Gahlot at Valley Offset Printers and Publishers, Dehra Dun, India.

FAO 2015. World deforestation slows down as more forests are better managed. News Article. www.fao.org/news/story/en/item/326911/icode/FAO. (accessed on 7.03.2018).

Ferdousee N, Jabbar F, Hossain MK and Hoque TMR 2011. Comparative growth performance of *Leucaena leucocephala* seedlings raised in nursery bed, polybag and root trainers. *International Journal of Environment* **1**(1): 14-20.

Gera M, Gera N, Bhandari AS and Pant NC 2000. Improved seedling quality of polybag plants of *Albizia procera*- use of mounted angle iron beds. *Indian Forester* **126**(9): 943-946.

Gokhle M and Bansal YK 2006. An avowal of importance of endangered tree *Oroxylum indicum* (Linn.) Vent. *Indian Journal of Natural Products and Resources* **5**(2): 112-114.

Gomez KA and Gomez AA 1984. *Statistical Procedures for Agricultural Research*. John Willey and Sons, New York, U.S.A.

Jackson ML 1973. *Soil Chemical Analysis*. Prentice Hall of India Pvt. Ltd., New Delhi.

Kala CP 2000. Status and conservation of rare and endangered medicinal plant in the Indian *Trans-Himalaya. Biological Conservation* **93**(3): 371-379.

Megna, R, Rasool M, Lal SB, Masoodi L and Mehboob S 2018. Effect of root trainers size ion quality of seedling production of *Jatropha carcus. Journal of Pharmacognosy and Phytochemistry* **7**(1): 1551-1554.

Mugloo JA, Khan PA, Mughal AH, Qasir KN, Zaffar SN and Parrey G 2015. Studies on refinement of container size and potting mixture for production of quality seedlings in Spruce (*Picea smithiana* Wall. Boiss). *Open Journal of Forestry* **5**: 733-739.

Nayar MP and Sastry ARK 1987. *Red Data of Indian Plants.* Vol 3. Botanical Survey of India, Calcutta, India.

Olsen, S.R., Cole, C.V., Watnabe, F.S., Dean, L.A. 1954. Estimation of available phosphorus in soils by extraction with sodium bicarbonate. Circular No. 939. Department of Agriculture, U.S.A.

Parle M and Bansal N 2006. Traditional medicinal formulation, Chyawanprash. A review*. Indian Journal of Traditional Knowledge* **5**(4): 484-488.

Ramankutty C, Warrier PK and Nambiar VPK 1995. *Oroxylum indicum. Indian Medicinal Plants* **4**(2): 186-190.

Rana RS and Sood KK 2012. Effect of cutting diameter and hormonal application on the propagation of *Ficusroxburghii* Wall. through branch cutting. *Annals of Forest Research* **55**(1): 69-84.

Roller KJ 1977. *Suggested minimum standards for containerised seedlings in Nova Scotia.* Report, Canadian Forestry Service Department of Environment Information. Frederiction, New Brunswisk, Canada.

Sahrawat KL, Nagavallemma KP, Wani SP, Stephane L, Padmaja VV, Vineela C and Babu R 2004. *Vermicomposting: recycling wastes into the valuable organic fertilizer*. Global Theme on Agriecosystems Report No. 8. pp 1-2. International Crops Research Institute for the Semi Arid Tropics, Andhra Pradesh, India.

Shah P, Singh K and Tiwari S 2007. In-vitro propagation of *Oroxylum indicum*-An endangered medicinal tree.*Biotechnology* **6**(2): 299-301.

Sivasankari B, Anitha WR and Thilagaverthy D 2010. Effect and application of vermicompost prepared from leaf materials on growth of *Vigna unguiculata* L. Walp. *Journal of Pure and Applied Microbiology* **4**(2): 889-898.

Subbiah BV and Asija GL 1956. A rapid procedure for estimation of available nitrogen in soil. *Current Science* **25**(2): 259-260.

Tian N, Fang S, Yang W, Shang X and Fu X 2017. Influence of container type and growth medium on seedling growth and root morphology of *Cyclocarya paliurus* during nursery culture. *Forests* **8**(10): 387.

World Health Organization (WHO) 2002. *WHO Traditional Medicine Strategy 2002-2005*. World Health Organization, Geneva.

Determination of Synergistic, Antagonistic effects of Pesticides and Co-toxicity Co-efficent

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Abstract: The interactions of the pesticides were analysed by co-toxicity coefficients and through the plotting of isobologram of the LD_{50} values. The co-toxicity of imidacloprid + atrazine ratios of 1:1 and 10:1 showed synergistic effects having the co-toxicity coefficients values of 122, 104 and 107, 116 for 6 and 24 hours, respectively whereas the 1:10 ratio showed antagonistic effects having co-toxicity coefficient values of 25 and 28 for 6 and 24 hours, respectively. The toxicity of imidacloprid + nicotine ratios of 1:1 showed synergistic effect with co-toxicity coefficient value of 136 for 6 hour, whereas 1:10 and 10:1 showed antagonism having co-toxicity coefficient values of 96 and 78 for the same 6h. In 24 hours, there were variations for 1:1 and 10:1 ratios showed antagonistic effect with co-toxicity coefficients of 66 and 57 respectively. The changes were in 10:1 ratio, which changed from being antagonism in 6 hour to synergism in 24h with co-toxicity coefficient of 111.

Keywords: Synergistic, Antagonistic, Pesticides, Co- toxicity

One of the suggested methods to slow down the development of resistance to insecticides by targeted insects is the use of synergists. According to Busvine (1971) Synergist is defined as a chemical that is not toxic itself but blocks one of the steps involved in the detoxification of the pesticide. In contrast other sources defined synergism as two effective (active) chemical agents rather than one involved in interactions (Plapp1979 and Berenbaum 1989). Report by Hayes et al (2002) revealed that high doses of atrazine induce abnormalities and deformities in non-target organisms and in addition, atrazine has shown to act synergistically with organo-phosorothioates chloropyrifos, methyl parathion and diazinon thereby increasing the toxicity of these organo-phosphorothioates to aquatic midge larvae *Chironomus tentans*.

The testing of synergism between insecticides and herbicide to determine the effects of age of pesticide, soil residue, soil type and turbulent water was tested by Lichtenstein and Liang (1974). The herbicides was applied to glass surfaces, however, when they were added to soils there was significant reduction in the toxicity of the insecticides and in the synergistic effect of atrazine to *D. melanogaster* and within four days the effects of atrazine as a synergist had declined and this reduction was seen again when soil was added to with parathion. It was concluded that presence of certain environmental conditions greatly influences the synergistic effects of herbicides and insecticides. Synergism in *Artemia Salina* was investigated by Wilkins and Metcalfe

1993. In their work they stated that the synergistic action of various insecticides and herbicides, plus caffeine on high risk aquatic crustacean was investigated by using the herbicides simazine, atrazine, bromacil, the OP Malathion and the carbamate carbofuran. It was found that there were high levels of synergism between these two groups as well as caffeine showed high level of synergism.

Pesticides create problems for both terrestrial and aquatic environment. The increasing and continuous use of pesticides especially in the tropical agriculture is a major concern about accumulation of residues in the soil, food crops, ground and surface water and also its effect on human health. It has been identified that the accumulations of pesticides in the soils and watercourses have ecological consequences. These ecological consequences include effects on non-targeted aquatic organisms such as fish and shrimps populations.

Organisms may take up pesticides through ingestion of food and water, respiration and through contact with skin. The pesticide that crosses the various barriers of the body reaches the metabolizing tissue or a storage organ. Toxicity of a chemical is usually expressed as the effective concentration or dose of the material that would produce a specified effect in 50% of a large population of a test species (EC_{50} or ED_{50}). If the effect recorded is death, the terms LC_{50} and LD_{50} are used. The no observed effect level or concentration (NOEL or NOEC) is the dosage level eliciting any type of toxicological response in the study (Severn and Ballard

1990). Smith and Krischik (1999) stated that the effect of imidacloprid on several non-target insects showed that the predator *Orius tristicolor* (white) suffered higher mortality when confined with imidacloprid treated foliage than when confined with untreated foliage. Anderson and Zhu (2004) evaluated two organophosphorodithioate and in binary combination with the herbicide atrazine using fourth –instar larvae of the aquatic midge, *Chironomus tent* indicated an increased toxicity of dimethoate, disulfoton, and demeton-s-methyl in binary combination with atrazine correlated to the increased inhibition of acetyl cholinesterase. Furthermore, cytochrome P450-dependent O-deethylation activity in the midges exposed to atrazine at 1000g l^{-1} was 1.5-fold higher than that in the control midges. The presence of mixtures of pesticides and metabolites in certain parts of the environment especially soils, surface and ground waters is continually documented (Bush way et al 1992). The reaction of organisms to these mixtures may not be true of many combinations evidence emerging of possible detrimental interaction with herbicides in the case of invertebrate animals (Douglas et al 2003).

. There is evidence of adverse effects of pesticides on the soil micro flora which has a critical role in the maintenance of soil fertility and the affected soil organisms can be replaced by more resistant ones (Gerber et al 1989). However, it is difficult to predict the long term effects of such structural changes in the micro flora, as they may lead to changes in the occurrence of soil borne pathogens (Elmholt et al 1991). Pimentel et al (1993) stated that aquatic toxicity of pesticides is often assessed by determining toxicity to algae, crustaceans and fish. Data on aquatic toxicity are available from most pesticides (Linder and Luttik 1995). The evaluation of Eco toxicity of substances is complicated because it involves thousands of different species that react differently when exposed to insecticides. Therefore the objecttives of the study were to determine the synergism, antagonism between imidacloprid and atrazine and to test hypothesis that the mixture of these pesticides are synergistic or antagonistic.

MATERIAL AND METHODS

Synergism of imidacloprid and atrazine, imidacloprid and nicotine were determined in the ratio of 1:1, 1:10 and 10:1 respectively. The stock preparation were carried out by weighing 2.0 mg of imidacloprid and 2.0 mg of atrazine and dissolved in 2 ml of acetone and serial dilution of five concentrations and control were prepared. In 1:10 and 10:1 ratios due to limited stock 1mg of each of the pesticides were dissolved in 5ml to give 0.2mg/ml. Then 1ml of this solution was pipette and added to 2.0mg of each of the pesticides and these gave the ratio of 200: 2000 (1 imidacloprid: 10

atrazine), 2000: 200 (10 imidacloprid: 1atrazine). In imidacloprid and nicotine where there is plenty of stock, the mass ratio 1:1, 1:10 and 10:1 weighed and serial dilution prepared.

The term co-toxicity co-efficient and synergistic ratio (SR) which are commonly used to calculate any synergistic or antagonistic effect that occur in a mixture, were used in the study. The co-toxicity coefficient as described by Sun and Johnson (1960) is calculated by the following formula: co-toxicity coefficient = (LD_{50} of the toxicant alone/ LD_{50} of the toxicant in the presence of synergist) x100. A co-toxicity coefficient of 100 indicates that there is not any interaction effect within the mixture while values in excess of 100 and below indicates the occurrence of synergistic and antagonistic effects respectively. The synergistic ratio, as defined in Busvine (1971) is the ratio of the quixotic dose of an insecticide alone to an equivalent dose in the presence of synergists and may be calculated by the following formula: Synergistic ratio equal to LD_{50} of the toxicant alone / LD_{50} of the mixture. Thus synergistic ratio bears the relation with co-toxicity coefficient.

Construction of isobologram: The isobole method as described by Hewlett and Placket (1979) was used to determine whether or not an interaction occurred in the mixtures. According to Berenbaum (1989) below the zero –interaction isobole of the mixture indicates synergism, whilst a point above zero indicates antagonism and also the isobole point that lies on the zero interaction indicates a zero –interactive mixture (addictives).

RESULTS AND DISCUSSION

Interaction of imidacloprid –atrazine ratios: The imidacloprid was considered as toxicant while atrazine is inhibitor. The interaction of imidacloprid +atrazine ratios of 1:1 and 10:1 indicated co-toxicity coefficient of 122 and 104 respectively for 6 hours and also in 24.hour, the co-toxicity coefficient values for 1:1and 10:1 are 107 and 116 respectively. This showed a moderate synergistic effect whereas 1:10 ratio for 6 and 24 hours indicated antagonistic effects with co-toxicity values of 25 and 28 respectively. This is in agreement with Sun and Johnson (1960) who stated that co-toxicity coefficient above 100 indicated synergistic effects while values below 100 indicates antagonistic effects. This synergism at these ratios may be because the herbicides may inhibit the metabolism of the insecticides so making it more lethal. The moderate synergism may be as a result of fast degradation of imidacloprid and also because the as the organisms absorbed the chemicals, they die and their body decays and these may have affected the result of this study. This result showed similar action in the environment although

the quantity of pesticides used cannot exist in the environment due to many factors such as leaching and volatilization into the atmosphere. Some herbicides and their depredates are as toxic or even more than their parent compounds (Kolpin et al 1998). In 10:1 ratio where atrazine dominated imidacloprid, the fast degradation of imidacloprid may have occurred leaving only atrazine and this may have resulted in antagonistic effect (Bush way et al 1992) .

Construction of Isobologram for imidacloprid –atrazine: The LD_{50} of imidacloprid and atrazine were calculated separately and in addition to the LD_{50} of imidacloprid mixed with atrazine in 1:1, 1:10 and 10:1 ratio were also calculated considering atrazine as an inhibitor the isobologram was constructed for the 6 and 24 hours. Also the results of these calculations are presented in Table 1, Fig 1 and 2 for the 6 and 24 hours.

Interaction of imidacloprid + nicotine ratios: The interaction is between two toxicants but the nicotine acted as synergists. The interaction between imidacloprid and nicotine ratios of 1:1 showed synergism at 6-hour with co-toxicity coefficient value of 136 whereas the ratios of 1: 10 and 10:1 showed antagonism with co-toxicity coefficient values of 96 and 78 respectively. At 24-hour, the data changed from synergism to antagonism for the ratio of 1:1 whereas 1:10 ration remained antagonist with co-toxicity coefficient values of 66 and 57 respectively. It was the ratio of 10:1 that showed synergism with co-toxicity coefficient value of 111. This data did not producing convincing results and therefore the result is doubtful. This is because the two chemicals were highly toxic on their own and have similar mode of action and was expected produce high synergistic effect. This is in agreement with Berenbaum, (1989). This may also have occurred because the two chemicals (imidacloprid and nicotine) inhibit the function of insect acetylcholine receptor (AchR). The fast degradation of imidacloprid, excretion and absorption rate of the compounds may have affected the result (Douglas et al 2003).

Construction of Isobologram for Imidacloprid –Nicotine: Having already calculated the LD_{50} of imidacloprid, nicotine and their mixtures in 1:1, 1:10 and 10:1 mass ratios, the isobologram of imidacloprid –nicotine for 6 and 24 hours were constructed and presented in the following tables and graphs. Furthermore, the co-toxicity coefficient and synergistic ratios of the mixtures were calculated.
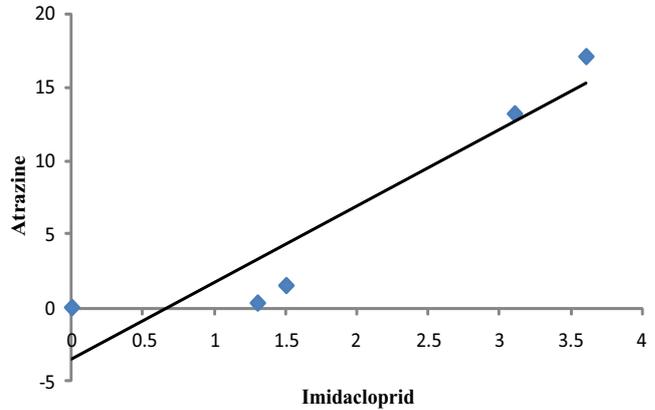

Fig. 1. 6-Hour isobologram for imidacloprid

Co-toxicity Coefficient of 1:1=122, 1:10=25 and 10:1=104.
Synergistic ratios of 1:1=1.22, 1:10=0.25 and 10:1=1.04
In 1.1 and 10.1 ratios indicate synergistic effects as the values are greater than 100 whilst 1:10 ratio indicates antagonistic effect as the value is less than 100.
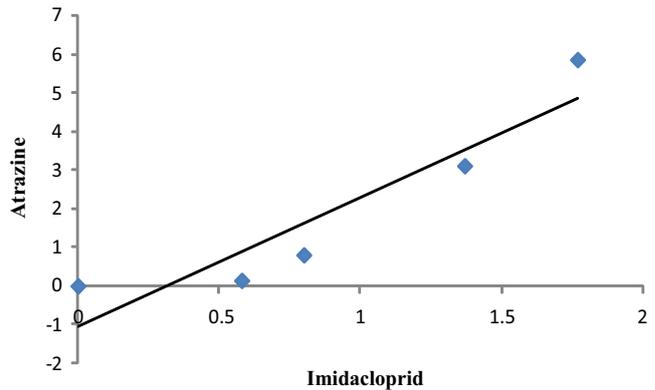

**Fig. 2.** 24-Hour isobologram for imidacloprid +atrazine

Co-toxicity co-efficient of 1:1 =107, 1:10=28 and 10:1=116.
Synergistic ratios of 1:1 = 1.07, 1:10=0.28 and 10:1=1.16.
There is no relationship between the points on the graph and as such makes the data doubtful but these statistical calculations showed exactly representation of mixtures.
In 1.1 and 10.1 ratios indicate synergistic effects as the values are greater than 100 whilst 1:10 ratio indicates antagonistic effect as the value is less than 100.

Table 1. 6 and 24- hours isobologram for Imidacloprid +Atrazine

Pesticides / Mixtures	6 hour		24 hour	
	Atrazine LD_{50} (PPM)	Imidacloprid LD_{50}(PPM)	Atrazine LD_{50}(PPM)	Imidacloprid LD_{50}(PPM)
Atrazine	0.0	3.6	0.00	1.77
Imidacloprid	17.1	0.0	3.1	0.00
Imidacloprid + Atrazine 1:1	1.5	1.5	0.8	0.8
Imidacloprid + Atrazine 1:10	13.2	1.3	5.84	0.58
Imidacloprid + Atrazine 10:1	0.31	3.1	0.14	1.37

Table 2. 6 and 24- hours isobologram for Nicotine + Imidacloprid

Pesticides / Mixtures	6hour		24 hour	
	Nicotine LD_{50} (PPM)	Imidacloprid LD_{50}(PPM)	Nicotine LD_{50}(PPM)	Imidacloprid LD_{50}(PPM)
Nicotine	0.00	3.58	0.00	1.77
Imidacloprid	3.73	0,00	2.49	0.00
Imidacloprid + Nicotine 1:1	1.32	1.32	1.35	1.35
Imidacloprid + Nicotine 1:10	3.38	0.34	2.81	0.28
Imidacloprid + Nicotine 10:1	0.42	4.15	0.15	1.45
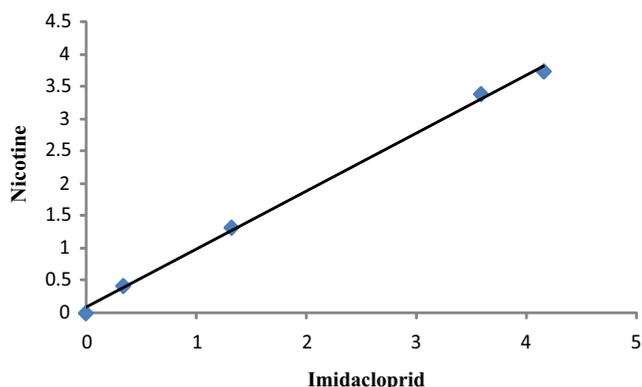
Fig. 3. 6-Hour isobologram of imidacloprid +nicotine

Co-toxicity coefficient for1:1=136, 1:10=96 and 10:1=78.
Synergistic ratio for1:1=1.36, 1:10=0.96 and 10:1=0.78
As we can see from the above graph, there is no relationship between the points and such makes the date doubtful but the statistical showed exact representation of the mixtures. Synergism only occurred in 1:1 ratio having co-toxicity coefficient value greater than 100. In 1:10 and 10:1 ratios indicate antagonistic effects as the co-toxicity values are less than 100.
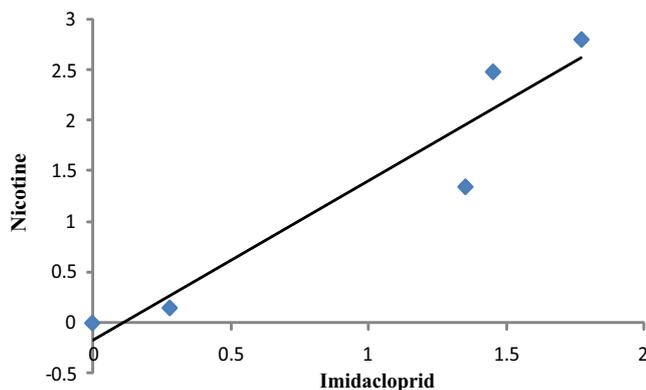
Fig. 4. 24-Hour isobologram of imidacloprid +nicotine

Co-toxicity coefficient for 1: 1 =66, 1:10=57 and 10:1=111.
Synergistic ratio for 1:1 =0.66, 1:10= 0.57 and 10:1=1.12
As we can see from the above graph, there is no relationship between the points and such the data is doubtful but statistical calculations represent exactly the point of the mixtures. In 1:1 and 1:10 indicate antagonistic effects as the co-toxicity values are less than 100 while   10:1 ratio indicate synergistic effect as the value is greater than 100.

CONCLUSION

The interaction between imidacloprid and atrazine indicated moderate synergistic effect for 6 and 24-h of exposure occurring at different ratios whereas one ratio in each of 6 and 24-h indicated antagonistic effect. In contrast the interaction between imidacloprid and nicotine indicated opposite of the result having only one ratio in each of 6 and 24-h showing synergistic effect whereas the rest of the mixtures showed antagonistic effect.

REFERENCES

Anderson TD and Zhu KY 2004. Synergistic and antagonistic effect of atrazine on the Toxicity of Organophosphorodithioate and organosphophorothioate insecticides to Chironomustentans (Diptera: Chironomidae. *Pesticide Biochemistry and Physiology* **80**: 54-64.

Berenbaum MC 1989 .What is synergy/? Pharmacological Reviews by the American Society for *Pharmacology and Experimental Therapeutics* **41:** 93-103.

Bushway RJ, Hurst HL, Perkins LB, Tian L, Cabanillas CG, Young BEJ, Ferguson BS and Jennings HS 1992. Atrazine, alachlor and Carbon furan Contamination of well water in Marine. *Bulletin of Environmental contamination and Toxicology* **49**:1-9.

Busvine JR 1971. A critical review of the techniques for testing insecticides. 2nd edition. Commonwealth Agricultural Bureaux, England, pp. 267-283.

Douglas WS, Macmtosh A and Clausen JC 2003. Toxicity of Sediments Contains atrazine and Carbon furan to larvae of the Midge Chironomus tentans. *Environmental Toxicology and Chemistry* **12:** 847-853.

Elmholt S, Frisvad JC and Thrane U 1991. The influence of fungicide effects on soil Mycoflora with special attention to tests of fungicide effects on soil –borne pathogens. pp. 227-243. In: J.Altman, Pesticide Interaction in Crop Production. *Beneficial and Deleterious Effects*. CRC press, Boca Raton, FL.

Gerber HR, Anderson JPE, Bugel-Mogensen B, Castle D, Domsch KH, Malkomes HP, Arnold DJ, van de Werf H, Verbrken R and Vonk JW 1989. Revision of Recommended laboratory tests for assessing side effects of pesticides on the soil micro-flora. 4th International Workshop, Basle, Braunschweig.

Hayes TB, Collins A, Lee M, Mendoza N, Noriega AA, Stuart and Vonk A 2002. Hermaphroditic demasculinized frogs after exposure to herbicide atrazine at low Ecologically relevant. *Proceeding of the National Academy of Science,* USA **99**: 5476-5480.

Hewlett PS and Placket RL 1979. An introduction to the interpretation of Quantal Responses in Biology, Edward Arnold publishers, London, 40-41.

Kolpin DW, Thurman EM and Linhart SM 1998. The environmental occurrence of herbicide: The importance of degrades inground water. *Archives Environmental Contamination Toxicology* **35**: 385-390.

Lichtenstein EP and Liang TT 1974. Synergism of insecticides. *Science* **186**: 1128-1130.

Linders JBHJ and Luttik R 1995. Uniform system for the evaluation of substances. ESPE, Risk assessment for pesticides. *Chemosphere* **31**: 3237-3248.

Pimentel D, Lori MA, Zepp BL, Tamara KP, Kleinman FV, John R, Ellen G, William S and Keeton GS 1993. Environmental and economic effects of reducing pesticide use in agriculture. *Agriculture, Ecosystems and Environment* **46:** 273-288.

Plapp FW 1979. Synergism of Pyrethriod insecticides by formamidine against Heliothis pest of cotton. *Journal of Economical Entomology* **72**(5): 662-679.

Severn DJ and Ballard G 1990. Risk / benefit and regulation .In: *Pesticides in the Soil Environment*. Book Series No2 *Soil Science Society of America*. Madison WI. 467-491.

Smith SF and Krischik VA 1999. Effect of systemic Imidachloprid on Coleomegilla maculata (Coleoptera-Coccinellidae). *Environmental Entomology* **28**(6): 1189-1195.

Sun YP and Johnson ER 1960. Analysis of joint action of insecticide against house flies. *Journal of Economical Entomology* **53:** 887.

Wilkins RM and Metcalfe RJ 1993. Toxicity of soil applied herbicides to brine shrimp larvae (*Artemia salina*) and synergism with other pesticides. Brighton Crop Production. Conference –Weed.

Effects of Micro-credit Policy on Fishery Agribusiness in Abakaliki Local Government Area of Ebonyi State, Nigeria

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Abstract: Simplification of operational procedures in credit administration to reduce cost and bureaucracy, as well as modification of the terms of financing under most policy initiatives in developing countries like Nigeria calls for concern. This study adopted a total sampling of 41 fishery agribusiness farmers from where data were collected with the aid of a well-structured questionnaire guided by interview schedule. Both descriptive and inferential statistical tools were used in data analysis. The socioeconomic characteristics of the fishery agribusiness farmers contributed about 61% in utilization of microcredit, as 73 and 70 per cent was a result of the combined influence of microcredit policies on access and utilization of microcredit. The major constraints to credit accessibility among fishery agribusiness farmers were credit policy, lack of information on availability of credit, illiteracy, inadequate information on credit accessibility and distance to source of credit. The study recommended that government should involve or consult the farmers during policy formulation; the government through the central bank of Nigeria and Nigeria deposit insurance cooperation should simplify operational procedures of microcredit institutions in credit administration to reduce cost and bureaucracy; farmers should be organized into functional co-operatives to meet up with microcredit policies as required by microcredit institutions amongst others.

Keywords: Micro-credit, Policy, Fishery agribusiness, Accessibility, Utilization, Microfinance institutions

One of the vital concerns of economists is how to ensure credit delivery to the agricultural sector with minimum difficulties in order to enhance maximum production of all agro-produce especially small scale agribusiness (Atagana and Kalu 2014). Credit is an important instrument for improving the welfare of the poor directly through consumption smoothing that reduces their vulnerability to short term income (Olatinwo Lawal and Ayojide 2012, Obisesan 2013 and Filli et al 2015). Microcredit is a process of providing financial service to the poor who are traditionally not served by the conventional financial institutions (Danso-Abbeam et al 2016 and Iderawumi and Ademola 2015). Credit policy can be defined as the totality of the entire range of activities carried out by a credit granting institution that have to do with selecting borrowers, determining the type of loan to be granted, the loan amount and maturity and the way in which the loan is to be secured, as well as the monitoring and recovery of loans (Tietze 2003). Credit policy can also be referred to as lending policy or criteria for obtaining loan from any financial institution (Lawal et al 2009). The basic policy which guides the agricultural sector in Nigeria is the new Agricultural Policy 2016, which is referred to as the Agriculture Promotion Policy. The policy centers on building on the successes of the agricultural transformation agenda, closing key gaps. As a consequence of gross under performance of credit outreach institutions, the CBN also implemented a micro credit policy, regulatory and supervisory framework (MFPRSF) in 2005.

The policy outlines government position/policy on commodity pricing, agricultural trade, exchange rate, agricultural land, food production, industrial raw material, crops, agricultural extension, agricultural credit and insurance, rural bank deposits, produce marketing, commodity storage and processing, agricultural cooperatives, water resources development, agricultural mechanization, rural infrastructure, agricultural statistics, agricultural investment and advisory services, whose supply and prices affects the profitability of agricultural business, research and development. Making credit available to fishery agribusiness farmers is considered essential in alleviating poverty and promoting economic development since credit is viewed as a significant input in agricultural production (Chisasa and Makina 2013). Although informal credit markets operate widely in rural areas, money lenders typically charge high interest rates and enter into exploitative relationships, inhibiting the rural poor from investing in production and income generation activities.

Despite these policies, fishery agribusiness is lagging behind in contributing to the economy of Nigeria due to lack of stable national credit policy and paucity of credit institutions which can assist farmers (Afolabi 2008). This posture is premised on the feeling that most fish farmers especially the

small scale ones are low income earners and cannot meet the credit policy requirement of the financial institutions such as demand for collaterals, their low savings capacity, lack of farm records and illiteracy, high rate of loan diversion among others on the part of the farmers. In order to provide solutions to the problem, the study described the socio-economic characteristics of fishery agribusiness farmers that benefited from micro-credit in the study area, determined the effects of socio-economic characteristics of the fishery agribusiness farmers on credit utilization, identified the major micro credit policies and its effects on fishery agribusiness; and analysed the constraints to credit accessibility by fishery agribusiness farmers in the study area.

Hypotheses

H_{o1}: The Socioeconomic characteristics of the fishery agribusiness farmers do not significantly affect their credit utilization in the study area.

H_{o2}: Microcredit policy has no significant effects on credit utilization of fishery agribusiness farmers

H_{o3}: Microcredit policy has no significant effects on amount of credit accessed by the fishery agribusiness farmers

MATERIAL AND METHODS

The study was carried out in Abakaliki Local Government Area of Ebonyi State, Nigeria. The area lies on longitude 6°45' North and latitude 8°65' East in the derived savanna of the south-east agro-ecological zone and has a landmass of 106 Km^2 and a population of 206343 (NPC 2018). The area has a total of 41 registered fishery agribusiness farmers (Federal Ministry of Agriculture 2016). A well-structured questionnaire augmented with interview schedule were used to collect primary data for the study. Both descriptive and inferential statistical tools were employed in data analysis. The socioeconomic characteristics of the fishery agribusiness farmers were analyzed descriptively using table, percentages and mean. The effect of microcredit policy and impact were analyzed with inferential statistics using OLS multiple regression analysis. The null hypothesis was tested at 5 per cent alpha level using F-test.

Model specification: Model for multiple regression analysis on effects of socio-economic characteristics of the fishery agribusiness farmers on credit utilization was stated as:

Y = f(X_1, X_2, X_3, X_4, X_5, X_6, X_7, X_8, X_9, X_{10})........implicit form

Y = b_o + b_1X_1 + b_2X_2 + b_3X_3 + b_4X_4 + b_5X_5 + b_6X_6 + b_7X_7 + b_8X_8 + b_9X_9 + $b_{10}X_{10}$ + et...explicit form

Where: Y= Amount of credit utilised (₦), b_o=Constant, b_1 –b_{10}=Regression coefficients, X_1 = Age of farmer (years); X_2 = Gender; (dummy: male =1, female = 0), X_3 = Educational qualification (years), X_4 = religion (dummy: Christian =1; Traditional=2; Islamic =3), X_5 = Marital status (married = 1,

single = 2, widowed = 3, separated = 4)

X_6 = Household size (number of persons). X_7 = Farming experience (years). X_8 = Annual income (₦). X_9 = Pond type (dummy: earthen= 1; concrete= 2; wooden vat= 3 tarpaulin= 4; plastic= 5) and X_{10} = Source of credit(dummy: BOA= 1; MFB= 2; Personal savings= 3; Isusu group= 4). et = stochastic error term

Model for multiple regression analysis on effects of microcredit policy on amount of credit accessed by fishery agribusiness farmers was stated as:

Y = f(X_1, X_2, X_3, X_4, X_5, X_6, X_7, X_8, X_9, X_{10})........implicit form

Y = bo + b_1X_1 + b_2X_2 + b_3X_3 + b_4X_4 + b_5X_5 + b_6X_6 + b_7X_7 + b_8X_8 + b_9X_9 + $b_{10}X_{10}$ + et...explicit form

Where: Y= Amount of credit accessed (₦), b_o=Constant, b_1 –b_{10} =Regression coefficients, X_1 = Mode of application (on-line =1; manual =2), X_2 = Provision of referee (cadre of the referee required =1; number of referee required =2), X_3 = Loan appraisal strategies (period of the appraisal=1; duration of appraisal=2; method of appraisal = 3; nature of the appraisal = 4), X_4 = Character assessment (duration of the assessment =0; nature of the assessment =1; requirements for the assessment = 2), X_5 = Approval process (complexity of the approval process =1; duration of the approval=2 approval time =3), X_6 = Provision of collateral (nature of the collateral=1; location of the collateral=2; standard of the collateral =3), X_7 = Provision of counterpart fund (Yes=1; No=0), X_8 = Provision of farm records (Yes=1; No=0), X_9 = Credit worthiness (Yes=1; No=0); and X_{10} = Disbursement process (time of disbursement=1; provision of processing fee=2; method of disbursement = 3), et = stochastic error term.

Model for multiple regression analysis on effects of microcredit policy on amount of credit utilized by fishery agribusiness farmers was stated as:

Y = f(X_1, X_2, X_3, X_4, X_5, X_6, X_7, X_8, X_9, X_{10})........implicit form

Y = bo + b_1X_1 + b_2X_2 + b_3X_3 + b_4X_4 + b_5X_5 + b_6X_6 + b_7X_7 + b_8X_8 + b_9X_9 + $b_{10}X_{10}$ + et...explicit form

Where: Y= Amount of credit utilised (₦), b_o=Constant, b_1 –b_{10}=Regression coefficients, X_1= Mode of application (on-line =1; manual =2), X_2= Provision of referee (cadre of the referee required =1; number of referee required =2), X_3 = Loan appraisal strategies (period of the appraisal=1; duration of appraisal=2; method of appraisal = 3; nature of the appraisal = 4), X_4= Character assessment (duration of the assessment=0; nature of the assessment=1; requirements for the assessment =2), X_5= Approval process (complexity of the approval process =1; duration of the approval process =2; approval time =3), X_6 = Provision of collateral (nature of the collateral=1; location of the collateral=2; standard of the collateral =3), X_7 = Provision

of counterpart fund (Yes=1; No=0), X_8 = Provision of farm records (Yes=1; No=0), X_9 = Credit worthiness (Yes=1; No=0) and X_{10} =Disbursement process (time of disbursement=1; provision of processing fee=2; method of disbursement = 3), et = stochastic error term.

Test of Hypothesis: F-test was used to test the hypothesis at 0.05 level of significance.

$$f\text{*-cal}= \frac{R^2\,(N-K)}{1-R^2\,(k-l)}$$

Where: R^2 = co-efficient of multiple determination, N = Sample size, K = Number of variables

Decision Rule: If f-cal> f-tab, reject the null hypothesis, otherwise accept its alternative.

RESULTS AND DISCUSSION

Effects of socio-economic characteristics of the fishery agribusiness farmers on microcredit utilization: The socio-economic characteristics are presented in Table 1. The coefficient of multiple determination (R^2) was 60.8% (Table 2). The 60.8% variation in amount of credit utilized was by combined effects of socioeconomic characteristics. The high value signifies that the socio economic characteristics of the fishery agribusiness farmers also had strong influence on the amount of credit utilized. The closeness of adjusted R^2 (56.2%) to R^2 (60.8%) in numerical value indicates that the explanatory power of the regression was not exaggerated. The overall influence was statistically significant. Isitor et al (2014) also reported socioeconomic characteristics of the farmers as the major factors defining their credit utilization. Hence the a priori expectations were met.

The coefficients of age (x_1)**,** religion (x_4), marital status (x_5) family size (x_6), annual income(x_8), and farming experience (x_{10}) indicated negative correlation. This means that it has an inverse relationship with the amount of credit utilized. The marginal effects of religion and annual income were significant at 1% level of probability, age was significant at 10%. The marginal effects of farming experience, marital status and family size were not significant at. Kuwornu et al (2012) who documented age to be 1, 5 and 10 per cent probability levels respectively. This is in line with the study of significant and negatively influenced credit utilization. This implies that a decrease in age (x_1)**,** religion (x_4), marital status (x_5) family size (x_6), annual income (x_8), and farming experience (x_{10}) increased the amount of credit utilized. The increase in age is expected to result to inactive, low risk taking such as loan acquisition and utilization and low productivity, thereby reducing the amount of credit to be utilized by the farmers. Isitor et al (2014) also asserted that age, family size and farming experience have negative relationship with utilization of credit. Farmers who are more

religious are also expected to divert some amount of loan for religious activities. Marital status and family size have the same effect. An increase in annual income led to a decrease in the amount of credit accessed and as farmer would not like to reduce his profit through interest rate as charged by the credit institutions. Hence, the a priori expectations were met, except for farming experience as it was expected that the amount of credit utilized would increase with an increased farming experience. Though the a priori expectation was not met, this finding is in tandem with the finding of Isitor et al (2014). Gender (x_2) significantly influenced the amount of credit utilized in fishery agribusiness. The direction of gender was positive implying that male utilize the credit obtained for fishery agribusiness more than their female counterpart. The marginal effect of gender is 0.632, implying that as the number of male fish farmers increase by one unit, the utilization of microcredit for fishery agribusiness increases by 0.632%. This is not in consonance with the findings of Dango-Abbeam (2016) who reported that female utilize credit more than male. This may not be applicable to fish farming as more men were engaged than female. The coefficients of pond type (x_9), source of credit (x_7) and educational qualification(x_3) show positive correlation and are directly related to amount of credit utilized. This implies that an increase in the pond type of fishery business, formal source of credit and educational qualification of the agribusiness farmers led to increased utilization of microcredit in the study area. The marginal effect of pond type and formal source of credit was significant while marginal effect of educational qualification was not significant. Hence the a priori expectations were met. This is true and also in consonance with the report of Abdelateif et al (2015) and Isitor et al (2014).

To justify the result, the test of hypothesis, which states that the socioeconomic characteristics of the fishery agribusiness farmers do not significantly affect their credit utilization in the study area showed that the f-cal (13.21) > f-tab at 5% (2.12) hence the null hypothesis was rejected while its alternative was accepted. This implies that the socioeconomic characteristics of the fishery agribusiness farmers significantly affected the amount of credit utilized in the study area.

Finally, the regression equation is shown as:

Y=11.9-0.2X$_1$+0.6X$_2$+0.0X$_3$-0.8X$_4$-0.1X$_5$-0.0X$_6$+0.6X$_7$-0.2X$_8$+0.1X$_9$-0.0X$_{10}$

(0.6) (0.1) (0.2) (0.1) (0.2) (0.1) (0.0) (0.1) (0.0) (0.0) (0.1)

Major credit policies that affects fishery agribusiness farmers: Credit policies can affect fishery agribusiness farmers in different ways such as the amount of credit

accessed and the amount of credit utilized. In considering this, multiple regression analysis were carried out to identify the major credit policies; its effects on amount of credit accessed and its effects on amount of credit utilized by the fishery agribusiness farmers.

The 73.0% change in amount of credit accessed by fishery agribusiness farmers was influenced by the combined effects of the credit policies ($R^{2} = 0.73$ %). This is quite high

indicating that the credit policies had a strong influence on credit accessibility of the fishery agribusiness farmers. The overall influence was significant. The result met the a priori expectations and was statistically reliable and in line with the study of Ugwumba and Omojola (2013) who identified these microcredit policy variables as a major constraint to access to credit. The coefficients of mode of application (X_1), provision of collateral (X_6) and disbursement process (X_{10}) are all

Table 1. Percentage distribution of the respondents according to their socio-economic characteristics

Socioeconomic variables	Description	Frequency	Percentage	Mean
Age (yrs)	20 and below	1	1.0	
	21-40	15	37.5	
	41-60	22	54.2	
	above 60	3	7.3	42
Gender	Female	16	39.6	
	Male	25	60.4	
Educational qualification (yrs)	no formal education	6	15.6	
	primary education	7	17.7	
	secondary education	13	30.2	
	tertiary education	15	36.5	
Religion	Christian religion	31	76.0	
	Traditional religion	10	24.0	
	Islamic religion	0	0	
Marital status	Single	7	15.6	
	Married	25	63.5	
	Widowed	6	14.6	
	Separated	3	6.3	
Family size	0-5	8	19.8	
	6-10	21	65.6	
	11-15	5	10.4	
	16-20	1	3.1	
	above 20	1	1.0	7
	0-100000	9	21.9	
	101000-200000	13	31.3	
	201000-300000	8	19.8	
	301000-400000	6	14.6	
	above 400000	5	12.5	221083
Pond type	Earthen	12	30.2	
	Concrete	22	55.2	
	Wooden vat	2	5.2	
	Tarpaulin	3	7.3	
	Plastic	2	2.1	
Farming experience (yrs)	0-5	5	11.5	
	6-10	20	51.0	
	11-15	13	31.3	
	16-20	3	6.3	
	Above 20	0	0	9.44
Access to loan	No	26	63.5	
	Yes	15	36.5	
Source of credit	bank of agriculture	10	24.0	
	microfinance bank	22	55.2	
	personal savings/friends	5	11.5	
	isusu group	4	9.4	
	1-100000	12	29.2	
	101000-200000	17	40.6	
	201000-300000	7	14.6	
	above 300000	5	11.5	207239
	Not utilized	1	2.1	
	fully utilized	37	90.6	
	partly utilized	4	7.3	205052

Source: Field Survey, 2017

negative and are statistically significant. This implies that an increase in these policies decreased amount of credit accessed by fishery agribusiness farmers. This is true and conforms to a priori expectations because an increase in these policies are expected to decrease the amount of credit accessed by fishery agribusiness farmers Filli et al (2015) and Omonona et al (2010) also observed that some credit policies such as lack of collateral security and formalities involved as major constraints to credits access among small scale fish farmers in Adamawa state, Nigeria.

The coefficient of credit worthiness (X_9) was positively and significantly related to amount of credit accessed. This indicates that an increase in the demand for credit worthiness by micro credit institution increased amount of credit accessed by fishery agribusiness farmers. Hence the a priori expectation was met as showed in UNCDF (2000) that most farmers are credit worthy.

The coefficient of provision of farm records (X_8),was negative and statistically significant. Indicating that an increase in the demand for farm records by micro credit institutions decreased the amount of credit accessed. Ayegba (2013) observed that lack of farm record is a major constraint to access to credit. To justify the result, the test of hypothesis which states that microcredit policy has no significant effects on amount of credit accessed by fishery agribusiness farmers showed that the f-cal (8.097) > f-tab at 5% (2.12) hence the null hypothesis was rejected while its alternative was accepted. This implies that the microcredit policy significantly affected the amount of credit accessed by fishery agribusiness farmers in the study area.

The final regression equation is shown as:

$$Y = -455351 - 52936X_1 - 42861X_2 - 3220X_3 + 15204X_4 - 6182X_5 - 39925X_6 - 6942X_7 - 42239X_8 + 31867X_9 - 9945X_{10}$$

A co-efficient of multiple determination (R^2) indicated 70.4% change in the amount of credit utilized by the fishery agribusiness farmers was influenced by the combined effects of the credit policies. This also showed that the credit policies had a strong influence on the amount of credit utilized by the

Table 2. Effects of socio-economic characteristics of the fishery agribusiness farmers on microcredit utilization

Variable code	Variable names	Regression coefficient	Standard error	t-value	Level of sign
b_0	Constant	11.997	0.666	18.000	*
X_1	Age	-0.283	0.165	-1.720	***
X_2	Gender	0.632	0.274	2.303	**
X_3	Edu. qualification	0.043	0.145	0.295	NS
X_4	Religion	-0.826	0.264	-3.129	*
X_5	Marital status	-0.147	0.139	-1.058	NS
X_6	Family size	-0.081	0.088	-0.927	NS
X_7	Pond type	0.686	0.155	4.426	*
X_8	Annual income	-0.204	0.060	-3.405	*
X_9	Source of credit	0.149	0.072	2.056	**
X_{10}	Farming experience	-0.030	0.150	-0.203	NS

Source: Filed Survey, 2017.
*,** and ***= Significant at 1,5 and t 10% level; NS not significant, R^2= 0.608 = 60.8% , Adj. R^2=0.562 = 56.2%, Standard error of estimates = 0.530, F-ratio = 13.211

Table 3. Effects of micro credit policies on amount of credit accessed by fishery agribusiness farmers

Variable code	Variable names	Regression coefficient	Standard error	t-value	Level of sign
b_0	Constant	-455351.82	200878.87	-2.26	**
X_1	Mode of application	-52936.25	22471.60	-2.35	**
X_2	Provision of referee	-42861.33	34272.23	-1.25	NS
X_3	Loan appraisal strategies	-3220.68	11211.43	-.03	NS
X_4	Character assessment	15204.31	14275.14	1.06	NS
X_5	Approval process	-6182.28	19098.05	-.32	NS
X_6	Provision of collateral	-39925.89	17603.35	-2.26	**
X_7	Provision of counterpart fund	-6942.96	16657.25	-.05	NS
X_8	Provision of farm records	-42239.89	24151.82	-.20	***
X_9	Credit worthiness	31867.40	12751.38	2.49	*
X_{10}	Disbursement process	-29945.82	14490.58	2.06	*

*,** and *** = Significant at 1 ,5 and 10 % level,R^2 = 0.730, Adj R^2=0.640. Standard error of estimates = 54949.90

fishery agribusiness farmers. The overall influence was depicted by the value of F-ratio (7.140), which was greater than F-tab (2.12) at 5% level of significance. The result met the a priori expectations and was statistically reliable. This is true and also in tandem with the study of Ayegba and Ikani (2013) concluded that banks demand for collateral and unnecessary delay in approval process is one of the major challenge to credit utilization, as respondents affirmed that late approval of loans constitute the major challenge in loan utilization. Most times you receive approval for the loan applied months after the planting seasons had expired and required to repay an unused loan with the interest. The coefficients of mode of application (X_1) and credit worthiness (X_9) indicated negative and statistically significant. This implies that an increase in these policies decreased the amount of credit utilized by the fishery agribusiness farmers. This is true and confirms to a priori expectations because an increase in these policies are expected to decrease the amount of credit utilized by the fishery agribusiness farmers since some farmers borrow from friends to offset the cost of applications and proof of credit worthiness and later pay back when the credit is accessed. The coefficients of provision of

collateral (X_6), provision of farm records (X_8) and disbursement process (X_{10}) are all negative and significant. The increase in these policy variables decreased the amount of credit and may be because farmers borrow money from friends to offset the cost of meeting up with these policy requirements and later pay back from the credit accessed, this will leave the farmer with less amount to be used for fish farming. Olatinwo et al (2012) and Ololade and Olagunju (2013) also observed that banks demand for collateral, guarantor, farm record are major challenges to credit utilization since some of the guarantors collect money to stand in for loan applicants. Some are paid to generate farm record for the farmer solely for the loan which in turn reduces the amount obtained for fish farming.

To justify the result, the test of hypothesis which states that microcredit policy has no significant effects on amount of credit utilized by fishery agribusiness farmers showed that the f-cal (7.140) > f-tab at 5% (2.12) hence the null hypothesis was rejected while its alternative was accepted. This implies that microcredit policy significantly affected credit utilization by fishery agribusiness farmers in the study area. The multiple regression equation is shown as:

Table 4. Effects of micro credit policies on the amount of credit utilized by the fishery agribusiness farmers

Variable code	Variable names	Regression coefficient	Standard error	t-value	Level of sign
b_0	Constant	-389058.83	202831.65	-1.91	***
X_1	Mode of application	-48794.29	22690.05	-2.15	**
X_2	Provision of referee	40884.35	34605.40	1.18	NS
X_3	Loan appraisal strategies	-5113.16	11320.42	-0.45	NS
X_4	Character assessment	19410.12	14413.91	1.34	NS
X_5	Approval process	6059.48	19283.71	0.31	NS
X_6	Provision of collateral	-35416.42	17774.48	-1.99	***
X_7	Provision of counterpart fund	-5576.78	16819.18	-0.33	NS
X_8	Provision of farm records	-45107.92	24386.60	-1.85	***
X_9	Credit worthiness	-29926.98	12875.34	-2.32	**
X_{10}	Disbursement process	-24970.07	14631.45	-1.70	***

*,** and *** significant at 1 5, and 10 % level , R^2 = 0.704 ,Adj R^2 =0.606 , Standard error of estimates = 55484.08

Table 5. Varimax rotated factor matrix on constraints to fishery agribusiness farmers credit accessibility

Constraints	Factor 1 Institutional	Factor 11 Socioeconomic
Credit policy	0.649	0.268
Lack of information on availability of microcredit	0.725	0.239
Illiteracy	0.226	0.708
lack of interest on microcredit	0.370	0.461
Inadequate information on credit accessibility	0.809	0.006
Problems of gender bias and household size and age	0.340	0.670
Distance to source of credit	0.748	0.286

$$Y = -389058 - 48794X_1 + 40884X_2 - 5113X_3 + 19410X_4 + 6059X_5 - 35416X_6 - 5576X_7 - 45107X_8 - 29926X_9 - 4970X_{10}$$

Constraints to credit accessibility : High loading variables were identified in each component matrix and named accordingly (Table 5). According to Kaiser's (1958) rule of thumb, variables with a coefficient of (0.40) or more have high loading and may be used in naming a factor. This rule has been generally applied (Nwibo and Okorie 2013 and Ezeh, 2013). From analysis of data obtained from field survey, two major constraints were extracted based on the respondent's responses. Those variables with factor loading of 0.40 and above at 10% overlapping variance were used in naming the constraints (Nwibo and Nwakpu 2017). Considerations were not given to those variables that loaded in more than one constraints and those lower than 0.40. Kessler (2006) reported each constrains a denomination that best describes or characterize the set of variables contained in it. The variables were grouped into two major constraints as institutional) and(socioeconomic). Under institutional factor, the specific constraining variables against fish farmers' access to credit were: credit policy (0.649) lack of information on availability of microcredit (0.725), inadequate information on credit accessibility (0.809) and distance to source of credit (0.748). Afolabi (2008) also reported that one of the reasons for the decline in the contribution of agriculture to the economy of Nigeria is the lack of stable national credit policy and paucity of credit institutions which can assist farmers. Ayigba and Ikani (2013) observed that the institutional lending system has failed to meet the objective for which they were set up.

CONCLUSION

Socioeconomic characteristics of the fishery agribusiness farmers played a significant role in credit utilization, such that the socio economic characteristics of the fishery agribusiness farmers strongly influenced the amount of credit utilized in the study area. Credit policy also affected the amount of credit accessed and utilized in the study area. The institutional constraints such as micro credit policy were the major constraints of the farmers in loan acquisition in the study area. The credit policies such as provision of farm records, provision of collateral, provision of referee, etc. have strong effects on access and utilization of microcredit by fishery agribusiness farmers as evident in their low level of access to credit. Based on the study, it is recommended that the government should involve or consult the farmers during policy formulation. Central bank of Nigeria(CBN) and Nigeria Deposit Insurance Cooperation (NDIC) should adequately monitor the credit institutions to regulate abuse of policies; the government should simplify operational procedures of microcredit institutions in credit administration to reduce cost and bureaucracy, Co-operatives and community based self-help organizations should be included in the credit delivery channel; there should be a proper training of credit beneficiaries by extension agents to ensure maximum use of credit accessed. Finally, farmers should be organized into functional co-operatives to meet up with microcredit policies as required by microcredit institutions.

REFERENCES

Abdelateif H I and Zareba FE 2015. Determinants of loan utilization and repayment behaviour among small farmers in North Kordofan of Sudan. *Global Advanced Research Journal of Agricultural Science* **4**(9): 2315-5094. 533-648.

Adewumi AA and Olaleye VF 2011. Catfish culture in Nigeria: Progress, prospects and problems. *African Journal of Agricultural Research* **6**(6): 1281-1285.

Afolabi JA 2008. Analysis of loan repayment among small scale farmers in south western Nigeria. *A Discriminant Approach Journal of Social Science* **17**(1): 83-88.

Ataganа S and Kalu C 2014. Evaluation of fund for agricultural credit guarantee scheme in Nigeria: A tool for economic growth and development. *Journal of Humanities and Social Science* (IOSR-JHSS) **19**(6): 2279-0837.

Ayegba O and Ikani DI 2013. An impact assessment of agricultural credit on rural farmers in Nigeria. *Research Journal of Finance and Accounting* **4**(18): 2222-1697.

Chisasa J and Makina D 2013. Bank credit and agricultural output in South Africa: A Cobb-Douglas empirical analysis. *International Business & Economics Research Journal* **12**(4), University of South Africa, South Africa.

Ebonyi State Economic Empowerment and Development Strategy (EB-SEEDS) 2004. Draft report of the EB-SEEDS committee on poverty reduction, growth and sustainable development strategy for Ebonyi State.

Ezeh AN 2013. Extension agents' access and utilization of information and communication technology (ICT) in extension service delivery in South East Nigeria. *Journal of Agricultural Extension and Rural Development* **5**(11): 266-276.

Federal Ministry of Agriculture and Water Resources, 2016. *Commercial Agriculture Development Project. Project Implementation Manual* (2009-2014) Prepared by: National Coordinating Office of National Food Reserve Agency. Federal ministry of agriculture data 2016, Nigeria

Filli FB, Onu JI, Adebayo EF and Tizhe I 2015. Factors influencing credits access among small scale fish farmers in Adamawa State, Nigeria. *Journal of Agricultural Economics Environment and Social Sciences* **1**(1): 46-55.

Danso-Abbeam G, Mensah TC and Antwi RA 2016. Agricultural Credit Utilization among Farmers in Bole district of Northern Region, Ghana,

Iderawumi AM and Ademola AO 2015. Impact of micro credit financing on agricultural production. *Anglisticum Journal (IJLLIS)* **4**(7-8): 1857-1878.

Isitor SU, Babalola DA and Obaniyi KS 2014. An analysis of credit utilization and farm income of arable crop farmers in Kwara State, Nigeria. *Global Journal of Science Frontier Research* **14**(10): 27 -33.

Kessler CA 2006. "Divisive key–factors influencing farm households soil and water conservation investment". *Journal of Applied Geography* **26**: 40-60.

Kuwornu JKM, Ohene-Ntow ID and Asuming-Brempong S 2012. Agricultural credit Allocation and constraint analyses of selected maize farmers in Ghana. *British Journal of Economics,*

Management and Trade **2**(4): 353-374.

Lawal JO, Omonona BT, Ajani OIY and Oni OA 2009. Determinants of constraints to credit access among cocoa farming households in Osun State, Nigeria. *Pakistan Journal of Social Sciences* **6**(3):159-163.

NPC 2018. *National population commission.National office of statistics publication Abuja, Nigeria.* Final result on the population figure of people living in Abakaliki LGA of Ebonyi State.

Nwibo SU and Okorie A 2013. Constraints to entrepreneurship and investment decisions among agribusiness investors in southeast, Nigeria. *International Journal of Small Business and Entrepreneurship Research* **1**(4): 38-50.

Nwibo SU and Nwakpu C 2017. Loan repayment capacity of cooperative farmers in Ohaukwu local government area of Ebonyi state. *Journal of Agriculture and Veterinary Science* **10**(5): 47-53.

Obisesan AA 2013. Credit accessibility and poverty among smallholder cassava farming households in south west. *Nigeria Greener Journal of Agricultural Sciences* **3**(2): 120-127

Olatinwo KB, Lawal MA and Ayojide S 2012. Analysis of rural farming households' access to credit in Kwara State, Nigeria *Journal of*

Agriculture and Food Sciences http://www.ajol.info/index.php/jafs/article/view/86850.

Ololade RA and Olagunju FI 2013. Determinants of access to credit among rural farmers in Oyo state, Nigeria. *Global Journal of Science Frontier Research Agriculture andVeterinary Sciences* **13**(2): 50-58

Omonona BT, Lawal JO and Oyinlana AO 2010. Determinants of Credit Constraint Conditions and Production Efficiency among Farming Households in Southwestern Nigeria. *Contributed Paper presented at the Joint 3rd African Association of Agricultural Economists (AAAE) and 48th Agricultural Economists Association of South Africa (AEASA) Conference,* Cape Town, South Africa, September 19-23, 2010.

Tietze U and Villareal LV 2003. M*icrofinance in fisheries and aquaculture: Guidelines and case studies.* FAO, pp.4-11.

Ugwumba COA and Omojola JT 2013. Determinants of loan repayment of livestock farmers under agricultural credit guarantee scheme (A.C.G.S) in Etche local government area of rivers state, Nigeria **2**(6) http://sjournals.com/index.php/AA/article/view/817

UNCDF 2000. UNCDF strategy for policy impact and replication in local government and microfinance. New York.

Validation of Residue Analysis Method for Sulfadiazine and Trimethoprim Drugs and their Residue Depletion in Chicken Eggs

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Abstract: A method, based on QuEChERS extraction and determination by liquid-chromatography tandem mass spectrometry (LC-MS/MS) technique was validated for simultaneous analysis of sulfadiazine (SDZ) and trimethoprim (TMP) residues in whole egg matrix. The limit of detection (LOD) and the limit of quantification (LOQ) were 0.21 and 0.29 µg/kg for SDZ, and 0.12 and 0.18 µg/kg for TMP, respectively. The intra and inter-day precisions of the method for both the analytes at LOQ level were ≤20%, with recoveries within the range of 80-110%. The method performance was in compliance with the criteria set by the Commission Decision 2002/657/EC guidelines. The method was applied to study depletion and distribution of SDZ and TMP residues in eggs after treating layer poultry birds with the therapeutic dose of application (100 mg/L of SDZ + 20 mg/L of TMP for 5 days) through drinking water. The SDZ residues tend to accumulate in egg white, while TMP residues accumulate in egg yolk. The residues of SDZ and TMP depleted to below their LOQs (SDZ- 0.29 µg/kg, TMP- 0.18 µg/kg) within 15 days.

Keywords: Sulfonamides, Diaminopyrimidines, Sulfadiazine, Trimethoprim, Residue depletion and distribution, Eggs, Poultry

Sulfonamide drugs in combination with diaminopyrimidine compounds (e.g., trimethoprim) are widely used in veterinary medicine for enhanced efficacy as bactericidal and anticoccidial agents. Out of these various combination drugs, sulfadiazine (SDZ) + trimethoprim (TMP) combination is recommended in poultry birds for the treatment of coryza, pullorum disease, fowl typhoid, and coccidiosis (Prescott 2013). However, these drugs have a tendency to get accumulated in chicken tissues and eggs (Mehtabuddin et al 2012) and their residues might cause a variety of health hazards including allergic reactions, skin rashes, renal function disorders, nausea, and hypersensitivity apart from the serious risk of antimicrobial resistance in human pathogens. Since chicken eggs are widely consumed in all age groups of people, and being a major ingredient of many processed food products, use of these drugs in layer poultry birds is a major concern. To ensure consumer safety, stringent regulations have been adopted worldwide to promote judicious use of antimicrobial drugs in animals reared for food (European Union (EU) regulation 37/2010/EC, Notification/Enf/FSSAI/2014 Part III Section 4). As such, application of sulfonamides and TMP drugs are prohibited for use in layer poultry birds in the EU countries. Further, no maximum residue limit (MRL) has been assigned in eggs for these drugs. Depletion and distribution of various sulfonamide drugs in chicken eggs have been reported earlier (Furusawa et al 1994, Furusawa et al 2010). Vandenberge et al (2012) reported residue depletion of SDZ in chicken eggs after applying SDZ drug at cross-contamination levels through the experimental feed. There are very few studies available focusing on depletion of SDZ and TMP residues after application at the therapeutic dose rate. The methods used for residue analysis in eggs were mainly based on HPLC-UV technique with limits of quantification (LOQs) ranging between 20-50 µg kg^{-1}. Nevertheless, considering restrictions in use of these compounds in layer poultry birds, it is necessary to evaluate their residues in eggs considering zero tolerance level.

With reference to the above gap in knowledge, this study was planned to evaluate the residue depletion and distribution of SDZ and TMP in eggs at the therapeutic dose level (SDZ: 25 mg kg^{-1} body weight (bw) and TMP: 5 mg kg^{-1} bw for 5 consecutive days). To ensure a precise and sensitive analysis of these drugs, an LC-MS/MS based method was thoroughly validated in whole egg matrix.

MATERIAL AND METHODS

Chemicals and reagents: Certified reference standards of SDZ (99.7%) and TMP (99.5%) were procured from Fluka, Sigma-Aldrich Chemie GmbH (Steinheim, Germany). All the other chemicals used were of analytical reagent (AR) grade from Sigma-Aldrich (Bangalore, India). C18 ENDCAPPED, a dispersive solid phase extraction (dSPE) sorbent, was procured from Agilent Technologies (Santa Clara, USA). Individual stock solutions of SDZ and TMP (about 1000 µg/ml) and intermediate working standard mixtures (10

µg/mL and 1 µg l^{-1}) were prepared in acetonitrile and stored at -20 °C.

Extraction method: The QuEChERS (quick, easy, cheap, effective, rugged, and safe) method, which was earlier reported for the analysis of flukicide and anthelmintic drugs in milk and liver (Kinsella et al 2009), was adopted with a few modifications after ensuring satisfactory performance of the modified method. The modifications included a change in the sample size (from 10 to 2.5 g), the addition of an equal amount of water before extraction, and a change in the sample to extraction solvent ratio from 1:1 to 1:4. In the final method, homogenized egg samples (2.5 g) were extracted using water (2.5 mL) and acetonitrile (10 mL) by means of high-speed homogenization for 1 min (DIAX-900, Heidolph, Germany). This was followed by the addition of anhydrous magnesium sulphate (2 g) and sodium chloride (0.5 g), and further vortexing (Genie 2T, Imperial Biomedicals, Mumbai, India) for 1 min. The mixture was then centrifuged (Kubota 6500, Kubota Corporation, Tokyo, Japan) for 5 min at 5000 rpm and the supernatant (2 mL) was transferred in a centrifuge tube. After the dSPE cleanup with C18 (50 mg/mL) + $MgSO_4$ (150 mg/mL), the extract (1 mL) was evaporated under a gentle stream of nitrogen (TurboVap LV; Caliper Life Sciences, Russelsheim, Germany). The dried residue was reconstituted in 1 mL of acetonitrile:water (10:90) by means of ultrasonication (30 seconds) and vortexing (30 seconds). The final extract was transferred to an Eppendorf tube (1.5 mL) and centrifuged (Microfuge Pico, Kendro D-37520, Osterode, Germany) for 5 min at 10000 rpm. After filtration through a PTFE membrane filter (0.2 µm), the extract (5 µL) was injected into the liquid chromatography tandem mass spectrometry hyphenated linear ion trap (LC-MS/MS Q-Trap) system [Shimadzu UFLC XR connected to API 5500 Q-Trap (Sciex, Toronto, Canada) mass spectrometer].

LC-MS/MS analysis: LC-MS/MS analysis was carried out using electrospray ionization (ESI) in the positive polarity and multiple reaction monitoring (MRM). The compound specific MS parameters were optimized (Table 1) by means of direct infusion. The source parameters were set as follows: ion source voltage (5500 V), nebulizer gas (30 psi), heater gas (60 psi), and ion source temperature (500 °C). The chromatographic separation of the test compounds was achieved on a Shim-pack XR ODS II (2.2 µm, 100 mm length,

2.1 mm ID; Shimadzu Corporation, Kyoto, Japan) HPLC column. The mobile phase composition comprised: (A) water (100%) with 0.1% formic acid, and (B) methanol: acetonitrile (80:20) with 0.1% formic acid; with gradient program, 0-1 min 2% B, 1-6 min 2-100% B, 6-8 min 100% B, 8-8.5 min 100-2% B, 8.5-11 min 2% B. The column oven temperature was maintained at 40 (±1) ºC with mobile phase flow rate of 0.3 mL/min and injection volume of 5 µL.

Method validation: For the validation study, residue-free control samples of eggs were obtained from a local organic producer. The method was validated as per the criteria laid down by the Commission Decision 2002/657/EC. Accordingly, method validation included evaluation of specificity, linearity, limit of detection, limit of quantification, accuracy, and precision.

Specificity: Residue free samples of whole eggs collected from different sources were analyzed and the specificity of the LC-MS/MS method was examined by evaluating signals (peaks) of any matrix co-extractives at the analyte retention times.

Calibration curve and linearity, limit of detection (LOD) and limit of quantification (LOQ): The solvent and matrix matched calibration curves were established for both the compounds within the range of 0.1-50 ng/mL. The LOD and the LOQ were obtained by adding 3 and 10 times the standard deviation of the measured noise corresponding to the retention times of SDZ and TMP in 20 blank samples to the mean blank (noise) value.

Method accuracy and precision: The accuracy and precision were estimated by spiking control whole egg matrix at LOQ, 1.5 × LOQ and 2 × LOQ, (n=6). The accuracy experiment was performed for three days and mean recoveries (%) and precision (intra-day and inter-day RSD) were estimated.

Field experiment: The experiments were carried out in accordance with the current 'Ethical Guidelines for Care and Use of Animals in Scientific Research', Indian National Science Academy, New Delhi.'

SDZ/TMP administration and sample collection in layer birds: Fifty clinically healthy laying hens (BV-300) (age 55 weeks, kept on non-medicated feed for 2 weeks) were selected and randomly housed in a three-tier cage system, each cage containing three birds. These hens were under

Table 1. Mass parameters

Analyte name	MF	MW	m/z	Q1	DP	EP	Q3	CE, CXP	Q3*	CE, CXP	t_R
Sulfadiazine	$C_{10}H_{10}N_4O_2S$	250.0524	[M+H]$^+$	251.0	37.0	10.0	156.0	21.0, 5.0	108.0	25.0, 7.0	4.91
Trimethoprim	$C_{14}H_{18}N_4O_3$	290.1379	[M+H]$^+$	291.0	77.0	10.0	261.0	33.0, 11.0	275.0	33.0, 16.0	4.51

MF: Molecular formula, Q1: Precursor ion, Q3: Quantifier product ion, Q3*: Qualifier product ion, DP: Declustering potential (V), EP: Entrance potential (V), CE: Collision energy (V), CXP: Collision cell exit potential (V), t_R: Retention time (min)

constant supervision of qualified personnel and a veterinarian. The birds had free access to water and feed, and their body weight did not change significantly during the course of the study. After the collection of the control sample, administration of 'sulfadiazine IP 10% w/w + trimethoprim IP 2% w/w' [(New Mortin-Vet (water dispersible powder: 1 g l^{-1} drinking water), Micro Labs Limited, Bangalore, India] was started through drinking water at the dose rate of 100 mg/L of SDZ and 20 mg l^{-1} of TMP for five consecutive days. Eggs (35-40) were collected daily during the treatment (T1-T5 or -4 to 0 days), and also after withdrawal of the treatment on the day 1, 2, 3, 4, 5, 6, 7, 9, 11, 15, and 21. These collected eggs were stored at 4ºC until delivered to the laboratory on the same day. For each sampling day, three sub-samples of 6 eggs each were drawn from the collected egg samples. Eggs were separated from shells, mixed together, thoroughly homogenized, and immediately subjected to extraction followed by analysis. To examine the distribution of drug residues in egg yolk and egg white, eggs (n=6) collected on the same day (2nd day) of drug withdrawal were broken, and yolk and white were separately homogenized. The weight of homogenized yolk and white were recorded and from this weight equivalent distribution (%) of drug residues were evaluated.

Field samples and data analysis: Quantitative analysis of SDZ and TMP in egg samples was carried out against the respective matrix matched calibration standards (0.1-50 µg l^{-1}) prepared by spiking control whole egg extracts (1 ml) just before evaporation step. Samples with analyte concentrations exceeding the highest calibration level were diluted appropriately with control extract and re-analysed.

RESULTS AND DISCUSSION

Method validation: In the control extracts of eggs, no interfering peaks were detected at the retention time of the test analytes, which demonstrated that analytical method was specific enough to analyse selected drug residues without matrix intefereces. The response of both SDZ and TMP was linear within the concentration range of 0.1-50 µg l^{-1} ($r^2 \geq 0.995$) in solvent as well as matrix matched standards. The estimated LODs for SDZ and TMP were 0.21 and 0.12 and the LOQs were 0.29 ($\approx$ 0.3) and 0.18 ($\approx$ 0.2) µg kg^{-1}, respectively. Figure 1 demonstrates the extracted ion chromatograms of SDZ and TMP, spiked at the LOQ levels. On the three consecutive days, control egg samples were spiked with SDZ and TMP at concentrations, 0.3, 0.45 and 0.6 µg/kg and 0.2, 0.3 and 0.4 µg kg^{-1}, respectively. The intra-day recoveries of SDZ and TMP were in the range of 85-99% ($\pm$ 20) and 85-110% ($\pm$ 18), respectively. The inter-day recoveries of SDZ were between 83-101% ($\pm$ 20) whereas,

TMP recoveries ranged between 86-110% ($\pm$ 20). The intra- and inter-day recoveries and precision were within the acceptable method performance criteria of Commission Decision 2002/657/EC which ranges 50-120% for concentration $\leq$ 1.0 µg kg^{-1} with precision (RSD, %) $\leq$ 20, demonstrating the suitability of this method for quantitative estimation of SDZ and TMP residues in this project.

Distribution and depletion of SDZ and TMP residues in eggs: With the average daily intake of 300 mL of water and the average body weight of 1.5 kg of the experimental layer birds, the estimated theoretical intake of SDZ and TMP were 20 and 4 mg/kg bw per day, respectively. The measured concentrations of SDZ and TMP in egg yolk and white were 740 and 2900 µg kg^{-1}, and 420 and 89 µg kg^{-1}, respectively. Taking into account the average weight (n=6) of egg yolk, and white (16 and 27 g, respectively), the weight equivalent % distribution of SDZ and TMP was estimated. The relative distribution of the SDZ and TMP residues in egg yolk and white were 13 and 87 per cent, and 74 and 26 per cent, respectively. Deposition of SDZ residues in egg white was 6.6 times higher (distribution ratio, egg white/yolk = 6.6) as compared to the yolk and deposition of TMP was 2.8 times higher in egg yolk against white (distribution ratio, egg white/yolk = 0.35). Considering the fact that the egg white contains about 90 per cent water and the egg yolk contains about 41% fat, the relative distribution of these drugs in the egg yolk and white could be associated with the hydrophilic character of SDZ and lipophilic nature of TMP.

The residue levels attained on day 1 of drug withdrawal

Table 2. Distribution and depletion of SDZ and TMP in eggs

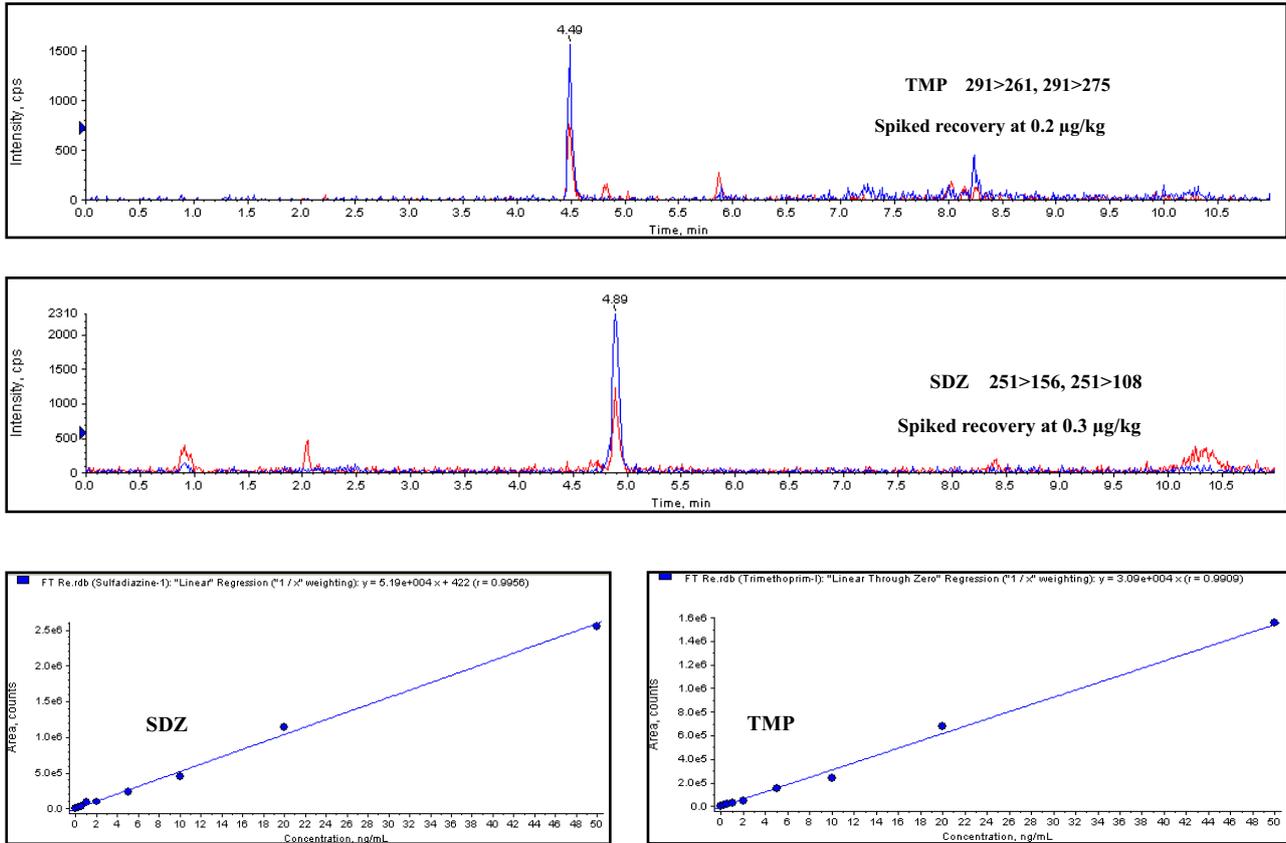| Days	SDZ residues Average ±SD (µg kg^{-1})	TMP residues Average ±SD (µg kg^{-1})
T1 (-4)	0.7±0.1	0.2±0.03
T2 (-3)	1850.1±318.2	151.4±15.9
T3 (-2)	1890.3±164.9	172.2±34.7
T4 (-1)	1900±180.4	231.3±15.7
T5 (0)	1960.3±325.2	250.1±34.8
1	1900.4±187.4	248±56.7
2	1250.3±263.9	241.2±30.3
3	255.1±44.3	231.3±42.6
4	76.8±10.7	220.4±17.0
5	30.1±7.6	162±21.1
7	18.2±4.1	101.1±19.2
9	1.1±0.2	18.5±3.8
11	BLQ	0.95±0.2
15	BLQ	BLQ
21	BLQ	BLQ

BLQ- Below limit of quantification

Fig. 1. SDZ (4.89 min) and TMP (4.49 min) at LOQ and their linear calibration curves

were 1900.4 µg kg^{-1} for SDZ and 248 µg kg^{-1} for TMP. Analysis indicates that more than 50% of the initial residue of SDZ and TMP got depleted on 3rd and 7th day respectively, after drug withdrawal. It was observed that residues of SDZ and TMP depleted below the LOQs (0.3 µg kg^{-1} for SDZ and 0.2 µg kg^{-1} for TMP) on the 11th and 15th day of drug withdrawal, respectively. The relatively slower depletion of TMP residues could be attributed to its prolonged deposition and high lipid solubility (Abu-basha et al 2009). However, in a similar study, Atta and El-zeini (2001) reported short withdrawal period of 4 days at equivalent dose rate (40% SDZ and 8% TMP @ 0.2 g l^{-1} drinking water) after evaluating residues in egg yolk and white in layer birds (age= 26 weeks) and considering MRL of 100 µg kg^{-1} for SDZ and 50 µg kg^{-1} for TMP. In the same study, residues of SDZ and TMP in egg yolk and white reached below their reported LOQs (SDZ= 15 and 20 µg kg^{-1} for yolk and albumen; TMP= 20 µg kg^{-1}) after 5-6 days of drug withdrawal (Atta and El-zeini 2001). In comparison to the above studies, the time required for depletion of SDZ and TMP residues in eggs below LOQs is relatively longer in the current study, which can be justified given that the LOQs achieved (0.3 µg kg^{-1} for SDZ and 0.2 µg kg^{-1} for TMP) are relatively much lower than previous studies.

The high residue levels attained in eggs and their prolonged depletion (up to 15 days) is a matter of concern given the fact that, eggs are consumed by all age groups including children, and their consumption is rising substantially in India due to its high nutritional value. Eggs are also a major ingredient for a variety of processed food products, bakery products, and nutritional supplements. Therefore, to control human exposure to these drugs which are critically important in human medicine as well, restricting their use in layer poultry birds and looking for safe alternative treatments to control bacterial and coccidial diseases in layer poultry birds are recommended from the study.

REFERENCES
Abu-basha EA, Gehring R, Hantash TM, Al-Shunnaq' AF and Idkaidek NM 2009. Pharmacokinetics and bioavailability

of sulfadiazine and trimethoprim following intravenous, intramuscular and oral administration in ostriches (*Struthio camelus*). *Journal of Veterinary Pharmacology and Therapeutics* **32**(3): 258-263.

Atta AH and El-zeini SA 2001. Depletion of trimethoprim and sulphadiazine from eggs of laying hens receiving trimethoprim ∕ sulphadiazine combination. *Food Control* **12**: 269-274.

European Commission. Commission decision 2002/657/EC of 14 august 2002 on implementing council directive 96/23/EC concerning the performance of analytical methods and the interpretation of results 2002/657/EC. *Official Journal of European Union* **L 221**: 8–36.

European Commission. Commission Regulation (EU) No. 37/2010 of 22 December 2009, on pharmacologically active substances and their classification regarding maximum residue limits in foodstuffs of animal origin. *Official Journal of European Union* **L15**: pp 1-72.

Furusawa N, Mukai T and Yoshida M 1994. Easiness of transfer of dietary sulfadimethoxine into eggs and its disappearance pattern from eggs. *Japanese Poultry Science* **31**: 168-180.

Furusawa N, Tsuzukida Y and Yamaguchi H 2010. Decreasing profile of residual sulfaquinoxaline in eggs. *British Poultry Science* **39**(2): 241-244.

Guidelines for Care and Use of Animals in Scientific Research, Indian National Science Academy 2000.

http://icmr.nic.in/bioethics/INSA_Guidelines.pdf (accessed May 15, 2014)

Kinsella B, Lehotay SJ, Mastovska K, Lightfield AR, Furey A and Danaher M 2009. New method for the analysis of flukicide and other anthelmintic residues in bovine milk and liver using liquid chromatography-tandem mass spectrometry *Analytica Chimica Acta* **637**(1–2): 196-207.

Mehtabuddin AA, Ahmad T, Nadeem S, Tanveer' ZI and Arshad' J 2012. Sulfonamide residues determination in commercial poultry meat and eggs. *Journal of Animal and Plant Sciences* **22**(2): 473-478.

Nagata T, Saeki M, Iidat T, Kataokat M and Shikanot S 1991. High performance liquid chromatographic determination of trimethoprim residues in egg yolk and albumen in a feeding experiment. *British Veterinary Journal* **147**: 346-351.

Prescott JF 2013 Sulfonamides, diaminopyrimidines, and their combinations, pp 279-294. In: Giguère S, Presscott JF and Dowling PM (eds), *Antimicrobial therapy in veterinary medicine*. John Wiley & Sons, Inc: Iowa, USA.

Vandenberge V, Delezie E, Huyghebaert G, Delahaut P, De Backer P, Daeseleire E and Croubels S 2012. Residues of sulfadiazine and doxycycline in egg matrices due to cross-contamination in the feed of laying hens and the possible correlation with physicochemical, pharmacokinetic and physiological parameters. *Food Additives and Contaminants* Part A **29**(6): 908-917.

Removal of Rhodamine B Dye from Aqueous Solution by Advanced Oxidation Process using ZnO Nanoparticles

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Abstract: Electrocatalytic oxidation of Rhodamine B (RhB) dye from aqueous solution was investigated with $RuO_2/IrO_2/TaO_2$ coated titanium electrodes using zinc oxide (ZnO) nano particles. ZnO nanoparticles were synthesized by chemical method; morphology and structure of the synthesized nanoparticles were characterized by Scanning Electron Microscope (SEM), X-ray diffraction (XRD). The electrical, optical and structural properties were studied. The parameters that influence the efficiency of the treatment were investigated, including dye initial pH, applied current density, concentration of dye, concentration of supporting electrolyte, stirrer speed and treatment time. The effective decolourization achieved in the presence of NaCl (0.05 M) as conductive electrolyte. Under the optimal conditions, the decolourization efficiency reached 91.5 per cent in 60 minutes of electrolysis. The pH was important parameter for the electrocatalytic oxidation process, the maximum efficiency of colour removal was achieved at pH 5.0. The degradation products of Rhodamine B were confirmed by GC-MS.

Keywords: Advanced oxidation, Colour removal, Rhodamine B dye, $RuO_2/IrO_2/TaO_2$ coated Titanium anodes

Waste water generated by several industries pose some serious health and environmental risks worldwide owe to the significant concentrations and/or large variety of toxic aromatic pollutants (Thiam et al 2014). Synthetic dyes are extensively used in textile dyeing, paper printing, colour photography, pharmaceutical, cosmetic and other industries (Prasad and Bhaskara Rao 2011 and Rahman et al 2016). Dye wastewater is one of the most difficult industrial wastewaters to treat since dyes have strong colour, high COD and low biodegradability. Azo dyes are the largest group of dyes used for dyeing cotton, rayon, silk, wool, nylon and leather (Wijetunga et al 2010). They have one or more azo groups having aromatic rings which are responsible for their intense colour and resistance to degradation under normal conditions like exposure to sunlight, water, soap, soil, etc., (Ghoneim 2011). Textile-processing waste water, typically with Rhodamine B dye content in the range 10-200 mg l^{-1} are usually highly coloured and discharge in open waters presents an aesthetic problem. RhB is harmful if swallowed by human beings and animals and causes irritation to the skin, eyes and respiratory tract (Rathinam et al 2016). Regulations across the world have become stricter, careful treatment of the effluents of textile and related industries before discharge are essential. This has resulted in a demand for environmentally friendly technologies to remove dyes from effluents (Rajabi et al 2016).

The conventional method such as biological oxidations is not effective in removing azo dyes because the breakdown of azo dye leads to the formation of aromatic amines which may be more toxic than the dye molecules. Some physicochemical methods such as coagulation, adsorption and ultrafiltration are found to be ineffective because these methods simply transfer the pollutants to another phase rather than destroying them (Khehra et al 2006). Zinc oxide (ZnO) is a suitable material for high temperature, high power electronic devices as the active material or as a suitable substrate for epitaxial growth of group III-nitride compound. UV photoconductivity of ZnO is governed by surface-related and bulk-related processes (Lee et al 2016). Over the past decade, the work of decolourizing and degrading dyes from aqueous solutions by electrocatalytic oxidation technology has been proved to be very effective. The electric current induces redox reactions resulting in the transformation/destruction of the organic compounds and their virtually complete oxidation to CO_2 and H_2O (Govindaraj et al 2013). In this study, the removal of RhB dye from its aqueous solution by electrocatalytic decolourization using a $RuO_2/IrO_2/TaO_2$ coated titanium electrodes is examined. The effects of important operating parameters such as anode material, applied current density, pH and concentration of the supporting electrolyte on the decolouration efficiency were investigated.

MATERIAL AND METHODS

Synthesis of ZnO nano particles: To prepare of ZnO nanoparticles in a typical experiment, 0.5 M aqueous solution of zinc acetate $(CH_3COO)_2Zn.2H_2O$ and 1 M

aqueous solution of sodium hydroxide (NaOH) were prepared in Millipore water. The NaOH solution was heated at the temperature of about 55ºC. The $(CH_3COO)_2Zn$ solution was added drop wise (slowly for 25 min) to the above heated solution under high-speed stirring. The beaker was sealed at this condition for above 2 hours. The precipitated ZnO nanoparticles were cleaned with Millipore water and ethanol. Then a white colour powder was calcined at 90°C and then grinded for uniformities of the powder. The dry synthetic powders were weighted and the percentage yields were calculated from the expected total amount of ZnO based on the solution concentration and volume and the amount that was actually crystallize. (Maríadel C. Cotto-Maldonado et al 2013).

Characterization analysis: As synthesized powder was studied by powder XRD method for compound confirmation. The XRD patterns of the powdered samples of the ZnO nanoparticles were analysed using an X'Pert-Pro, PAN analytical (with λ=1.5405 Å Cu-Kα radiation) operating at room temperature. Microstructural morphology of the sample was investigated using SEM study. A SEM of oxford model Leo 1550 was used for the morphlogical and average particle size study. Linear optical characteristics of the as

synthesized samples were studied by UV visible spectrophotometer studies. The UV-visible absorption spectrum was recorded using Lambda 35, Perkin-Elmer double beam UV-visible absorption spectrometer.

Preparation of synthetic RhB dye wastewater: The dye stock solution of 1000 mg l^{-1} was prepared by dissolving RhB dye (Merck, India), with double distilled water. The synthetic dye working solution concentration of 25 mg l^{-1} was prepared by dissolving the dye stock solution into distilled water and added appropriate amount of supporting electrolyte.

Electrocatalytic experimental setup: The electrocatalytic system used in this study was of bench scale. The system consisted of a DC power supply, a power control, an electrocatalytic reactor and a magnetic stirrer. The electrocatalytic reactor was an undivided reactor of 650 mL with a set of two $RuO_2/IrO_2/TaO_2$ coated titanium electrodes was internally looped to form an anode and cathode assembly. The $RuO_2/IrO_2/TaO_2$ coated titanium rods with a coating thickness of 6mm were obtained from M/s Titanium and Tantalum Products, Chennai, India. An active total anodic surface area was 118 cm^2. The electrodes were connected to the DC power supply in monopolar parallel mode with a gap of 6 mm between them to minimize the ohmic losses and the electrocatalytic reactor was operated in batch galvanostatic mode. The power supply unit was supplied by a Mighty Electronics Equipments Corporation Pvt. Ltd., Coimbatore, India. The pH of the synthetic wastewater was adjusted by 0.1 M hydrochloric acid (Merck, India) or 0.1 M sodium hydroxide (Merck, India) and measured by an Elico pH meter (India). The conductivity of solutions was raised and adjusted to different values by the addition of NaCl (Merck, India). All experiments were carried out in duplicate at room temperature.

Experimental and analytical procedure: In each experiment, five hundred milliliters of synthetic wastewater containing 50 mg/L RhB dye solution and added 10 mg/L of ZnO nanoparticle into dye solution and then sodium chloride (as a supporting electrolyte) mixed with desired concentration was used in a 0.65L glass reactor. After adjusting the desired solution pH the applied current density, stirring speed at 250 rpm maintained to get homogeneous solution in the batch reactor. Experiments were performed at four different speeds such as 150, 200, 250 and 300 rpm under the following experimental conditions; 25 mg/L of RhB dye concentration, 20 mA/cm^2 of applied current density and treatment time of 60 min. At different electrolysis times, 20 ml of treated solution was taken, settled for 25 min, filtered by membrane filter and colour intensity was measured at λmax = 541 by using UV/Vis spectroscopy (Shimadzu UV-1700 spectrophotometer, Japan). Before and at the end of each
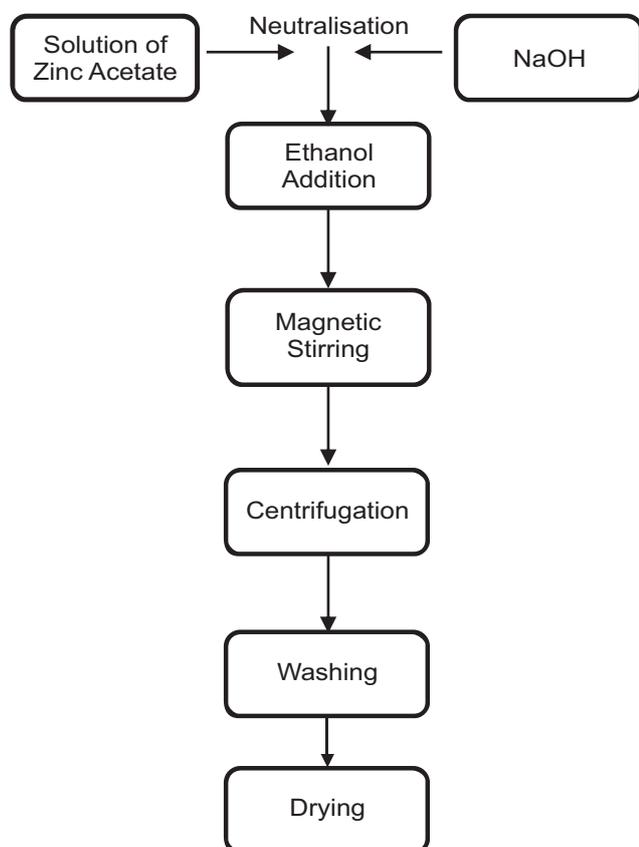

Fig. 1. Flowchart showing the synthesis of ZnO nano particles

run, electrode surfaces were thoroughly washed with distilled water.

Analysis and calculations: The colour removal was chosen as a key parameter for evaluating the effect of electrocatalytic treatment process. Colour removal efficiency was determined according to Eq. (1):

$$\text{Colour removal efficiency (\%)} = \left(\frac{A_o - A}{A_o}\right) \times 100 \qquad (1)$$

Where, A_0 and A are the light absorbance of dye before and after electrocatalytic treatment, respectively.

RESULTS AND DISCUSSION

Structural characterization of ZnO nanoparticles: X-ray diffraction is a well known technique for the structural identification and determination of the crytallite size (Fig. 2). The narrower and higher intense peaks are obtained in the diffraction pattern samples formed at high evaporation rate. The crystallite/particle size has been calculated using the Debye-Scherrer equation for all diffraction peaks. The particle size of the sample ranged between 50 and 65nm. The XRD pattren intensity peaks coordinated with JCPDS file number 790206 and it is confirmed that the crystalline sample is of ZnO has hexagonal structure which lattice parameters a=3.238Å and c=5.177Å.

The particle morphologies of the prepared ZnO nanoparticles were observed by SEM (Fig. 3). The SEM image shows random distribution of the ZnO nanoparticles having non-spherical shape and average diameter of 10µm at 90^0 C temperature and 5µm at 330^0C temperature (Maríadel C. Cotto-Maldonado et al 2013).

The FTIR spectrum of ZnO sample, palletised with KBr, were recorded over 400 to 4000 cm^{-1} (Fig. 4). The transmittance spectrum of ZnO nanoparticles shows main absorbtion bands centred at 521 to 3407 cm^{-1} and several features are located at 2276, 1640, 1557, 1411 and 860 cm^{-1}.

The absorbtion bands centred at 1411 to 424 cm^{-1} can be associated with ZnO bond vibration, comparing with standard IR of ZnO powder. Pellet of ZnO has a strong peak at 3777 cm^{-1} is observed which is very sensitive to stretching vibrations of OH bond. The application peaks at 2278, 1640, 1557, 1411 and 860 cm^{-1} can be related to N-H, N-O bond. (Rajivgandhi et al 2015). The value of impedance decreases as the frequency increased (Fig. 5). So, the conductivity increases when the frequency is increased. The dispersion of dielectric constant with frequency was examined. The main important operating parameters such as the initial pH, dye concentration, applied current, supporting electrolyte concentration and treatment time must be fixed for the further investigation of other parameters.
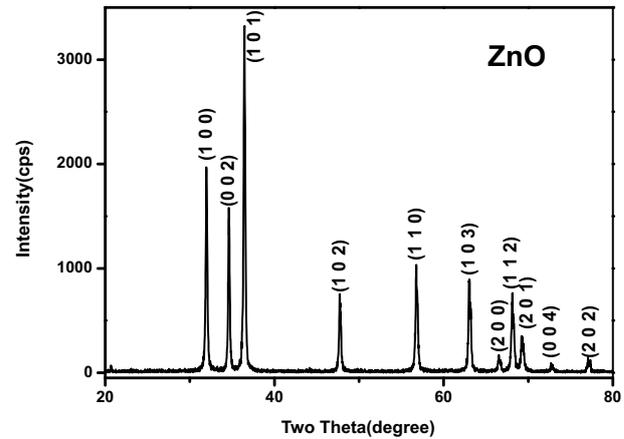

Fig. 2. The XRD patterens for powder sample of ZnO nanoparticle at high evaporation rate
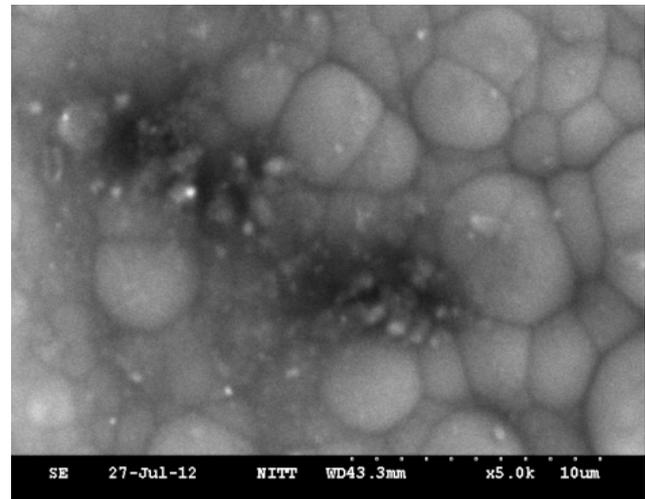

Fig. 3. SEM image of ZnO nano particles

Effect on decolourization of initial pH: In waste water treatment, solution pH is an important parameter. In anodic oxidation, under the influence of solution pH, the results are diverse and contradictory due to different organic structures and electrode materials and this has been reported in many studies (Panizza and Cerisola 2004). Some authors observed that oxidation process is more favourable in acidic media (Rabaaoui and Allagui 2012). In contrast, others indicated that the efficiency of the process was increased in alkaline media (Pacheco et al 2011). Therefore, it can be determined that the effect of pH strongly depends on the nature of the investigated organics. Therefore, the effect of pH on the degradation rate of RhB dye was studied at pH values of 3, 5, 7 and 9 at current density of 20 mA/cm^2, electrolyte concentration of 0.05M and treatment time of 60 min. The varying initial pH from 3 to 9 has significant influence

on the colour removal (Fig. 6). The decolouration of RhB dye in the acid medium is more efficient than the decolourization in alkaline and neutral medium. The colour reduction attains more than 91.4% at pH 5.0 with a total disappearance of the colour but it does not exceed 80.2 per cent at pH 9.0. This is very important because industrial wastewater may have different pH values. Many investigators explained this fact on the basis that the generation of chlorine/ hypochlorite does

not depend on the initial pH conditions (Rajkumar and Kim 2006). Therefore, pH 5.0 was chosen for further investigation.

Effect of concentration of the supporting electrolyte on decolourization: The effect of the electrolyte concentration was studied in the range 0.025-0.1M NaCl under the same experimental conditions. The effect of *NaCl* concentration under fixed current density ($20mA/cm^2$) and dye
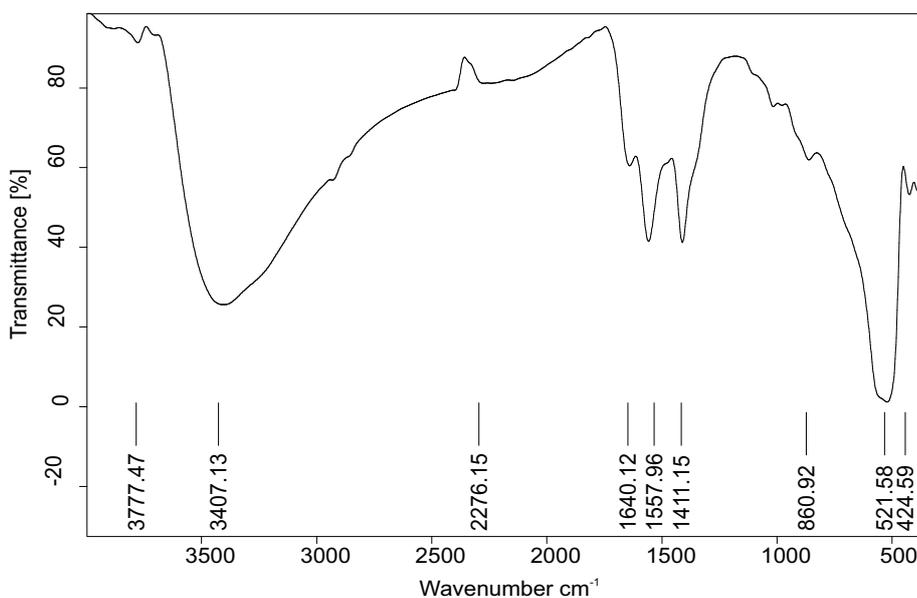
Fig. 4. FTIR spetrum of ZnO nanoparticles
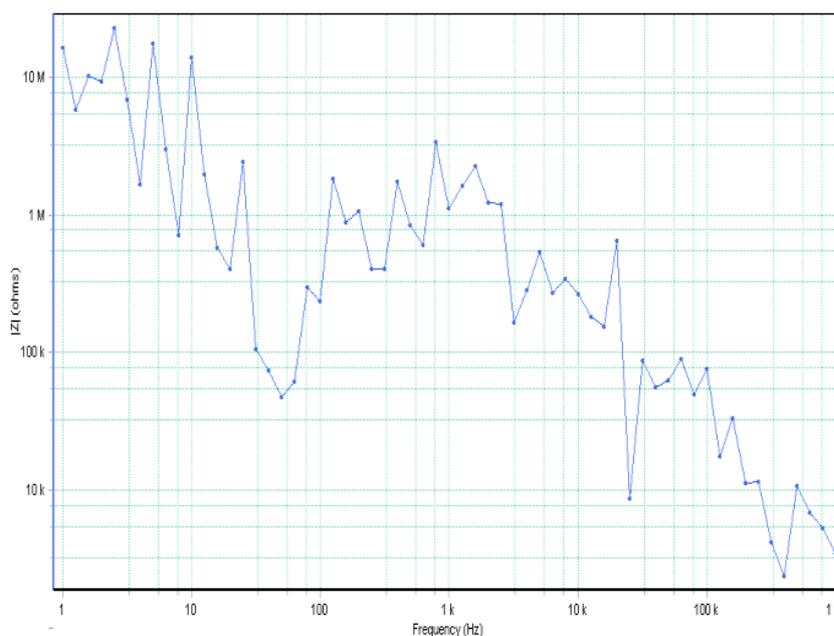
Fig. 5. Variation of impedance with frequency of ZnO

concentration (25 mg l^{-1}) (Fig. 7) that the increasing chloride concentration increases the percentage of colour removal. NaCl concentration of 0.05M had maximum (91%) colour removal was achieved. Higher concentration was not influenced significantly, indicating the electrolyte is inert to RhB dye degradation.

Effect of current density on decolourization: The percentage colour removal during the electrocatalytic oxidation at different current densities (Fig. 8). The colour removal efficiency was increased with increasing current density and is due to the increase of Cl$_2$, HOCl and OCl$^-$ concentrations in the cell solution, which eventually increase the dye degradation (Thiam et al 2014). Beyond 20mA/cm^2 there is no significant increase in the colour removal efficiency, this may be attributed to the fact that the discharge potential Cl$_2$ increases with current density and becomes close to the discharge potential of O$_2$.

The more strong oxidant, as H$_2$O$_2$ and OH, electro-generated by water was discharged to oxidize RhB dye with increase of current density. When the current density was above 20 mA/cm^2, the decolourization efficiency grew slowly, but electrical power consumption increased fastly. The decolourization efficiency was almost independent of power consumption. It could be presumed that high current density leads to low current efficiency, because of side reactions particularly solvent breakdown. Therefore, the optimal current density of 20 mA/cm^2 was maintained for the successive electro catalytic decolourization of RhB dye.

Effect of concentration of the RhB dye on decolorization: The industrial wastewater usually contains different concentrations of RhB dye. It is very significant, from a practical point of view, to study the effect of the initial concentration of dye on the performance of the electrocatalytic oxidation process in the removal of pollutants. The rate of colour removal decreases with the increase in initial dye concentration, this may be due to, increasing dye concentration consumes Cl$_2$ and OCl$^-$ rapidly with a consequent decrease in their concentration at a given current density (Fig. 9). The results can be explained in terms of diffusion control, assuming that degradation takes place on the electrode surface mediated by hydroxyl radicals. At low initial concentration, the electrocatalytic reaction is faster than the diffusion. When the initial concentration increases, more organic substances are transferred to the surface of electrode and the amount of colour reduction is decreased. The OH radicals that are generated are limiting in this case, and the degradation efficiency would decrease with increased initial concentration of the dye (Martinez-Huitle and Brillas 2009).
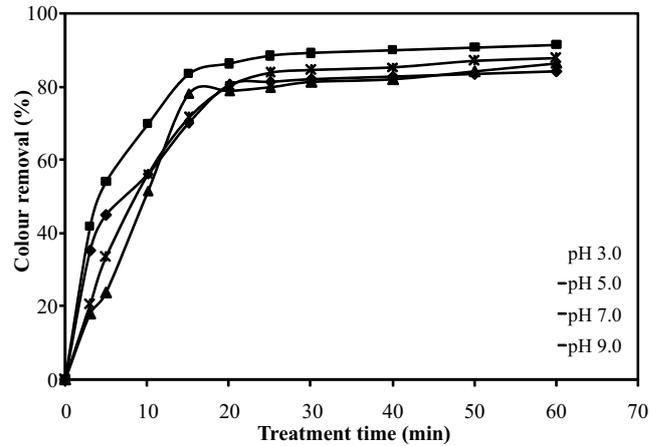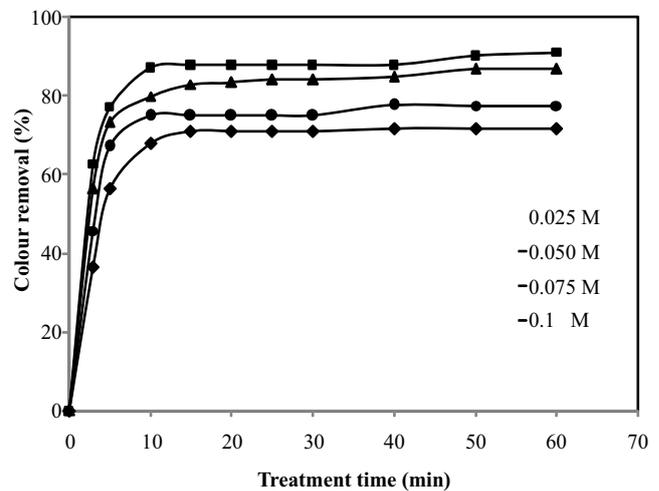

Fig. 6. Effect of initial pH on decolourization

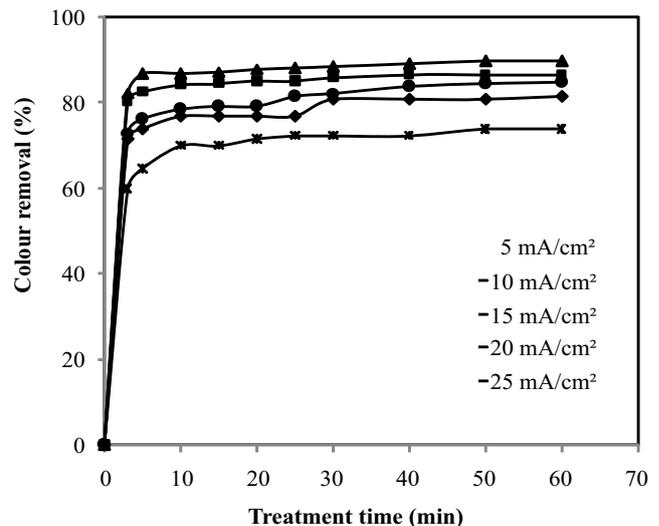**Fig. 7.** Effect of supporting electrolyte concentration on decolourization

Fig. 8. Effect of current density on decolouration
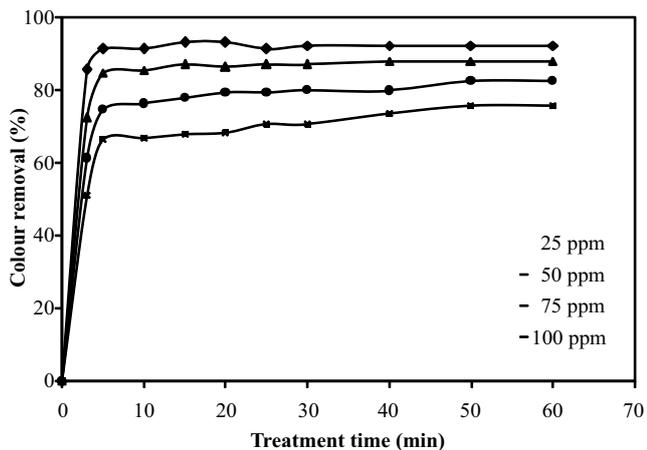
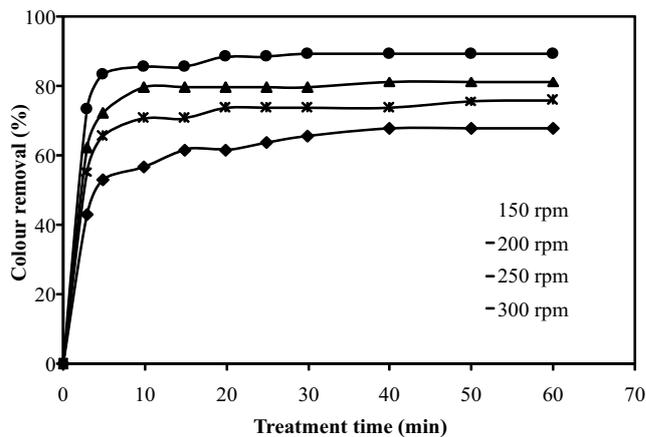**Fig. 9.** Effect of dye concentration on decolouration

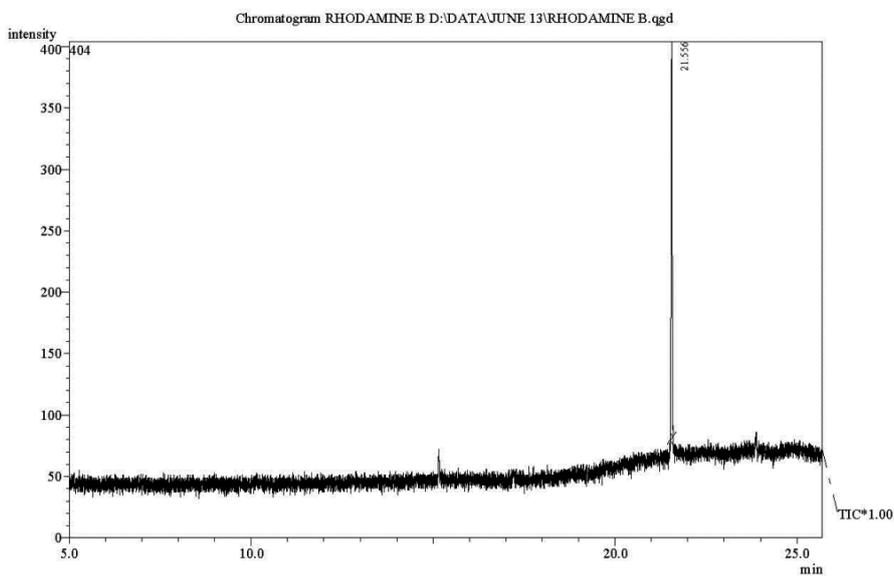**Fig. 10.** Effect of stirring speed on decolourization

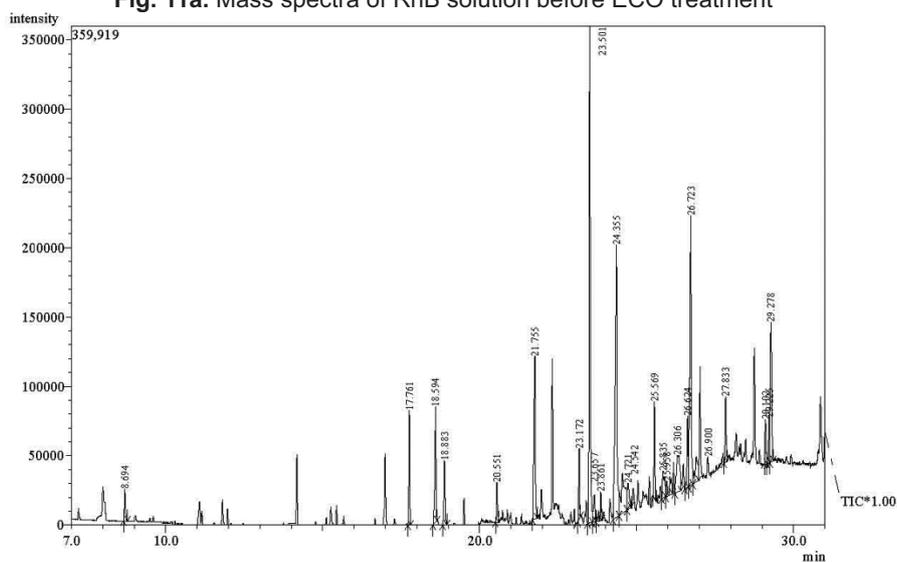**Fig. 11a.** Mass spectra of RhB solution before ECO treatment


Fig. 11b. Mass spectra of RhB solution after ECO treatment

Effect of stirring speed on RhB dye decolourization: The percentage colour removal slightly increase from 67.7 to 89.26 with 150 to 200 rpm of stirrer speed and then further increasing stirrer speed from 200 to 300 rpm colour removal decreases from 89.26 to 75.98 per cent (Fig. 10). The enhancing effect of stirrer speed on the rate of colour removal becomes less pronounced at high stirrer speeds (e.g.>200 rpm) probably because the diffusion–controlled cathodic reduction of hypochlorite and its anodic oxidation reaction are favoured at higher stirrer speed. High stirrer speed leads to more rapid and high efficient electrocatalytic process. This confirms the fact that the colour removal reaction is diffusion
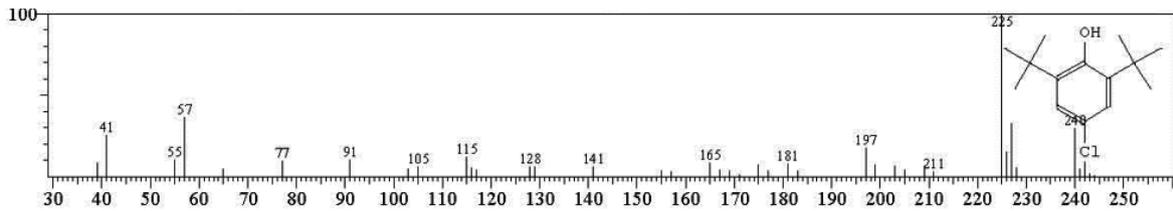
M/Z 240,$C_{14}H_{21}ClO$ Phenol,4-chloro-2,6-bis (1,1-dimethyl)-SS 2,6-Bis(1,1-dimethylethyl)-4-chloro-phenol 2,6-Ditert-butyl-4-chlorophenol
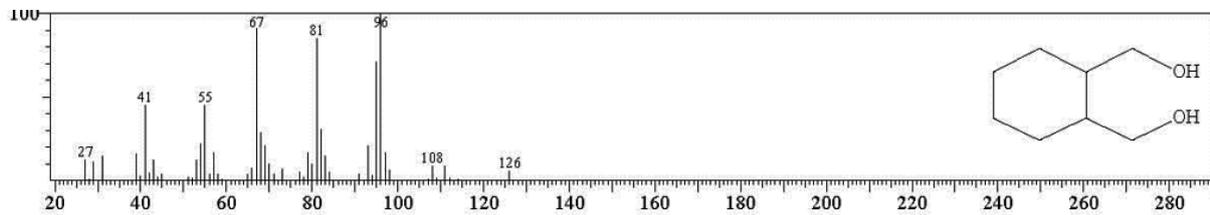
M/Z 126,$C_8H_{16}O_2$ Cyclohexan,1,2-Bis (Hydroxymethyl)
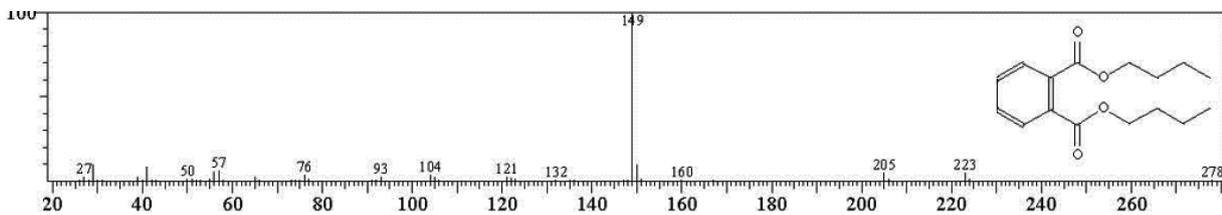
M/Z 149,$C_{16}H_{22}O_4$ Dibutyl phthalate 1, 2- benzene dicarboxylic acid, dibutyl ester phthalic acid, dibutyl ester n-Butyl phthalate Buthyl phthalate
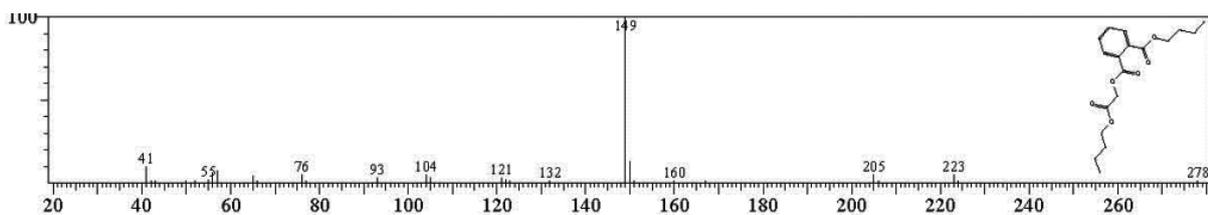
M/Z 223,$C_{18}H_{24}O_6$ 1, 2-benzene dicarboxylic acid, 2-butoxy -2- oxo ethyl butyl ester phthalic acid, butyl ester, EST
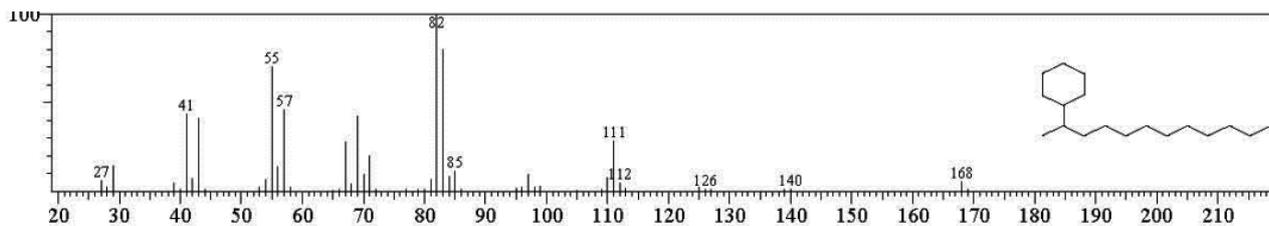
M/Z 82,$C_{18}H_3$ (1-Methyl undecyl) cyclohexane cyclohexane, (1-methylundecyl)

Fig. 12. Mass spectrum of RhB dye degradation by product by ECO process

controlled, the increase in rotational speed leads to increase in the intensity of turbulence and reduces the diffusion layer thickness at the electrode surface and improves the mixing conditions in the electrolyte bulk. The enhance rate of transfer of the reactants and products to the anode surface (El–Ashtoukhy et al 2009). The electrocatalytic oxidation of RhB dye was effective using 200 rpm as stirrer speed for other experiments.

GC-MS analysis: The mass spectra of RhB before and after degradation (decolouration) and the probable degradation products by ECO image indicates the ring opening of RhB to form different degradation products including benzoic acid and benzonium ion which are relatively non-toxic compare to RhB (Fig. 11a, b). The RhB dye degradation by product obtained by electrocatalytic oxidation process was confirmed by using gas chromatography and mass spectrum analysis (Fig. 12). The degradation byproducts namely, Phenol,4-chloro-2,6-bis (1,1-dimethyl)-SS 2,6-Bis (1,1-dimethylethyl)-4-chloro-phenol 2,6-Ditert-butyl-4-chlorophenol, Cyclohexan,1,2-Bis (Hydroxymethyl), Dibutyl phthalate 1,2-benzene dicarboxylic acid, dibutyl ester phthalic acid ,dibutyl ester n-Butyl phthalate Buthyl phthalate, 1,2-benzene dicarboxylic acid, 2-butoxy -2- oxo ethyl butyl ester phthalic acid,butyl ester EST, (1-Methyl undecyl) cyclohexane cyclohexane, (1-methylundecyl).

CONCLUSION

The investigation has shown that satisfactory removal efficiency (91.5%) of RhB can be obtained by advanced oxidation process using ZnO nanoparticles. The RhB removal rate is highly influenced by pH and the maximum removal was observed at pH 5. Thus on the basis of the experimental and theoretical data it can be concluded that ZnO nanoparticles can be used for efficient removal of RhB.

REFERENCES

El–Ashtoukhy ES, Amin Z and Abdel–Wahab NK 2009. Treatment of paper mill effluents in a batch stirred electro chemical tank reactor. *Chemical Engineering Journal* **146**: 205-210.

Ghoneim MM, El-Desoky HS and Zidan NM 2011. Electro-Fenton oxidation of sunset yellow FCF azo-dye in aqueous solutions. *Desalination* **274**: 22-30.

Govindaraj M, Rathinam R, Sukumar C, Uthayasankar M and Pattabhi S 2013. Electrochemical oxidation of bisphenol-A from aqueous solution using graphite electrodes. *Environmental*

Technology **34**: 503-512.

Khehra MS, Saini HS, Sharma DK, Chandha BS and Chimni SS 2006. Biodegradation of azo dye C.I Acid Red 88 by an anoxic-aerobic sequential bioreactor. *Dyes and Pigments* **70**: 1-7.

Lee KM, Lai CW, Ngai KS and Juan JC 2016. Recent developments of zinc oxide based photocatalyst in water treatment technology: A review, *Water Research* **88**: 428-448.

María del C. Cotto-Maldonado, Teresa Campo, Eduardo Elizalde, Arancha Gómez-Martínez, Carmen Morant and Francisco Márquez 2013. Photocatalytic degradation of Rhodamine-B under UV-Visible light irradiation using different nanostructured catalysts. *American Chemical Science Journal* **3**: 178-202

Martinez–Huitle CA and Brillas E 2009. Decontamination of wastewaters containing synthetic organic dyes by electrochemical methods: A general review. *Applied Catalysis. B: Environment* **87**: 105-145.

Pacheco MJ, Santos, Ciríaco VL and Lopes A 2011. Electrochemical degradation of aromatic amines on BDD electrodes. *Journal of Hazardous Materials* **186**: 1033-1041.

Panizza M and Cerisola G 2004. Influence of anode material on the electrochemical oxidation of 2-naphthol part 2 bulk electrolysis experiments. *Electrochimica Acta* **49**: 3221-3226.

Prasad A and Bhaskara Rao KV 2011. Physico chemical analysis of textile effluent and decolorization of textile azo dye by bacillus endophyticus strain vitabr13. *The IIOAB Journal* **2**: 55-62.

Rabaaoui N and Allagui MS 2012. Anodic oxidation of salicylic acid on BDD electrode: variable effects and mechanisms of degradation. *Journal of Hazardous Materials* **243**: 187-192.

Rahman B, Mizanur Rahman MA, Abu Shaid M, Bashar MM and Khan MA 2016. Scope of reusing and recycling the textile wastewater after treatment with gamma radiation. *Journal of Cleaner Production* **112**: 3063-3071.

Rajabi AA, Yamini Y, Faraji M and Nourmohammadian F 2016. Modified magnetite nanoparticles with cetyltrimethylammonium bromide as superior adsorbent for rapid removal of the disperse dyes from wastewater of textile companies. *Nano Chemistry Research* **1**: 49-56.

Rajivgandhi S, Dinesh Kumar A, Sundareshwaran R and Vineeth V 2015. Synthesis and Characterization of ZnO Nanoparticles, *International Journal of Innovative Research in Technology, Science & Engineering* **1**: 73-78.

Rajkumar D and Kim JG 2006. Oxidation of various reactive dyes with in situ electro-generated active chlorine for textile dyeing industry wastewater treatment. *Journal of Hazardous Materials B* **136**: 203-212.

Rathinam R, Govindaraj M, Vijayakumar K and Pattabhi S 2016. Decolourization of Rhodamine B from aqueous by electrochemical oxidation using graphite electrodes. *Desalination and Water Treatment* **57**: 16995-17001.

Thiam A, Zhou M, Brillas E and Sires I 2014. Two-step mineralization of Tartrazine solutions: Study of parameters and by-products during the coupling of electrocoagulation with electrochemical advanced oxidation processes. *Applied Catalysis B: Environmental* **151**: 116-125.

Wijetunga S, Li XF and Jix C 2010. Effect of organic load on decolouration of textile wastewater containing acid dye in up flow anaerobic sludge blanket reactor. *Journal of Hazardous Materials* **177**: 792-798.

Effect of Antioxidant Reagents and Silicon Spraying on Phenol, Flavonoid and Anthocyanin in Oat Varieties

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Abstract: A field experiment was conducted during 2017 and 2018 at Bida'a-Mashrua/Babylon Governorate within l $32^0 31'$ atitude north and $44^0 21'$ east latitude, to study the effect of three silicon spraying levels (0, 0.5 and 1.0 mM) and four treatments of antioxidant reagent (control, 50 mg.l^{-1} ascorbic acid, 0.5 mMsalicylic acid and both of acids) on some active substances in two oat varieties (Shafaa and Oat 11) grain. The phenolc, flavonoids, and anthocyaninswere significantly higher in Shafaa. Both of antioxidant reagent spraying (salicylic and ascorbic acids) as single spraying were superior in increasing phenols, flavonoids, and anthocyanins contents in grains. Silicon spraying in both concentrations was superior as compared to control treatment and high concentration was superior in increasing grain content of phenols, flavonoidsand anthocyanins.

Keywords: Oats, Phenols, Flavons, Anthocyanins

Oats is an annual herbaceous plant, entering the human and animal food, because of its containing of important nutrients. To expand the cultivation of this crop, it is necessary to introduce genetic structures that respond well to the conditions of the Iraqi environment. In recent years, silicon element has attracted the attention of specialists in physiology and plant nutrition, and experiments have been conducted on this nutritious element. Silicon is an essential element in cell walls, making it more rigid (He et al 2013). It can improve photosynthesis activity and efficiency in the plant and thus increase dry matter, which associated with increasing grains number (Korndofer and Lepsch 2001). Oat growth, production and quality can be improved by adding some chemical compounds such as salicylic acid and ascorbic acid. Salicylic acid improve plant growth, photosynthesis efficiency and plant tolerance for various stresses (Hayat and Ahmed 2008) and increasing antioxidants activity (Shi and Zhu 2008). Ascorbic has an important role in the protection of plants from optical oxidation and also participates in the synthesis of ethylene, gibberellins and anthocyanin (Smirnoff 2000), control of flowering date and start aging (Barth and Tullio 2006). Because of the positive role of both salicylic acid and ascorbic acid, as well as silicon and lack of studies on its effect on oat plant, the importance of this study was to determine the response of two oat genotypes to silicon, salicylic acid and ascorbic in Babylon province where it is first grown.

MATERIAL AND METHODS

A field experiment was carried out during 2017 and 2018 growth seasons at AlBida'a / Mashrua, Babylon within $32^0 31'$ latitude north and $44^0 21'$ longitude east, by cultivating two oat genotypes to determine the physical and chemical effectiveness of silicon, ascorbic and salicylic acids on active compounds. The experiment was in split-split plot arrangement in randomized complete block design with three replications. The main plot consist of the two oat genotypes [Shafaa$_{(a1)}$ and Oat 11$_{(a2)}$] and the split plot consist antioxidant reagent [control$_{(b1)}$, 50 mg.l^{-1} ascorbic acid$_{(b2)}$, 0.5 mM salicylic acid $_{(b3)}$and both of acids $_{(b4)}$], and the split-split plot consist of silicon treatments [0$_{(c1)}$, 0.5 $_{(c2)}$and 1.0 $_{(c3)}$mM). The field was prepared and divided according to the design and the experimental unit were 3 × 2 m (included 10 lines with a length of 3 meters and a distance of 20 cm between one line and another. The seed rate was 100 kg ha^{-1} and the fertilization was added according to the recommendations (160 kg N ha^{-1} in urea and 85 kg P_2O_5 ha^{-1} in triple super phosphate) at soil preparing time. Oat genotypes were seeded on November 20, 2016 and November 25, 2017. The spraying was done twice in tiller stage and elongation stage. After harvesting, grains were taken randomly from each experimental unit to determine its content of some active compounds. Grain extract was estimated according to the method of Hu et al (2010). Total phenols and flavonoids (mg kg^{-1}) were determined by method of Liu et al (2011).Total anthocyanins was estimated by optical absorption method

by changing the pH of the sample (Ranganna 1977) and applying the equation adopted by Guisti et al (2001). The results were statistically analyzed and the means were tested according to the least significant difference.

RESULTS AND DISCUSSION

Phenol contents: There was significant effect of oat genotypes with the superiority of Shafaa genotype in increasing grain phenols content (113.25 and 122.61 mg kg^{-1} dry weight) compared to Oat 11 genotype for both seasons respectively (Table 1). This result is consistent with Sandhu et al (2017). Spraying of salicylic and ascorbic acids alone or together caused a significant effect as compared to control treatment. Salicylic acid spray resulted in significantly higher content of phenols in grains which differed significantly from ascorbic acid in the first season. This result was consistent with Simaei et al (2012). Silicon spray had a significant effect on phenols content and high level gave the highest 114.53 and 129.12 mg kg^{-1} dry weight compared to control treatment in both season respectively. Low level silicon spraying caused a significant effect compared to control. Hagiboland et al (2017) also observed that phenols compounds were increased by Si treatment. Salicylic spray on Shafaa genotype in first season and Oat 11 in second season with mean phenol contents of 134.69 and 146.74 mg kg^{-1} dry weight. The interaction of silicon spraying with genotype was significant and higher level with Shafaa genotype was superior in both seasons while control treatment with Oat 11 gave the lowest means of 94.83 and 108.26 mg kg^{-1} dry weight. Spraying of high level of silicon with salicylic acid in first season and with ascorbic acid in second season gave higher average of 134.55 and 157.98 mg kg^{-1} dry weight respectively. Generally, Shafaa genotype with ascorbic acid and high level of silicon spraying gave significantly the higher

Table 1. Effect of genotype, antioxidant reagents and silicon spraying on phenols (mg Kg^{-1} dry weight)

A	B	First season			Second season		
		A1	A2	C*B	A1	A2	C*B
C1	B1	86.07	70.58	78.33	94.60	81.75	88.18
	B2	119.64	112.69	116.16	128.30	125.58	126.94
	B3	133.13	119.60	126.36	134.80	138.01	136.40
	B4	81.78	76.44	79.11	105.00	87.70	96.35
C2	B1	93.02	78.04	85.53	99.95	88.50	94.23
	B2	129.02	113.09	121.05	138.35	146.25	142.30
	B3	132.95	126.98	129.96	143.35	144.50	143.93
	B4	98.58	83.64	91.11	107.31	91.93	99.62
C3	B1	97.38	82.15	89.76	101.70	98.90	100.30
	B2	139.05	126.47	132.76	162.35	153.60	157.98
	B3	138.00	131.09	134.55	145.78	157.70	151.74
	B4	110.44	91.64	101.04	109.83	103.10	106.46
Mean of A		113.25	101.03		122.61	118.13	
CD (p=0.05)		A=1.6 ABC=11.7		CB=8.6	A=3.7 ABC=7.8		CB=5.6
		Interaction of A*C in 1st season			Interaction of A*C in 2nd season		
		A1	A2	C mean	A1	A2	C mean
C1		105.15	94.83	99.99	115.67	108.26	111.97
C2		113.39	100.44	106.91	122.24	117.80	120.02
C3		121.22	107.84	114.53	129.91	128.33	129.12
CD (p=0.05)		AC=5.3		C=4.6	AC=3.8		C=3.3
		Interaction of A*B					
		A1	A2	B mean	A1	A2	B mean
B1		92.16	76.92	84.54	98.75	89.72	94.23
B2		129.24	117.42	123.33	143.00	141.81	142.41
B3		134.69	125.89	130.29	141.31	146.74	144.02
B4		96.93	83.90	90.42	107.38	94.24	100.81
CD (p=0.05)		AB=6.5		B=5.3	AB=2.5		B=1.9

average of 139.05 and 162.35 mg kg^{-1} dry weight, while Oat 11 genotype with control (without spraying) gave the lowest average of 70.58 and 81.75 mg kg^{-1} in both seasons, respectively.

Flavonoids contents: The oat genotypes had a significant effect on grain content of flavonoids and Shafaa genotype was superior significantly by increasing the content of flavonoids to 37.89 and 44.66 mg kg^{-1} dry weight as compared to Oat 11, which gave a lower average of 33.75 and 38.52 mg kg^{-1} dry weight for both seasons respectively (Table 2). This result was consistent with Sandhu et al (2017). Ascorbic and salicylic acids spraying caused a significant effect and salicylic acid spray treatment gave significantly higher flavonids content (44.12 and 48.58 mg kg^{-1}dry weight) for both seasons respectively, which differ significantly compared to ascorbic acid spray (39.58 and 45.27 mg kg^{-1} dry weight) for both seasons. Control treatment significantly gave the lowest average of 30.02 and 35.13 mg g^{-1}dry weight respectively for both seasons. This result was consistent with

Simaei et al (2017). Silicon spray caused a significant effect and high silicon level was superior and gave the highest average of 39.46 and 43.65 mg kg^{-1} dry weight for both seasons compared to control treatment which gave 31.77 and 39.67 mg. Low level silicon was significantly higher than control treatment (36.23 and 41.45 mg kg^{-1} dry weight). This results was consistent with Hagiboland et al (2017) Salicylic and ascorbic acids spray treatments varied in their effect on the flavonids content according to genotypes. Salicylic acid spray on Shafaa genotype achieved the highest average of 47.84 and 51.59 mg kg^{-1} dry weight for both seasons, while Oat 11 genotype with control gave the lowest average of 29.46 and 31.77 mg kg^{-1}. The interaction of silicon with genotypes caused a significant effect and Shafaa genotype with high level of silicon was superior by giving 42.79 and 46.57 mg kg^{-1} dry weight for both seasons respectively, while Oat 11 genotype with control treatment gave the lowest average of 31.29 and 36.48 mg kg^{-1} dry weight for both seasons. Spraying of silicon and antioxidant reagent caused

Table 2. Effect of genotype, antioxidant reagents and silicon spraying on flavonids (mg Kg^{-1} dry weight)

A	A	First season			Second season		
		A1	A2	C*B	A1	A2	C*B
C1	B1	26.98	25.52	26.25	37.00	30.82	33.91
	B2	35.95	33.56	34.76	46.75	39.36	43.06
	B3	39.05	38.79	38.92	49.85	42.68	46.27
	B4	27.03	27.28	27.16	37.83	33.08	35.46
C2	B1	30.65	30.15	30.40	37.60	30.79	34.19
	B2	43.15	36.87	40.01	48.33	42.67	45.50
	B3	49.67	39.58	44.63	51.27	45.38	48.33
	B4	31.00	28.73	29.86	41.00	34.53	37.76
C3	B1	34.15	32.70	33.42	40.85	33.70	37.28
	B2	49.24	38.70	43.97	49.99	44.50	47.25
	B3	54.80	42.81	48.81	53.66	48.61	51.13
	B4	32.98	30.31	31.65	41.78	36.11	38.95
Mean of A		37.89	33.75		44.66	38.52	
CD (p=0.05)		A= 3.0 ABC=1.7		CB=1.2	A=2.2 ABC=2.3		CB=1.7
		Interaction of A*C in 1st season			Interaction of A*C in 2nd season		
		A1	A2	C mean	A1	A2	C mean
C1		32.25	31.29	31.77	42.86	36.48	39.67
C2		38.62	33.83	36.23	44.55	38.34	41.45
C3		42.79	36.13	39.46	46.57	40.73	43.65
CD (p=0.05)		AC=0.97	C=0.61		AC=1.1		C=0.93
		Interaction of A*B					
		A1	A2	B mean	A1	A2	B mean
B1		30.59	29.46	30.02	38.48	31.77	35.13
B2		42.78	36.38	39.58	48.36	42.18	45.27
B3		47.84	40.39	44.12	51.59	45.56	48.58
B4		30.43	28.77	29.56	40.21	34.57	37.39
CD (p=0.05)		AB=1.1	B=0.8		AB=1.1		B=0.89

a significant effect and high silicon level with salicylic acid spray in first season and ascorbic acid with low silicon level in second season gave higher flavonids content, while control treatment gave the lowest average of 26.25 and 33.91 mg kg^{-1} dry weight for both seasons respectively. In general, Shafaa genotype with salicylic and high level of silicon spraying gave high average of 54.80 and 53.66 mg kg^{-1} dry weight for both seasons, while Oat 11 genotype without spraying gave the lowest average of 25.52 and 30.82 mg kg^{-1} dry weight for both seasons.

Anthocyanins contents: The oat genotypes had significant effect on anthocyanins grain content and Shafaa genotype was superior significantly to Oat 11 (Table 3). Sandhua et al (2017) also observed same trend. Spraying of salicylic and ascorbic acids caused a significant effect compared to control and salicylic acid was superior for both seasons. This result was consistent with Simaeiet al (2017). Silicon spray treatments was significantly better with anthocyanins content

of 6.61 and 6.52 mg kg^{-1} dry weight for both seasons compared to control. Hagiboland et al (2017) documented the similar observations. The effect of anti-oxidant spraying was varied with the different oat genotypes. Salicylic acid spray on Shafaa genotype gave the highest mean of 7.51 and 8.11 mg kg^{-1} dry weight for both seasons, while control with Shafaa genotype in first season and both of acids on Oat 11 genotype gave the lowest average in second season. High silicon level on Shafaa genotype gave the highest average of 7.11 and 8.47 mg kg^{-1} dry weight, while control with Oat 11 genotype gave the lowest average. Salicylic acid with high silicon significantly gave the higher average (7.13 and 7.63 mg kg^{-1}) as compared to control treatment (4.18 and 4.61 mg kg^{-1} dry weight)for both seasons respectively. In general, Shafaa genotype with high level of silicon and ascorbic acid in first season and with salicylic acid in second season gave highest average .

The plants have various protective mechanisms against

Table 3. Effect of genotype, antioxidant reagents and silicon spraying on anthocyanins (mg Kg^{-1} dry weight)

A	B	First season			Second season		
		A1	A2	C*B	A1	A2	C*B
C1	B1	4.29	4.07	4.18	5.15	4.08	4.61
	B2	6.62	5.04	5.83	7.76	4.20	5.98
	B3	7.21	5.41	6.30	7.21	5.34	6.27
	B4	6.61	5.67	6.14	6.99	3.74	5.36
C2	B1	4.54	5.28	4.91	6.32	5.03	5.67
	B2	7.70	5.61	6.65	7.39	5.50	6.45
	B3	7.59	6.16	6.88	6.94	4.20	5.57
	B4	6.74	5.42	6.08	6.92	3.38	5.15
C3	B1	5.66	5.59	5.62	6.91	4.10	5.50
	B2	7.88	6.26	7.07	9.04	4.76	6.90
	B3	7.74	6.53	7.13	10.18	5.08	7.63
	B4	7.16	6.07	6.61	7.75	4.35	6.05
Mean of A		6.64	5.59		7.38	4.48	
CD (p=0.05)		A=0.8 ABC=1.3		CB=0.9	A= 2.1 ABC=1.9		CB=1.4
		Interaction of A*C in 1st season			Interaction of A*C in 2nd season		
		A1	A2	C mean	A1	A2	C mean
C1		6.18	5.05	5.61	6.78	4.34	5.56
C2		6.64	5.61	6.13	6.89	4.53	5.71
C3		7.11	6.11	6.61	8.47	4.57	6.52
CD (p=0.05)		AC=0.6		C=0.48	AC=0.9		C=0.7
		Interaction of A*B					
		A1	A2	B mean	A1	A2	B mean
B1		4.83	4.98	4.90	6.13	4.40	5.26
B2		7.40	5.63	6.52	8.06	4.82	6.44
B3		7.51	6.03	6.77	8.11	4.87	6.49
B4		6.84	5.72	6.28	7.22	3.82	5.52
CD (p=0.05)		AB=0.7		B=0.6	AB=1.2		B=0.9

ROS and the antioxidants are the first line to protect cells from the damaging effects of ROS. Salicylic and ascorbic acids spraying as antioxidants, helps to prevent oxidation, and suppress ROS which resulting from stress and metabolism. Antioxidant defense mechanisms include both enzymatic and non-enzymatic compounds and active substances that have the ability to control irregular oxidation processes (Gill and Tuteja 2010). The addition of salicylic acid (as a phenolic compound) caused an increase of phenols and flavonoids in grains content. This in turn encourages the activation of antioxidant system compounds, including anthocyanins (Vermerris and Nicholson 2006). Potassium silicate solution may reduce the permeability of plasma membranes in leaf cells and thus improve leaf infrastructure preservation of cell shape and structure, which in turn improved the process of photosynthesis and activate the defense system of the plant by inhibiting ROS. This, in turn may lead to product secondary compounds such as phenols and flavonoids, as secondary system to inhibit ROS. Theanthocyanins stabilize the cell water voltage, by increasing plant phenols content and these phenols work as a catalyst to increase the activity and effectiveness of antioxidant enzymes.

CONCLUSION

There were significant differences among oat genotypes ,Shafaa genotypes gave high grain content of phenols, anthocyanins and flavonids compared to oat 11 genotype. Spraying of ascorbic acid, salicylic acid orsilicon caused significant and positive effect on increasing grain content of phenols, anthocyanins and flavonids. The interactions of spraying ascorbic acid or salicylic acid with silicon on Shafaa genotypes gave significant the highest grain content of phenols, anthocyanins and flavonids content.

REFERENCES

Barth C, DeTullio M and Conklin PL 2006. The role of ascorbic acid in the control of flowering time and the onset of senescence. *Journal Experimental Botany* **57**(8): 1657-1665.

Gill SS and Tuteja N 2010. Reactive oxygen species and antioxidant machinery in abiotic stress tolerance in crop plants. *Plant Physiology Biochemical* **48**: 909–930.

Guisti MM and Wrolstad RE 2001. Characterization and Measurement of Anthocyanins by UV-Visible Spectroscopy. *Current Protocols in Food Analytical Chemistry*. New York: John Wiley & Sons, p F1.21- F1.2.13.

Hajiboland R, Cherghvareh L and Dashtebani F 2017. Effects of silicon supplementation on wheat plants under salt stress. *Journal Plant Process and Function* **5**(18): 1-11.

Hayat S, Ali B and Ahmed A 2008. Salicylic Acid Biosynthesis, Metabolism and Physiological Role in Plants. In: *Salicylic Acid: A plant hormone*. Springer Netherlands **57**: 1-14 .

He CW, Wang LJ, Liu J, Liu XL, Li L, Ma J, Lin YJ and Xu FS 2013. Evidence for 'silicon' within the cell walls of suspension-cultured rice cells. *New Phytologist* **200**: 700–709.

Hu QL, Zhang LJ, Li YN, Ding YJ and Li FL 2010. Purification and antifatigue activity of flavonoids from corn silk. *International Journal Physiology Science* **5**(4): 321-326.

Korndorfer G and Lepsch I 2001. Effect of silicon on plant growth and crop yield. *Studies in Plant Science* **8**: 133-147.

Liu J, Wang C, Wang Z, Zhang C, Lu S and Liu J 2011a. The antioxidant and free-radical scavenging activities of extract and fractions from corn silk (*Zea mays* L.) and related flavones glycosides. *Food Chemistry* **126**: 261-269.

Longo L and Vasapollo G 2006. Extraction and identification of anthocyanin from Smilax aspera L. berries. *Food Chemistry* **94**: 226-231.

Ranganna S 1977. *Manual of Analysis of Fruit and Vegetable Products*. Tata McGraw-Hill, New Delhi, p. 634.

Sandhu KS, Godara P, Kaur M and Punia S 2017. Effect of toasting on physical, functional and antioxidant properties of flour from oat (*Avena sativa* L.) cultivars. *Journal Saudi Society Agriculture Science* **6**(1-7): 197-203

Shi Q and Zhu Z 2008. Effects of exogenous salicylic acid on manganese toxicity, element contents and antioxidative system in cucumber. *Environment Experiment Botany* **63**: 317-326.

Simaei M, Nejad RAK and Bernard F 2012. Exogenous application of salicylic acid and nitric oxide on the ionic contents and enzymatic activities in Nacl-stressed soybean plants. *American Journal Plant Science* **3:** 1495-1503.

Smirnoff N and Wheeler GL 2000. Ascorbic acid in plant: Biosynthesis and function. *Biochemical Molecular Biology* **35**(4): 291-314.

Vermerris W and Nicholson R 2006. *Phenolic Compounds Biochemistry*. Springer, pp 276.

Ecological Niche Modeling of *Salacia* Species in Western Ghats

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Abstract: Occurrence and distributional studies of *Salacia beddomei*, *S. macrosperma* and *S. gambleana* were carried out in six districts of Central Western Ghats of Karnataka region. Various bio-climatic variables such as mean temperature, annual precipitation *etc.*, were used to identify the potential geographical distribution of *Salacia* using DIVA-GIS application. Study identified 23, 22 and 25populations of *S. beddomei*, *S. macrosperma* and *S. gambleana* respectively in Central Western Ghats. The crest line and high rainfall Western hilly slopes of Western Ghats were predicted to be highly suitable for the species, suggesting a high habitat-specificity and restricted distribution of *Salacia*. These predicted areas could be taken as best ecological niche for the conservation of species through species recovery programme.

Keywords: Geographic distribution, Niche modeling, Western ghats

Plants from the Western Ghats, India are increasingly gaining importance for their new disease curative properties. Nearly, 1600 species of plants are endemic among the 5000 reported species (Nayar 1996). Among the 34 global biodiversity hot spots, Western Ghats of India occupies the fifth position according to the economic potential of its biological resources. The forests and hilly region of this area is a treasure trove of about 700 medicinal plants (Gupta et al 2010). Of these medicinal plants, *Rauvolfia serpentina, Coscinium fenestratum, Nothapodytes nimmoniana, Salacia chinensis* cure many major ailments like blood pressure, cancer, diabetes, etc. (Thriveni et al 2015). *Salacia* is one of the genus belongs to the family Celastraceae, the 'staff tree' family, gaining an international recognition as an anti-diabetic plant. Active chemical compounds of *Salacia* such as mangiferin, salacinol and kotalanol are found effective in treating type II diabetes. *Salacia chinensis, S. reticulata* and *S. oblonga* are species being used as a source for these compounds. The genus *Salacia* constitutes approximately with over 200 species worldwide mainly confined to the tropical and sub-tropical regions of the world (Mabberley 2008). They are woody climbers naturally found in tropical regions. The genus *Salacia* comprises of several medicinally important species (S. *oblonga, S. reticulata, S. chinensis* etc). However, the species is widely used in folk medicine since antiquity for its anti-diabetic, antibacterial properties (Yuhao et al 2008). It is a large genus of climbing or scandent shrubs or often small trees represented by 22 species in India (Sujana et al 2015) of which 15 species are known to occur in Peninsular India (Ramamurthy and Naithani 2000). More than 10 species of *Salacia* reported from the Western Ghats

and of these most of them are endemic (Nayar 1996,Sasidharan 2004, Ramamurthy and Venu 2005, Udayan et al 2013, Sujana et al 2015). Among them, 7 species are reported in Karnataka (Roopa et al 2017).

In the southern part of India, different species of genus *Salacia* is an important raw material in a number of classical formulations. These species are distributed in the evergreen and semi-evergreen forests of the Western Ghats. The raw materials of various *Salacia* species including *Salacia beddomei*, *S. macrosperma* and *Salacia gambleana* are traded in large quantities in the name of 'Saptharangi' in southern India. The increased demand for high metabolite (mangiferin, salacinol and kotalanol) and over harvest of these species from wild for active ingredients has created adverse effect on its natural population and put them at extreme risk for their survival. Considering the perceived threat, poor natural regeneration, population decline, the species has been assigned threat status to many species in the genus *Salacia*. Despite its criticality and pharmaceutical importance, there is a large gap in our understanding of its distribution of natural stands, which is a pre-requisite for effective conservation. With this backdrop we attempted to identify the population distribution in the Central Western Ghats and also using this data we have tried to predict the possible sites of occurrence of *Salacia* species in Western Ghats using ecological niche modeling tools for the conservation and management of species.

MATERIAL AND METHODS

The study was undertaken in the central Western Ghats region of Karnataka, India and it was restricted to floristically

rich primary evergreen and semi-evergreen forest types of Belagavi, Uttara Kannada, Shivamogga, Udupi, Dakshina Kannada andChikkamagaluru districts of Karnataka. Entire forest areas (< 500 to 1400 m) of Central Western Ghats were considered wherein the temperature of the coldest month varied between 17 °C to 22 °C. The dry season among the forest types ranged from 4 to 6 months from December to May and the annual rainfall received between 2000 mm to 3500 mm which is ranged from June to September. Reconnaissance survey for natural populations of *Salacia beddomei, S. gambleana* and *S. macrosperma* was under taken in 22 forest ranges. The geo-coordinates and the elevation of all natural populations were recorded using geographical positioning system (Make: GARMIN, GPSMAP 60 CSx) to the nearest 20 m (Table 1). Secondary data collected on the distribution of *Salacia beddomei, S. gambleana* and *S. macrosperma* from various sources such as forest department records, published literature and also interaction with the forest officials. This information was used in preparing the type localities, which was used as base for further explorations.

Ecological niche modeling: The ecological niche modeling offers great potential for species delimitation especially for endemic species with more poorly known distributions. (Peterson and Soberon 2012, Raxworthy et al 2007). Niche model was adopted to develop the potential geographic distribution map of *Salacia* across the Western Ghats region following Ganeshaiah et al (2003). The program DIVA-GIS ver 5.0.02 with the Bioclim classic model was used to predict the distribution of the species in the entire range. DIVA-GIS model was applied with the following bio-climatic variables, viz., annual mean temperature, mean monthly temperature range, isothermality, temperature seasonality, maximum temperature of warmest month, minimum temperature of coldest month, temperature annual range, mean temperature of wettest quadrant, mean temperature of driest quadrant, mean temperature of warmest quadrant, mean temperature of coldest quadrant, annual precipitation, precipitation of wettest month, precipitation of driest month, precipitation seasonality (CV), precipitation of wettest quarter, precipitation of driest quarter, precipitation of warmest quarter, precipitation of coldest quarter to identify

Table 1. Forest ranges and their geo-coordinates

Forest range	Forest division	District	Latitude (N)	Longitude (E)	Altitude (M)
Kanakumbi	Belagavi	Belagavi	14.69128^0	74.35372^0	529
Jamboti	Belagavi	Belagavi	14.69771^0	74.23761^0	623
Castle Rock	Haliyal	Uttara Kannada	14.49111^0	74.35372^0	429
Jaglpete	Haliyal	Uttara Kannada	15.21706^0	74.37661^0	405
Dandeli	Haliyal	Uttara Kannada	15.11370^0	74.33173^0	421
Kumbarwada	Haliyal	Uttara Kannada	15.10409^0	$74 33594^0$	422
Yellapura	Yellapura	Uttara Kannada	14.00168^0	74.67575^0	401
Idagundi	Yellapura	Uttara Kannada	14.91380^0	74.60969^0	389
Hulekal	Sirsi	Uttara Kannada	14.61208^0	74.55955^0	405
Janmane	Sirsi	Uttara Kannada	14.44075^0	74.67822^0	413
Kyadagi	Sirsi	Uttara Kannada	14.32669^0	74.68911^0	501
Siddapura	Sirsi	Uttara Kannada	14.27728^0	74.76922^0	462
Gerusoppa	Honnavar	Uttara Kannada	14.27623^0	74.72994^0	409
Kargal	Sagar	Shivamogga	14.19097^0	74.83233^0	437
Kollur	Kundapura	Udupi	13.88936^0	74.81827^0	356
Hosanagara	Sagar	Shivamogga	13.81286^0	74.96609^0	418
Agumbe	Shimoga	Chikkamagaluru	13.52549^0	75.99531^0	659
Hebri	Karkala	Udupi	13.21510^0	74.99617^0	372
Kerekatte	Chikkmagaluru	Chikkamagaluru	13.26601^0	75.15766^0	691
Naravi	Karkala	Udupi	$13. 35162^0$	75.08025^0	329
Gundya	Mangalore	Dakshina Kannada	12.84395^0	75.56066^0	263
Sakaleshpura	Hassan	Hassan	12.83852^0	75.65851^0	411

the potential geographical distribution of *Salacia* species. A total of 20 geo-coordinate points obtained from the primary and secondary sources were used to run the program (www.divagis.org). Based on the habitat suitability the software categorizes the area in different colours as excellent, medium and poor habitats with different algorithms of 0.5 to 0.75 percentile, 0.25 to 0.5 percentile and 0 to 0.25 percentile areas of suitability, respectively. 0.75 to 1.0 percentile for areas of very high and excellent suitability in terms of habitat match.

RESULTS AND DISCUSSION

Total twenty three populations of *Salacia beddomei,* twenty two populations of *S. macrosperma* and twenty fivepopulations of *S. gambleana* were identified in the central Western Ghats (Table2). Among the populations of a target species, the *S. macrosperma* was identified in all the six forested districts of central Western Ghats (Belagavi, Uttara Kannada, Shivamogga, Udupi, Dakshina Kannada and Chikkamagaluru) whereas *S. gambleana* and *S. beddomei* was from five and two districts respectively. It was observed that *Salacia macrosperma*, *S. gambleana* and *S. beddomei* were more predominant in Uttara Kannada districts compared to other districts of Central Western Ghats. However, this region forms the northern geographic limit for several species of plants and it share highest number of

species from southern and northern region because of central location where bio-geographical transition takes its place (Gunaga and Vasudeva 2015).

Predictive map: The predictive distribution map in general agreed with the observed distributional pattern of the species. It is predicted that hilly forested areas of Western Ghats is suitable ecological niche for the *Salacia* species. (Fig. 1). It is illustrated that *Salacia beddomei* was more predominant in central Western Ghats, whereas, the occurrence of *Salacia gambleana* predicted in the entire Western Ghats region especially from Belagavi of Central Western Ghats to Thrissur and Idukki districts of Southern Western Ghats. The *Salacia macrosperma* was predicted with high distribution in the northern and central Western Ghats. This suggests that the restricted distribution of *S. beddomei* in the central Western Ghats compared to *S. gambleana* and S*. macrosperma*. The niche maps indicated that the areas of southern part of central Western Ghats were predicted to be an excellent niche habitat for the distribution of *S. gambleana* from Sharavathi Wild Life Sanctuary (Part of Uttara Kannada and Shivamogga) downwards to Agumbe and Kuduremukh National Park (Chikkamagaluru and Dakshina Kannada border). It is also pointed out that the central region of central Western Ghats would be the best ecological niche for *S. beddomei*. Further, because of better adaptability, *S. macrosperma* distributed in all ranges throughout the central
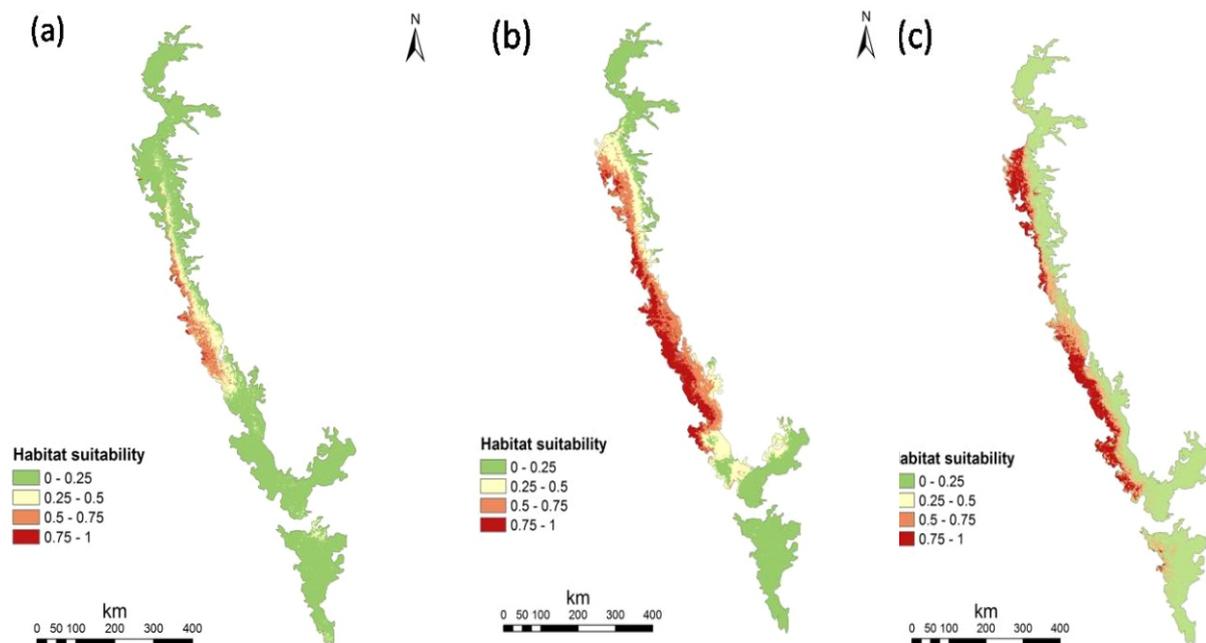

Fig. 1. Predicted potential distribution map of *Salacia* in Western Ghats using DIVA-GIS (a) *Salacia beddomei* (b) *S. macrosperma* (c) *S. gambleana*

Table 2. Number of locations of species occurrence

Species	No. of locations of species occurrence in different districts of Central Western Ghats, Karnataka						Total population
	Belagavi	Uttara Kannada	Shivamogga	Udupi	Dakshina Kannada	Chikkamagaluru	
Salacia beddomei	03	20	--	--	--	--	23
S. macrosperma	01	10	03	02	04	02	22
S. gambleana	--	10	10	02	02	01	25

Western Ghats from northern Jamboti and Kanakumbi of Belagavi districts to Derani and Gundya of Dakshina Kannada district. This clearly indicates the areas that support better growth and regeneration of the species. Using DIVA-GIS,Yethish (2006), Thriveni et al (2015) and Sumangala et al (2017) have showed that this hypothesis holds good with respect to *Coscinium fenestratum* and *Myristica malabarica, Knema attenuata, Dysoxylum malabaricum*, *Vateria indica* and *Saraca asoca* in Western Ghats.

CONCLUSION

Salacia beddomei, S. macrosperma and *S. gambleana* are the endemic species with high medicinal value which are distributed in evergreen, semi-evergreen and riparian vegetation of the Central Western Ghats. The potential distribution maps identified Central and Southern Western Ghats are the best ecological niche for *Salacia* species. These predicted areas could be prioritized for the conservation and reintroduction of species in the existing population following forest gene bank concept to improve the genetic diversity of the species (Ravikanth et al 2010). Conservation of these can also take up in the sacred groves and coffee plantations *etc*. However, these areas sustain small holder production and offer more scope for conservation of biodiversity (Maheshwarappa et al 2018).

REFERENCES

Ganeshaiah KN, Narayani Barve, Nilima Nath K, Chandrashekar M, Swamy and Uma Shaanker R 2003. Predicting the potential distribution of the sugarcane wooly aphid using GARP and DIV-GIS. *Current Science* **85:** 1526-1528.

Gunaga SV and Vasudeva R 2015. Do fresh waters wamps of the central western ghats differ in their species composition across latitude? *Indian Journal of Ecology* **42**(1): 135-138.

Gupta V, Bhardwaj M and Dashora K 2010. Endemic medicinal plants of western Ghats-Their collection and conservation. *Journal of Economic and Taxonomic Botany* **34**(2): 353-358.

Mabberley DJ 2008. *The Plant-Book: A Portable Dictionary of the Vascular Plants.* Cambridge, UK: Cambridge University Press.

Maheshwarappa V and Vasudeva R 2018. Structural and floristic diversity of different landscape in western ghats of Kodagu, Karnataka, India. *Indian Journal of Ecology* **45**(3): 462-469.

Nayar MP 1996. *Hotspots of Endemic Plants of India, Nepal and Bhutan, Thiruvananthapuram, TBGRI.* Vedams e-Books, New Delhi, India.

Peterson AT and Soberon J 2012. Species distribution modeling and ecological niche modeling: Getting the concepts right. *Brazilian Journal of Nature Conservation* **10**(2):102-107.

Ramamurthy K and Naithani BD 2000. *Salacia*. In: Singh NP, Vora JN, Hajra PK and Singh DK (eds.). *Flora of India* **5:** 150-162.

Ramamurthy K and Venu P 2005. *Salacia*. In: Daniel, P. (ed.) *Flora of Kerala* **1:** 718-722. Botanical Survey of India, Kolkata.

Ravikanth, G, Vasudeva R, Ganeshaiah KN and Uma Shaanker R 2010. Garcinia forest gene banks: an alternative approach for the conservation of Garcinia genetic resources of the Western Ghats. pp. 1-13. **In**: R Vasudeva, BS Janagoudar, BMC Reddy, Bhuwon Sthapit and HP Singh (eds.) Garcinia Genetic Resources: Linking Diversity, Livelihood and Management, *National Symposium on Garcinia Genetic Resources: Linking diversity, livelihood and management*, May 8-9, 2010,College of Forestry, Sirsi, India.

Raxworthy CJ, Ingram CM, Rabibisoa N and Pearson RG 2007. Applications of Ecological niche modeling for species delimitation: A review and empirical evaluation using day geckos (*Phelsuma*) from Madagascar. *Systematic Biology* **56**(6): 907-923.

Sasidharan N 2004. *Biodiversity Documentation for Kerala*. Part 6. Flowering Plants: Kerala Forest Research Institute, Peechi, Kerala, India.

Sujana KA, Nagaraju S, Ratheesh Narayanan MK and Anil Kumar N 2015. *A New Species of Salacia* (Celastraceae) from India. *Taiwania* **60**(2): 91-94.

Sumangala RC, Rosario S, Charles B Ganesh D and Ravikanth G 2017. Identifying conservation sites for *Saraca asoca*: An important medicinal plant using ecological niche Models. *Indian Forester* **143**(6): 531-536.

Thriveni HN, Gunaga SV, Ramesh Babu HN and Vasudeva R 2015. Ecological niche modeling, population status and regeneration of *Coscinium fenestratum* colebr. (Menispermaceae): a medicinally important liana of the central Western Ghats. *Tropical Ecology* **56**(1): 101-110

Udayan PS, Yohannan MS, Devipriya R, Devipriya V and Pradeep AK 2013. *Salaciavellaniana*. Udayan, Yohannan and Pradeep (Celastraceae), A new species from India. *Candollea* **68**:147-149.

Gupta V, Bharadwaj M and Dashora K 2010. Endemic medicinal plants of western ghats-their collection and conservation. *Journal Economic Taxonomy Botany* **34**(2): 353-358.

Yethish 2006. *Mapping the Distribution of Selected RET (Rare Endangered and Threatened) Tree Species of Central Western Ghats using Ecological Niche Modelling*. Dissertation, University Agricultural Sciences, Bangalore.

Yuhao Li, Tom Hsun-Wei Huang, Johji Yamahara 2008. *Salacia* root, a unique Ayurvedic medicine, meets multiple targets in diabetes and obesity. Minireview. *Life Sciences* **82:** 1045–1049.

Socio-personal Dynamics of Adoption of Different Agroforestry Systems in Sub-tropics of Jammu and Kashmir

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Abstract: The objective of the study was to identify the existing agro forestry systems in the Jammu district and the factors affecting their adoption by the farming community for their sustainable livelihood. Two major agroforestry systems were identified in the study area i.e. agri-silvi-cultural system and agro-silvo-pastoral system contributing 23 and 77 per cent in their livelihood respectively. The results indicated that the farming systems were mainly based on the production of annual crops. Tree component continued to exist in the farming system which played a significant role in the production and combined yield to the households in respective area. Binary logistic regression model was applied to work out various factors affecting the respondents design to adopt agri-silvicultural system and out of six independent variables; schooling years, farming experience, extension contacts had positive influence and age, family size and size of land holding had negative influence on the adoption of agroforestry systems. Only age of the farmers had significant negative effect on the farmers' decision to adopt agrisilvicultural system.

Keywords: Adoption, Agroforestry, Agrisilvicultural, Agro-silvo-pastrol, Livelihood

India has a long traditional history of agroforestry and a variety of indigenous agroforestry systems are present in different parts of the country. Most of these systems however, are location specific and information on them is mostly anecdotal. Therefore, their benefits have remained vastly underexploited. The situation is now slowly but steadily changing with incorporation of modern agroforestry practices and intensive study of the traditional practices. It has been well documented that agroforestry systems can address major land-use problems of rainfed farming agricultural systems include agroforestry and a great deal can be accomplished by improving the indigenous systems. Therefore, most of the research results obtained from such efforts are also largely location-specific. Until the 1990s, agroforestry research in developing countries, were largely focused on livelihood aspects, such as the contribution to household economy and profitability relative to agriculture. Potentiality of agroforestry systems has been well documented and accepted in mitigating global climate change (Verchot et al 2007). Both environmental and socio-economic factors have played an important role in adoption of innovations in agroforestry technologies by farmers (Neupane et al 2002). Where subsistence agriculture is the backbone of local livelihoods, the necessity to encourage and embolden farmers to adopt agroforestry on farmland has been established. The present study was therefore aimed to study the tree based systems to diagnose the influence of various socio-economic and farming aspects on adoption of traditional agroforestry in Jammu district of Jammu and Kashmir.

MATERIAL AND METHODS

The investigation was carried out in Jammu district of Jammu and Kashmir, an Indian state located in northwestern Himalaya, 74° 24' and 75° 18', E longitude and 32° 50' and 33° 30' N latitude. Multistage random sampling method was used for selection of respondents. Jammu district was purposively selected for the present study because of satisfactory prevalence and adoption of traditional as well as improved agroforestry systems. Jammu district has 20 blocks, out of those 10 blocks were selected for proposed research study. This stage was also purposive as these 10 blocks have majority of rain fed area. Villages were selected on the basis of random sampling method. Two villages were selected from 10 blocks consisting 20 villages in total and 08 farmers/ households were selected randomly as respondents from each selected village, thus making a total sample size of 160 respondents. Data collected from sampled respondents of different blocks were clubbed into three different agriculture sub divisions i.e. Akhnoor, Marh and Dansal, because administrative set up of State Agricultural Department at field level is divided into different sub-divisions and moreover dissemination of new agricultural technology is managed primarily at sub-division

level. Descriptive statistics and binary logistic regression model was applied.

RESULTS AND DISCUSSION

The social personal variable; average age, education and family size did not show any significant difference in Akhnoor, Dansal and Marh sub division (Table 1). The difference in the average operational land holdings of all three sub divisions was statistically non-significant. Overall average land topography in study area was 0.7 hectare and 0.05 hectare under plain and sloppy, respectively. Overall average number of land fragments in Jammu district was 1.6 (Table 2). The average farming experience of respondents in Jammu district was 30 years. The 8 per cent respondents had membership in some social organizations, whereas, majority of the respondents in the study district were not having any affiliation with social group. In the study area 42 per cent respondents had extension contacts (Table 3).

Two agroforestry systems namely agrisilvicultural and agrosilvopastoral system were mainly identified in study area. Overall in study area of Jammu district comprises 23 percent of the respondents were practicing agrisilvicultural system whereas 77 per cent the agrosilvopastoral system. This corroborates with the findings of Baffoe-Asare et al (2013) and Dhadwal et al (1991) (Table 4). In Akhnoor sub division 52, 29, 11, 4 and 4 per cent of fruit trees were planted on the boundary, scattered, block, intercrop and line planting respectively (Table 5). In same sub division 40, 27, 15, 9 and 6 percent timber trees were planted with an arrangement on boundary, scattered, block, intercrop and line planting respectively, followed by 48, 30, 15, 3 and 4 per cent fodder trees along the boundary, scattered, block, intercrop and line

Table 1. Socio-personal profile of respondents

Parameter	Agriculture sub division			Overall percentage (n=160)
	Akhnoor (n=80)	Dansal (n=48)	Marh (n=32)	
Average age	51.85 ±11.78	49.64 ±9.60	50.46 ±10.64	50.91±10.92
Age categories (per cent farmers)				
18-40yrs	17	13	15	15
41-60yrs	59	66	64	62
61-80yrs	24	21	21	23
Education (per cent farmers)				
Illiterate	4	3	4	3
Primary	45	50	44	46
Middle	29	25	22	25
Matric	14	16	12	14
10+2	6	4	12	8
Graduate and above	2	2	5	4
Average education (formal no. of schooling year completed)	6.8±2.62	6.9 ±2.70	7 ±2.87	6.8 ±2.68
Average family size	6 ±2.76	6 ±2.79	6 ±2.92	6 ±2.79

Table 2. Land holding and farm size detail of respondents

Particular	Agriculture sub-division			Overall percentage
	Akhnoor (n=80)	Dansal (n=48)	Marh (n=32)	
Average operational land holding (ha)	0.8 ±0.72	0.6±0.56	0.7±0.43	0.7±0.52
		F=0.63, P=0.47 NS		
Area under topography (ha)				
Plain	58.7	34.2	22.6	115.5
Slopy	7.6	0	0.5	8.1
Average topography (ha)				
Plain	0.7±0.50	0.7±0.34	0.7±0.43	0.7±0.44
Slopy	0.09±0.34	0	0.01±0.06	0.05±0.25
Average number of land fragments	1.6±1.48	1.7±1.40	1.5±1.60	1.6±1.47

planting respectively. In Akhnoor sub division 48, 23, 15, 8 and 7 per cent fuel trees were with the arrangement of boundary, scattered, block, intercrop and line planting respectively. In Dansal sub division 51, 33, 7, 5 and 4 per cent fruit trees were planted at an arrangement of boundary, scattered, block, intercrop and line planting respectively (Table 5). Also 44, 27, 14, 11, and 6 per cent timber trees were planted on the boundary, scattered, block, intercrop and line planting respectively whereas, 50, 30, 15, 3 and 3 per cent fodder trees along the boundary, scattered, block, intercrop and line planting respectively. 47, 32, 13, 5 and 4 per cent fuel trees were planted at the arrangement of boundary, scattered, block, intercrop and line planting respectively. In Marh sub division 47, 32, 13, 5 and 4 per cent fruit trees were planted by respondents along the boundary, scattered, block, intercrop

Table 4. Prevalence of agroforestry systems (percent)

Agricultural Sub- division system	Akhnoor (n=80)	Dansal (n=48)	Marh (n=32)	Overall percentage N=(160)
Agrisilvicultural system	20	28	22	23
Agrosilvopastoral system	80	72	78	77

and line planting respectively, 38, 23, 13, 5, and 4 percent timber trees were under the arrangement of boundary, scattered, block, intercrop and line planting respectively, followed by fodder trees. In Marh sub division 52, 37, 6, 4 per cent fuel wood trees were available on the boundary, scattered, block and intercrop, respectively. The existence of woody perennials on the fields along with the annual crops and livestock plentifully rationalize the fact that people of the

Table 3. Average farming experience and social participation of the respondents

Particular	Agriculture sub-division			Overall percentage (n=160)
	Akhnoor (n=80)	Dansal (n=48)	Marh (n=32)	
Average farming experience (years)	31 ±12.53	28±9.16	30±10.09	30±11.13
		F=0.79, P=0.46 NS		
Social participation (percentage)				
Membership of an organization	6	14	12	08
No membership	94	86	88	92
Extension Contacts with different agencies (percentage)				
Yes	40	40	50	42
No	60	60	50	58

Table 5. Arrangements of woody perennials on farmland (per cent)

Agriculture subdivision	Akhnoor (n=80)				Dansal (n=48)				Marh (n=32)			
Arrangement	Fruit	Timber	Fodder	Fuel	Fruit	Timber	Fodder	Fuel	Fruit	Timber	Fodder	Fuel
Boundary	51.9	40.5	47.8	47.5	50.8	44.0	50.0	46.7	46.3	38.2	44.9	51.4
Scattered	28.8	26.8	29.6	23.4	33.5	26.4	29.7	31.8	40.2	23.4	30.6	36.8
Block	11.5	15.4	14.8	14.6	7.2	14.0	14.9	13.1	7.3	17.0	14.3	5.9
Intercrop	3.8	9.4	3.5	7.6	4.8	10.4	2.7	4.7	3.7	10.6	6.1	4.2
Line planting	4.0	6.3	4.3	7	3.7	5.3	2.7	3.7	2.5	10.8	4.1	0.0

Table 6. Factors affecting the adoption of agri-silvicultural system (Binary logistic regression)

Independent variable	B	SE	Wald	p value	Model Summary
Agrisilvicultural system					
Schooling years	0.048	0.089	0.285	0.593	-2Log likelihood=160.009a, Nagelkerke R^2 =.098
Family size	-0.091	0.077	1.387	0.239	
Land holding	-0.305	0.391	0.607	0.436	
Farming experience	0.073	0.041	3.124	0.077	
Extension contacts	0.454	0.404	1.258	0.262	
Age	-.099	0.043	5.325	0.021	
Constant	1.819	1.720	1.119		

area practice different forms of agroforestry systems. The results are in accordance with the findings of Nair (1998) and Campbell et al (1981) (Table 5). Only age of the farmers had significantly negative effect on the farmers' decision to adopt agrisilvicultural system. For a unit increase in farmers age, the chances of adopting agrisilvicultural system decreased by a factor of 0.099. Nagelkerke R^2 value suggested that 9.8% variation in the adoption of agrisilviculture was due to these independent variables (Table 6).

CONCLUSION

The traditional agroforestry systems were common in rain-fed areas of Jammu district. But well-designed agroforestry practices were not common. The farmers retained/planted trees on their fields primarily for fruits, fuel-wood and fodder purpose. The trees on their fields were mostly not planted by people but that regenerated naturally. The forest department, agriculture department and other extension workers can play significant role to create awareness among the people for application of well-designed agroforestry systems and up-scaling their adoption and securing their livelihood on sustainable basis.

REFERENCES

Baffoe-Asare R, Danquah JA and Annor-Frempong F 2013 Socio-economic factors influencing adoption of Codapec and Cocoa High–tech technologies among small holder farmers in central region of Ghana. *American Journal of Experimental Agriculture* **3**(2): 277-292.

Campbell BM, Clarke JM and Gumbo DJ 1991. Traditional agroforestry practices in Zimbabwe. *Agroforestry Systems* **14**: 99-111.

Dadhwal KS, Sharma NK and Saroj PL1995. Diagnosis and possible interventions in designing agroforestry systems in north-western plains of Uttar Pradesh-a case study. *Indian Journal of Soil Conservation* **23**(1): 47-53.

Nair PKR and Dagar JC 1991. An approach to developing methodologies for evaluating agroforestry systems in India. *Agroforestry Systems* **16**(1): 55-81.

Neupane RP, Sharma KR and Thapa GB 2002. Adoption of agroforestry in the hills of Nepal: a logistic regression analysis. *Agricultural Systems* **72**(3): 177-196.

Verchot LV, Van Noordwijk, M Kandji, S Tomich, T Ong, C Albrecht and Palm C 2007. Climate change: linking adaptation and mitigation through agroforestry. *Mitigation and Adaptation Strategies for Global Change* **12**(5): 901-918.

Combination of Agricultural Waste and Saw Dust into Biomass Material for Briqutte

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Abstract: Study was undertaken to examine the development and characterization of agricultural waste as well as sawdust briquette. The selection, collection, drying up and proper sizing of residue is significant in the pre-treatment processes for turning the mixture into the briquette. The testing parameter considers some best bio-waste suitable, like volatile matter, ash content, proximate analysis, moisture content, carbon and heating value. On the basis of test report, it was observed that in the briquette making process cashew nut shell, neem leaf and saw dust are considered as best bio-waste mixture. Further, the cost of briquette making could be reduced by using appropriate apt mixture of bio-wastes.

Keywords: Sawdust, Moisture content, Total ash content, Fixed carbon, Volatile matter, Gross calorific value

By fulfilling approximately 14 per cent of the global energy needs, biomass has accomplished fourth ranks among the worldwide energy resource. In developing nations, the biomass is providing 35 per cent of their energy needs and hence considered as the most significant source of energy. However, fuel briquette is the energy source that can fulfill such sustainability requirements. Due to low cost production and easy accessibility, it is replacing the use of firewood and charcoal in domestic cooking as well as agro-industrial operations with subsequent reduction in high demand on both. Moreover, briquettes are preferred over fuel wood for several advantages, like greater heat intensity, cleanliness, easy to use and requirement of relatively smaller storage space. Direct burning of agricultural residues is very inefficient due to the transportation, storage and handling problems associated (Pallavi et al 2013). In addition to these, sawdust can produce briquettes with higher calorific value (Olorunnisola et al 2004). Nigeria produced briquettes from cold densified rice straw using sawdust as a binder (Rahaman et al 2017).

Recognized for its rich agricultural resources, India is experiencing the problem of generating 50 million tons of waste, which is about 30 per cent of its total production (Cheng et al 2010). Nowadays the focus is on converting wastage into green energy instead of ploughing them into soil. Biomass can be utilized as biofuel as they not only offer sustainability, but also the advantages of CO_2 neutralization. Most interestingly, the consumption of CO_2 by the biomass from the atmosphere is same as their release amount during the combustion of biomass (Demirbas et al 2004, Verma et al

2011). Further, wood processing industry is generating large amounts of biomass wastage in the form of wood sawdust. Due to high heat generation capacity, the wood biomass is considered as one of the preferable choice in this field (Chau et al 2009). However, direct usage of sawdust is not a convenient matter due to difficulty in the following factors, like low energy density, unstable combustion rate, high particle emission, spontaneous combustion, storage and transportation (Demirbas et al 2004 and Verma et al 2011). Hence, the practical solution is to compact the low density sawdust into high density biomass briquette. It can be stated that sawdust briquettes are the best choice among other briquettes. In southern India, however, most of the medium scale industries prefer sawdust briquette. High demand has also been observed in the briquette market with raw biomass (sawdust) in the market simultaneously. As a consequence, rising cost is quite natural for briquette and sawdust. The industry is looking for alternative fuel, which resulted in a reduction in demand of sawdust with producing the mixed briquette. Hence, biomass waste materials can easily access the bio wastes, like rice husk, sugarcane baggage, groundnut shell, coir pith, neem leaf and others, and mix them with sawdust for briquette making. So, it can be stated that this is one of the best alternatives to reduce deforestation. The present study based on combination of agricultural waste and saw dust into biomass material for Briqutte

MATERIAL AND METHODS

The selected bio wastes are collected and some of bio

waste needs shredding or drying. The selected bio-wastes are mixed as per the ratio in sawdust 80% remaining different bio-waste are mixed as different samples scheduled (Table 1). The mixture is fed into piston type briquetting machine and ten different samples of 60mm diameter (Fig. 1). The samples are tested as per the following proximate analysis and heating value as it is and dry basis. After evaluation, the suitable bio- waste is taken for mixing with saw dust (Fig. 2).

Volatile matter: Analysis of volatile matter was accomplished according to ASTM. Standard raw samples of about four grams were heated in a furnace for seven minute at 950 +- 20°C. Volatile matter was then determined by measuring the weight loss excluding weight of moisture driven off at 105°C.

Moisture content: Moisture content of raw materials was determined using the following procedure of ASTM standard. About two grams of the sample were taken in a crucible and dried at 105 ± 2°C. The moisture content was determined by weight measurement in three hours intervals and expressed in percentage wet basis.

Ash content: The oven dried samples were then heated in a muffle furnace in order to determine the ash content as stated in ASTM standard. The ash content was measured by weighing and expressed as a percentage of sample oven dried weight.

Fixed carbon: The fixed carbon in percentage was calculated finding the difference between 100 and the sum of the volatile matter, moisture content and ash content.

Heating value: Gross heat of combustion of sawdust was mixed with bio-waste to make briquette. The heat value was determined according to ASTM standard by oxygen bomb calorimeter. The samples were weighed and placed in-side the bomb calorimeter. Then oxygen was filled with pressure

Fig. 2. Sample briquettes

inside the calorimeter after burning the fuel, the liberated heat causes the temperature rise. The amount of heat liberated by the sample was determined by multiplying the measured temperature rise with the energy equivalent of the calorimeter. To obtain the heating value on a unit weight basis, the liberated heat was divided by the weight of the sample as in Table 3.

$$\text{Heating value (KJ/Kg)} = [W \times (T_1 - T_2)]/M \qquad (1)$$

Where W is the energy equivalent of the calorimeter, T_1-T_2 is the temperature rise in a calorimeter and M is the mass of the sample

Energy equivalent (W) of calorimeter was 10027.42 KJ/°C by using standard values.

RESULTS AND DISCUSSION

Moisture content: Sawdust 80% + rice husk 10% +groundnut shell 10% (sample 9) has the highest and sample 6 has the lowest moisture percentage. The inverse effect of this moisture can be observed on the heating value. However, where the moisture content is high, the liberation of
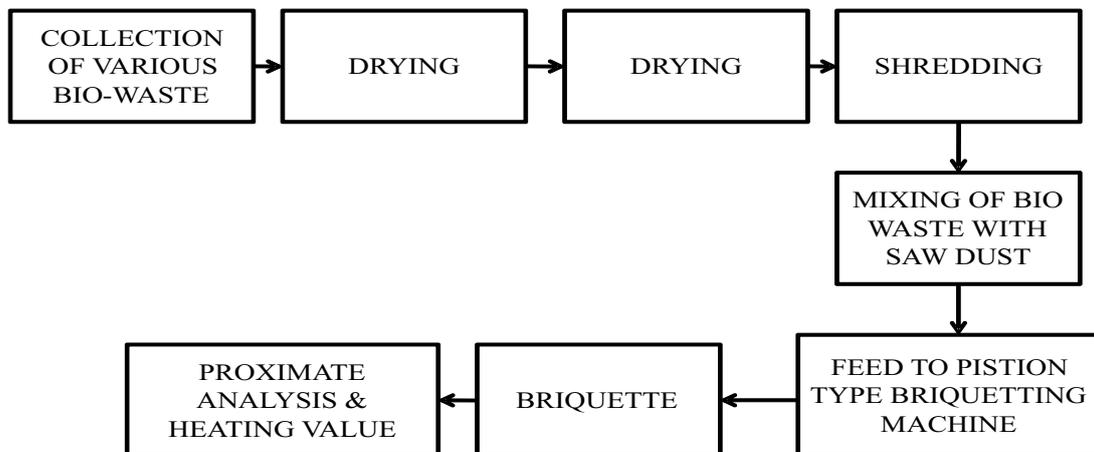

Fig. 1. Scope of work

heat will be lower during the combustion Hence, sawdust 80+neem leaf 20% (sample 6) with least value of moisture content (7.54%) recorded calorific value of 4256 KJ kg^{-1}. Sawdust 80% + rice husk 10%+groundnut shell 10% (sample 9) with the highest value of moisture content (9.50%), with calorific value of 4190 KJ kg^{-1} (Table 2).

Ash content: The ash contents were maximum in sample 8 (5.44 %) and minimum in sample 5 (0.91 %). Although, significance of ash content on heating value is not yet established, yet ash is considered as a measure of non-combustible in organics in biomass. Further, the higher ash content affects the heating value. Apart from these, slagging and fouling problems emerge from the ash fusion that ultimately led to correction as well as reduction in combustion efficiency. The sample 8 recorded the highest value with ash and calorific value of 3941 KJ kg^{-1}. Further, the sample with lower value of ash content had calorific value of 4195 KJ kg^{-1}. On the basis of ash %, the sample 5 (sawdust and sugarcane bagasse) is considered as the best bio-waste mixture for making briquette.

Volatile matter: Sample 7 were with highest (76.09 %) and sample 10 with the lowest (67.91 %) volatile matter. Since the high amount of volatile matter is involved in the biomass, therefore a positive influence of the same can be observed on the sustainability of combustion. Due to this high volatile matter content, the biomass becomes a highly reactive fuel with a faster combustion. Sample 10 with least value of volatile matter have heating value of 4040 KJ kg^{-1}. Sample 7 with the highest volatile matter has heating value of 4063 KJ kg^{-1}. With the respect of this parameter, it can be stated that both are almost same and thereby the best one is selected on the basis of other constraints.

Fixed carbon: The sample 6 recorded higher fixed carbon (19.82%) and sample 7 lower percentages of fixed carbon (10.23%). After expulsion of all the volatile matter, the fixed carbon content is the available portion of carbon of the combustion. During combustion, fixed carbon is seen as the main energy generation source. The sample 6 with higher value of fixed recorded calorific value of 4256 KJ kg^{-1}. The sample 7 with lower carbon value had calorific value of 4063

Table 1. Composition of sample

Sample	Content of bio waste (%)*	Need of shredding	Need of drying
Sample 1	Cashew nut shell 20%	No	No
Sample 2	Rice straw 20%	Yes	No
Sample 3	Tamarind shell 20%	No	No
Sample 4	Bran 20%	No	No
Sample 5	Sugar cane baggage 20%	Yes	Yes
Sample 6	Neem leaf 20%	No	Yes
Sample 7	Rice husk 10% + Coir pith 10%	No	Yes
Sample 8	Groundnut shell 10% + Coir pith 10%	No	Yes
Sample 9	Rice husk 10% + Groundnut shell 10%	No	No
Sample 10	Cow dunk 10% + Coir pith 10%	No	Yes

*Include in addition to 80 % sawdust

Table 2. Proximate analysis of biomass samples

Sample	Fixed carbon (%)	Volatile matter (%)	Ash (%)	Moisture content (%)	Heating value after drying (KJ/Kg)	Heating value before drying (KJ/Kg)
Sample 1	15.37	73.09	2.88	8.68	4686	4280
Sample 2	14.82	72.77	3.71	8.70	4378	3997
Sample 3	17.43	73.24	1.09	8.24	4275	3923
Sample 4	13.93	73.46	3.29	9.32	4162	3773
Sample 5	18.08	73.33	0.91	7.68	4544	4195
Sample 6	19.82	71.44	1.20	7.54	4604	4256
Sample 7	10.23	76.09	4.87	8.81	4456	4063
Sample 8	12.07	73.94	5.44	8.55	4310	3941
Sample 9	11.67	74.64	4.19	9.50	4372	4190
Sample 10	18.90	67.91	3.83	9.36	4458	4040

KJ kg^{-1}. On the basis of fixed carbon, sample 6 is selected as the best one.

Higher heating value of biomass: This property depends on several factors, like biomass constituent, moisture content and ash content. Sample 1 and sample 6 can be selected with higher and lower heating value of 4280 KJ kg^{-1} and 4256 KJ kg^{-1} respectively.

CONCLUSIONS

In this research work, the calorific value of briquette of sample 6 was 4256 KJ/Kg. In the next best sample, i.e. sample 1, the mixture of cashew nut shell and sawdust had resulted in nearly pure sawdust briquette with a heating value of 4280 KJ/Kg. Apart from this, the trend of importing logs by the timber merchants of southern India is now replaced by importing of wood of required size on the basis of need. This has resulted in high demand of sawdust. As a consequence, exploration of optimal source for making briquette has resulted in finding as well as utilization of the alternative biomass raw materials, like cashew nut shell, neem leaf along with sawdust.

REFERENCES

Akowuah JO, Kemausuor F and Mitchual SJ 2012. Physico-Chemical Characteristic and Market Potential Of Sawdust Charcoal Briquette. pp. 1-6. Proceedings of the 55th *International Convention of Society of Wood Science and Technology* August 27-31, 2012 - Beijing, CHINA.

Chau J, Sowlati T, Sokhansany S, Preto F, Melin S and Bi X 2009. Techno-economic analysis of wood biomass boilers for the green house industry. *Application Energy* **86**(3): 64-71.

Cheng H and Ha Y 2010. Municipal solid waste as a renew-able source of energy : Current status and future partices in China. *Bioresoure Technology* **101**(11):16-24.

Demirbas A 2004. Combustion characteristics of different biomass fuels. *Progress in Energy and Combustion Science* **30**(2):19-30.

Gowan MC 1991. Controlling the green house effect; the role of renewable energy. *Energy Policy* **1**(1):1-8.

Gravalos I, Kateris D, Xyradakis P, Gialamas T, Loutridis S and Augousti A 2015. Study On Calorific Energy Values of Biomass Reduced Pallets for Heating Purpose, In *Forest engineering; meeting the needs of the society and the environment*; FORMEC symposium-2015 July 11-14,Padua, Italy.

Grover PD and Mishra SK 1995. Biomass Briquetting: Technology and Practices Proceedings on the International Workshop on *Biomass Briquetting,* New Delhi, India, 3–6 April1995.

Hall DO, Rosillo-Calle F and De Groot P 1992 Biomass energy reasons from case studies in developing countries. *Energy Policy* **20**(1): 62-73.

Jenkins BM, Baxter LL, Miles Jr TR and Miles TR 1998. Combustion properties of biomass. *Fuel Process Technology* **54**(1):17-46

Kaliyan N and Morey RV 2006 Densification characteristics of corn stover and switchgrass. *Trans on American Society of Agricultural and Biological Engineers* **52**(3): 907-920.

Loo SV and Koppejan J 2008. *The Handbook of Biomass Combustion and Co-Firing.* London: Earthscan.

Olorunnisola AO 2004. Briquetting of rattan furniture waste. *Journal of Bamboo and Rattans* **3**(2): 139-149.

Singh A and Singh Y 1982. Briquetting of paddy straw. *Agricultural Mechanization in Asia, Africa and Latin America* **13**(4): 42-44.

Sun S, Zhao Y, Ling F and Su F 2009. experimental research on air staged cyclone gasification of rice husk. *Fuel Process Technolo*gy **90**(4): 65-71.

Verma VK, Bran S, Vandendael I, Latha P, Hubin A and Ruyckj De 2011. Residential pellet boilers in Belgium; Standard laboratory and real life performance with respect to European standard and quality labels. *Applied Energy* **88**(26): 28-34.

Werther J and Saenger M 2000. Combustion of agricultural residues. *Progress in Energy and Combustion Science* **26**(1):1-27.

Pallavi HV, Srikantaswamy S, Kiran BM, Vyshnavi DR and Ashwin CA 2013. Briquetting agricultural waste as an energy source. *Journal of Environmental Science, Computer Science and Engineering & Technology* **2**(1): 160-72.

Romallosa ARD and,-Kraft E 2017 Feasibility of biomass briquette production from municipal waste streams by integrating the informal sector in the Philippine. *Resources* **6**(12): 1-19.

Rahaman SA and Salam PA 2017 Characterization of cold densified rice straw briquettes and the potential use of sawdust as binder. *Fuel Process Technolo*gy **158**: 9-19.

Variation in Esterase Activity among Various Populations of *Helicoverpa armigera* (Hubner) in Northern India

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Abstract: *Helicoverpa armigera* causes severe yield losses across the globe and has achieved resistance against many pesticides. The major mechanism of resistance in this pest is elevated level of esterases. The present studies were directed to estimate the general esterase activity and specific esterase activity of six populations of *H. armigera* collected from different agro climatic regions of north India viz. Hisar, Bathinda, Kangra, Solan, Theog and Kinnaur. The results indicated higher esterase activity in populations from pesticide intensive areas i.e. Punjab and Haryana compared to Himachal Pradesh. Maximum general esterase activity was found in Bathinda (401.75 μg α-naphthol formed) and Hisar (401.75 μg α-naphthol formed), whereas, minimum esterase activity was found in Kinnaur (198.88 μg α-naphthol formed). These studies will be helpful in formulating strategies for management of this pest and determining its resistance status.

Keywords: *Helicoverpa armigera*, Esterase activity, Population variations

Helicoverpa armigera is one of the important pests of agriculture crops throughout the world. This pest causes severe yield losses to various species of cereals, pulses, cotton, vegetables and fruit crops as well as wild hosts. It is a key pest of cotton, pigeon pea, chickpea, sunflower, tomato, sorghum, okra and corn in India and reported from more than 182 plant species world over (Gowda 2005). This pest causes huge economic losses to the agricultural crops all the world. Globally this pest has been reported to cause a damage greater than $2 billion annually, excluding socio-economic and environmental costs associated with its control (Tay et al 2013). In India around 75% of the insecticides used in cotton are directed against this pest (Kranthi et al 2002). The utilization of pesticides for the management of this pest has remained as the major strategy all over the world. This has led to the development of resistance in this insect against many pesticides (Fitt and Wilson 2000, Yang et al 2013). The major mechanism for the metabolically induced resistance involves the overexpression of the esterases in the resistant individuals (Abd El-Latif and Subrahmanyam 2010b). Esterases are the isozymes which are produced by the insects for accomplishing detoxification and sequestration of organophosphate and carbamate pesticides (Byrne and Devonshire 1993). It has been reported that in field population of *H. armigera*, pyrethroid resistance has been developed which is linked largely to the overproduction of esterase isozymes which are thought to sequester and hydrolyse the pyrethroids correlating to its resistance factor (Srinivas et al 2004, Yang et al 2005). Similarly *H. armigera*

resistant to organophosphates or synthetic pyrethroids is associated with higher carboxyl-esterase activity compared to susceptible controls (Campbell 2001, Bues et al 2005). Keeping in view these facts, the present studies were carried out on relative variations in the esterase activity among six populations of this pest collected from different agro-climatic region of North India viz. Himachal Pradesh, Punjab and Haryana.

MATERIAL AND METHODS

Sampling locations: The larvae and adults of *H. armigera* were collected from four different agroclimatic zones of Himachal Pradesh and two locations of the neighbouring states of Punjab and Haryana. The details of the locations and their geographical attributes are presented in the Table 1.

Extraction of enzyme: For the extraction of enzyme, two 3rd instar larvae of *H. armigera* were homogenized in 3 ml of maceration buffer i.e. 0.1M sodium phosphate buffer (pH 6.5) containing 0.1 per cent Triton X-100 in pre-chilled Teflon homogenizer. The homogenate was thereafter centrifuged at 10,000 rpm at 4°C for 20 minutes. The supernatant thus obtained was utilized as enzyme extract. This enzyme extract was used for the determination of the protein content and the general esterase enzyme activity of the insects.

Protein assay: Protein content was determined as per the method of Lowry et al. (1951). Standard curve was prepared by different concentrations (20, 40, 60, 80, 100 micro gm/ml) of Bovin serum Albumin. Only water and reagents were taken for the blank.

Estimation of general esterases: Esterase activity towards α-naphthyl acetate was estimated following the method of Wool and Greenberg (1990). The reaction mixture was prepared by mixing 2.0 ml of 0.1M sodium phosphate buffer with 0.1 ml of enzyme extract. Then reaction was initiated by adding 0.2 ml of 3mM α-naphthyl acetatae to this mixture. The mixture was incubated at 30°C for 30 minutes and the reaction was stopped by adding 0.5 ml of Fast Blue B solution (0.3% Fast Blue B salt in 3.5% of sodium dodecyl sulphate). The rate of formation of α-naphthol was measured after 10 minutes at 602nm using a UV visible spectrophotometer (Shimadzu Corporation, Japan) against blank containing sodium phosphate buffer, substrate solution and Fast Blue B solution. Standard curve was prepared by using different concentrations (0.5, 1.0, 1.5, 2.0, 2.5 micro gm/ml) of α-naphthol. The enzyme activity was expressed in the form of μgm of α-naphthol formed/min/g of *H. armigera* and μM of α-naphthol formed/min/g. Similarly specific activity was expressed in the form of μgm of α-naphthol formed/min/mg protein and μM of α-naphthol formed/min/mg protein.

RESULTS AND DISCUSSION

Activity of general esterases: The highest activity of the enzyme was in the Bathinda population (415.85 μgm of α-naphthol formed/g of *H. armigera* /min) followed by the population of Hisar. The populations of Himachal Pradesh expressed comparatively lesser activity of the enzyme (198.88 to 292.75 μgm of α-naphthol). The general esterase activity gave similar trend when expressed as μM of α-naphthol formed. The Bathinda population had significantly maximum activity (2.88) followed by the Hisar, Kangra, Theog and Solan populations whereas, the Kinnaur population had the least activity (1.38) and was significantly different from other populations.

Estimation of proteins: The concentration of protein varied within different populations of *H. armigera* (Table 3). The highest protein content was observed in Bathinda population (34.21mg/g) followed by the Hisar population. The least values were observed in the Kinnaur population (29.19) followed by the Solan population (30.68).

Table 2. General esterase activity of six populations of *Helicoverpa armigera*

Locations	α-naphthol formed/g of *Helicoverpa armigera* / min (μg)	α-naphthol formed/g of *Helicoverpa armigera* / min (μM)
Hisar	401.75 ±1.93	2.79 ±0.01
Bathinda	415.85 ±7.36	2.88 ±0.05
Solan	241.33 ±1.69	1.67 ±0.01
Theog	243.33 ±2.30	1.69 ±0.02
Kangra	292.75 ±3.94	2.03 ±0.03
Kinnaur	198.88 ±1.29	1.38 ±0.01
CD (p=0.05)	11.15	0.08

Specific activity of esterases: Specific activity of esterases was calculated in the form of μgm of α-naphthol formed/min/mg protein (Table 3). The results followed almost similar trend as that of general esterase activity. The populations from Punjab and Haryana locations had higher specific activity compared to Himachal populations. The highest specific activity was in Bathinda population (12.16) followed by Hisar population. Among populations of Himachal Pradesh, the Kangra population had the highest specific activity followed by Solan and Theog population whereas, the Kinnaur population had the least specific activity. Similar results were obtained when, the specific activity was expressed as nM of α-naphthol formed/ mg of protein /min as Bathinda population (84.3) had the highest activity followed by Hisar, Kangra, Solan and Theog population whereas, Kinnaur population showed the least specific activity. These results indicated that the Bathinda population was the most resistant to pesticides among all these followed by the Hisar population. In Himachal, the Kangra population had the maximum resistance followed by Solan and Theog populations. The Kinnaur population had the least pesticides resistant traits. The difference in the esterase activity among various population of *H. armigera* during the present studies may be attributed to the difference in their resistance level as is evident from various studies across the world. Variability in the esterase activity of *H. armigera* at different locations of Punjab was observed by

Table 1. Sampling locations and their geographical attributes

Location	State	Latitude (°N)	Longitude (°E)	Altitude (amsl)
Kangra	Himachal Pradesh	32.10	76.27	733 m
Solan	Himachal Pradesh	30.92	77.12	1,502 m
Theog	Himachal Pradesh	31.12	77.35	1,965 m
Kinnaur (Kalpa)	Himachal Pradesh	31.53	78.25	2,960 m
Bathinda	Punjab	30.22	74.95	210 m
Hisar	Haryana	29.15	75.70	215 m

Table 3. Specific activity of esterases in six populations of *Helicoverpa armigera*

Locations	μg of α-naphthol formed/mg of protein/min	nM of α-naphthol formed/ mg of protein /min	Protein (mg/g of *Helicoverpa armigera*)
Hisar	11.95 ±0.07	82.9 ±0.49	33.64 ±0.33
Bathinda	12.16 ±0.07	84.3 ±0.47	34.21 ±0.53
Solan	7.87 ±0.06	54.6 ±0.44	30.68 ±0.04
Theog	7.24 ±0.02	50.2 ±0.15	33.62 ±0.27
Kangra	9.24 ±0.05	64.1 ±0.37	31.67 ±0.29
Kinnaur	6.82 ±0.06	47.3 ±0.42	29.19 ±0.43
CD (p=0.05)	0.18	1.22	1.04

Sidhu and Sohal (2007). The highest activity was observed from Mansa population which was known to be resistant to many insecticides. Similarly, a study conducted by Abd El-Latif and Subrahmanyam (2010a) revealed that Nagpur and Delhi strains of *H. armigera* which are resistant to deltamethrin have higher esterase activity compared to the susceptible strain. Nagpur and Delhi strains showed a specific activity of 0.465 and 0.353 µmol of α -naphthol produced/mg protein/min whereas, the susceptible strain had a specific activity of 0.204 µmol of α-naphthol produced/mg protein/min. Studies by Wu et al. (2011) showed that enhanced hydrolysis by esterase isozymes contributes to the resistance of *H. armigera*. The mean esterase activity of the resistant YGF strain was 489 nmol/min/mg protein, 1.9-fold higher than that of the susceptible SCD strain, 258 nmol/min/ mg protein. The esterase activity was positively correlated with increased frequencies of resistance in 15 populations of the tobacco budworm, *Heliothis virescens*, across Louisiana, USA (Harold and Ottea 2000).

However it has also been found that enhanced general esterase activity could not be a sole indicator of the resistance in the insects towards the pesticides. Several workers found anomalies in the relationship of the resistance and esterase activity. Resistant field populations were found to have lower level of mean esterase activity than susceptible control in some studies (Wool and Greenberg1990). The activities of general esterase of different strains of *H. armigera* collected from cotton fields in Adana, Hatay, Antalya (Turkey) were 0.65, 0.8 and 1.14 fold, respectively with respect to the susceptible strain. Adana and Hatay strains had lower general esterase enzyme activities than that of susceptible strain. However, general esterase enzyme activity in Antalya strain was found to be similar to the susceptible strain (Karaagac et al 2011). No relation between the elevated esterases activity and the resistance was observed by Ibrahim and Ottea (1995). These findings reflects the heterogeneity in resistance mechanisms among populations. It can be inferred that esterases are not the only resistance

mechanism in these populations. Thus, the validity of enzyme activities measured with model substrates as indicators of metabolic resistance to insecticides cannot be assumed. Resistance as determined by the metabolic detoxification may be inferred from any change in the general esterase activity of the individuals (Ffrench-Constant and Devonshire 1988). The identification of specific enzymes and their assays are required for better understanding the relationship between resistance mechanism and esterase activity.

CONCLUSION

The study demonstrated the variations among *H. armigera* populations with respect to their esterase activity. The populations from Punjab and Haryana showed higher level of esterase activity indicating a higher level of the resistance in these populations. The populations of Himachal Pradesh had a lower resistance level as evident from their esterase activity. Measurement of esterase activity of different *H. armigera* populations may find utility in the pest management strategy involving insecticide use and determination of the development of resistance in the populations of this pest.

REFERENCES

Abd El-Latif AO and Subrahmanyam B 2010a. Pyrethroid resistance and esterase activity in three strains of the cotton bollworm, *Helicoverpa armigera* (Hübner). *Pesticide Biochemistry and Physiology* **96**: 155-159.

Abd El-Latif AO and Subrahmanyam B 2010b. Pyrethroid synergists suppress esterase-mediated resistance in Indian strains of the cotton bollworm, *Helicoverpa armigera* (Hübner). *Pesticide Biochemistry and Physiology* **97**: 279-288.

Bues R, Bouvier JC and Boudinhon L 2005. Insecticide resistance and mechanisms of resistance to selected strains of *Helicoverpa armigera* (Lepidoptera:Noctuidae) in the south of France. *Crop Protection* **24**: 814-820.

Byrne FJ and Devonshire AL 1993. Insensitive acetylcholinesterase and esterase polymorphism in susceptible and resistant populations of Tobacco Whitefly Bemisia tabaci (Genn.). *Pesticide Biochemistry and Physiology* **45**: 34-42.

Campbell BE 2001. *The role of esterases in pyrethroid resistance in Australian populations of the cotton bollworm, Helicoverpa armigera (Hübner) (Lepidoptera: Noctuidae)*, Ph.D. Thesis. Australian National University, Canberra, Australia.

Ffrench-Constant RH and Devonshire AL 1988. Monitoring

frequencies of insecticide resistance in *Myzus persicae* (Sulzer) (Hemiptera: Aphididae) in England during 1985-1986 by immunoassay. *Bulletin of Entomological Research* **78**: 163-171.

Fitt GP and Wilson LJ 2000. Genetic engineering in IPM: Bt cotton, In: Kennedy GG, Sutton TB (Eds.) *Emerging technologies in integrated pest management: concepts, research and implementation.* APS Press, St Paul, MN, USA, pp. 108–125.

Gowda CLL 2005. *Helicoverpa* - the global problem. In: Sharma, HC (ed) *Heliothis/Helicoverpa management: emerging trends and strategies for future research*. Oxford and IBH publishing co. New Delhi. pp. 1-6.

Harold JA and Ottea JA 2000. Characterization of esterases associated with profenofos resistance in the tobacco budworm, *Heliothis virescens*. *Archives of Insect Biochemistry and Physiology* **45:** 47-59.

Ibrahim SA and Ottea JA 1995. Biochemical and toxicological studies with field populations of *Heliothis virescens*. *Pesticide Biochemistry and Physiology* **53**: 116-128.

Jairaj S 1990. The problem of *Helicoverpa armigera* in India and its integrated pest management, pp. 1-16. *In: Heliothis* management. Proceedings of the *National Workshop Centre for Plant Protection Studies,* Tamil Nadu Agricultural University, Coimbatore.

Karaagac SU, Iscan M and Gurkan MO 2011. Determination of enzyme activities of susceptible and field populations of *Helicoverpa armigera* (Hübner) (Lepidoptera: Noctuidae) and its relationship with insecticide resistance**.** *Bitki Koruma Bülteni* **51**(1): 61-75.

Kranthi KR, Jadhav DR, Kranthi S, Wanjari RR, Ali SS and Russell D 2002. Insecticide resistance in five major insect pests of cotton in India. *Crop Protection* **21**: 229–460.

Lowry OH, Rosenbrough NJ, Farr AL and Randall RJ 1951. Protein measurement with folin phenol reagent. *Journal of Biochemical Chemistry* **193**: 265-275.

Sidhu MS and Sohal BS 2007. Esterase activity and I_{50} variations in *Helicoverpa armigera* (Hubner) from different locations in Punjab. *Journal of Insect Science* **20**(1): 15-20.

Srinivas R, Udikeri SS, Jayalakshmi SK and Sreeramulu K 2004. Identification of factors responsible for insecticide resistance in *Helicoverpa armigera*. *Comparative Biochemistry and Physiology Part C: Toxicology and Pharmacology* **137**: 261-269.

Tay WT, Soria MF, Walsh T, Thomazoni D, Silvie P, Behere G T, Anderson C and Downes S 2013. A brave new world for an old world pest: *Helicoverpa armigera* (Lepidoptera: Noctuidae) in Brazil. *PLoS ONE.* **8**(11): 1-7.

Wool D and Greenberg S 1990. Esterase activity in whiteflies (*Bemicia tabaci*) in Israel in relation to insecticide resistance. *Entomologia Experimentalis Et Applicata* **57**: 251-258.

Wu S, Yang Y, Yuan G, Campbell PM, Teese MG, Russell RJ, Oakeshott JG and Wu Y 2011. Overexpressed esterases in a fenvalerate resistant strain of the cotton bollworm, *Helicoverpa armigera. Insect Biochemistry and Molecular Biology* **41**: 14-21.

Yang E, Yang Y, Wu S and Wu Y 2005. Relative contribution of detoxifying enzymes to pyrethroid resistance in a resistant strain of *Helicoverpa armigera. Journal of Applied Entomology* **129**(9/10): 521–525.

Yang Y, Li Y and Wu Y 2013. Current status of insecticide resistance in *Helicoverpa armigera* after 15 years of Bt cotton planting in China*. Journal of Economic Entomology* **106**: 375–381.

Evaluation of Aquaculture Units Established in Inland Salt Affected Areas of District Fazilka, Punjab

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Abstract: Underproductive or unproductive (zero earning) inland salt affected waterlogged areas in northern states of India offers an opportunity for commercial utilization and productive use through aquaculture. The present study was taken up in two inland salt affected waterlogged villages (Shajrana and Bahadur Khera) in district Fazilka of Punjab, to evaluate the status of aquaculture units with respect to water quality and suitability for rearing of freshwater and brackish water species. The water samples, collected from twenty two aquaculture units from selected villages, were analysed for different physico-chemical parameters viz., pH, salinity, electrical conductivity, total hardness, total alkalinity and salts including sodium, calcium, potassium, magnesium, chloride and sulphate. All the units surveyed during the present study, were being used for rearing of freshwater carps like *Catla catla* (Catla), *Labeo rohita* (Rohu), *Cirrhinus mrigala* (Mrigal), *Ctenopharyngodon idella* (Grass carp) and *Cyprinus carpio* (Common Carp), under semi intensive polyculture system and the salinity of 02 (9.09%), 08 (36.36%) and 12 (54.54%) units was found to be <5, 5 and >5 ppt, respectively. Out of 22 aquaculture units surveyed, only 02 units with salinity range 3-4 ppt (< 5 ppt), were found suitable for rearing freshwater carps without any intensive technological intervention, while productivity of fresh water carps in 08 aquaculture units (5ppt) is not expected to remain sustainable on long term basis and rest of the units (12) with salinity levels >5 ppt (6-14 ppt) are not suitable for any profitable carp culture practices.

Keywords: Inland saline areas, Aquaculture, Punjab, Sustainability

In north India, salt affected soils have converted a large area of fertile lands in arid and semi-arid region to non-productive waste lands. The total salt affected soils in India have been documented to be 6.74 million hectare (mha), including 5.50 mha of inland salt affected soils in non-coastal states and 1.24 mha saline soils in the coastal states (Mandal et al 2010). About 12 lakh ha (1.2 m ha) of inland salt affected soils have devastated agriculture in Punjab (1.51 lakh ha), Haryana (2.32 lakh ha), Rajasthan (3.75 lakh ha), Bihar (1.53 lakh ha), Uttar Pradesh (1.37 lakh ha), Madhya Pradesh (1.39 lakh ha) and Jammu and Kashmir (0.17 lakh ha). Punjab constitutes 5.03 m ha of geographical area, with ground water quality varying from good (59%), marginal (22%) to poor (19%). The poor waters are saline (22%), sodic (54%) and saline-sodic (24%), which is unfit for human consumption as well as agricultural and industrial use (Minhas and Bajwa 2001). In the recent past, efforts have been made to utilize these areas for aquaculture, especially the areas affected by dual problem of underground water salinity and water logging (Pathak et al 2013, Dhawan et al 2016). Although, there is ample scope of rearing brackish water finfish/shellfish species in these areas (Jain 2007, Pathak et al 2013), but due to non availability of seed and

climatic restrictions, freshwater carp culture was tested, demonstrated and replicated successfully in low saline areas (≤ 5ppt) of the region, with a productivity range of 3.5 to 4.75 t ha^{-1} yr^{-1}, involving technological interventions with respect to species combination, stocking densities and water quality management (Dhawan et al 2009, 2010, 2016, Ansal et al 2013, 2016).

Salinity is one of the most significant abiotic factors in aquaculture and favourable levels for survival and optimum growth of aquatic organisms varies with species (Mubarik et al 2015). Most of the aquatic organisms are adapted to tolerate some degree of salinity stress. However, aquatic organisms with restricted and wide range of salinity tolerance are categorized as stenohaline and euryhaline species, respectively. Fresh water carps are stenohaline species and hence, grow well in hypo-osmotic environment, but they have been reported to tolerate, survive and grow at low level of salinities (Ansal et al 2013, Chandra and Joshi 2015, Kültz 2015, Dhawan et al 2016, Bhatt et al 2018, Kumar et al 2018, Singh et al 2018). Salinity variations leads to osmoregulation stress in these species with significant effect on its physiology and also alters the water quality, which may lead

to poor growth and mortality, if altered beyond the tolerance levels of species concerned (Gholampoor et al 2011). In last 5 years, aquaculture has been taken up in over 600 acres of salt affected water logged waste lands in south west districts of Punjab, including Sri Mukatsar Sahib, Fazilka and Ferozepur (Dhawan et al 2016, Kumari et al 2018). Success of rearing freshwater carps in inland salt affected areas largely depends on the factor that salinity of the ponds remains ≤5 ppt, because salinity > 5ppt is detrimental for their growth and survival in saline water (Dhawan et al 2010, Ansal et al 2013, Islam et al 2014). Hence, the current study was pursued to ascertain the suitability of aquaculture units established in salt affected areas of district Fazilka for rearing freshwater and brackish water species with respect to salinity.

MATERIAL AND METHODS

Two salt affected villages of south west district Fazilka (Fig. 1) i.e, Shajrana (30.403729ºN, 74.025535ºE) and Bahadur Khera (30.0923927ºN, 74.35739526ºE) were selected for the present study, where aquaculture units had been established in last 5 years. Water samples were collected from 22 aquacultures units (in triplicates) in sterilized plastic bottles and transported to GADVASU, Ludhiana, for further analysis with respect to various physio-chemical parameters, including pH, salinity, electric conductivity (EC), total hardness (TH), total alkalinity (TA) and salt concentration viz; sodium (Na^+), potassium (K^+), calcium (Ca^{+2}), magnesium (Mg^{+2}), sulphate (SO_4^{-2}) and chloride (Cl^{-1}), as per standard methods of APHA (2012). The pH, EC and salinity were measured using pH meter (LI, 127, ELICO), digital conductivity meter (EC-3, COM-80, HM Digital), and digital salinity meter (ELICO), respectively. Standard titration methods were used for estimation of TA, TH, Ca^{+2} and Mg^{+2} concentration, while Na^+ and K^+ concentrations were estimated by flame emission photometric method. 'Argentometeric' and 'Turbidimetric' methods were used for analyzing Cl^{-1} and SO_4^{-2} concentrations, respectively.

RESULTS AND DISCUSSION

All of the aquaculture units surveryed in the villages Shajrana and Bahadur Khera (district Fazilka), were rearing freshwater carps viz., *Catla catla* (Catla), *Labeo rohita* (Rohu), *Cirrhinus mrigala* (Mrigal), *Ctenopharyngodon idella* (Grass carp) and *Cyprinus carpio* (Common Carp), under semi-intensive poly-culture system. Among the 22 aquaculture units surveyed, salinity range of 2 (9.09%), 8 (36.36%) and 12 (54.54%) units was < 5, 5 and >5 ppt, respectively. Salinity in 5 aquaculture units in Shajrana and 3

in village Bhadhur Khera was ≥ 8 ppt, which is highly detrimental to stenohaline fresh water carps (Table 1and 2). The pH of water (7.61-8.97) in all the aquaculture units (22) was within recommended range for freshwater carps (Boyd and Tucker 1998). The EC and TH of water increased in accordance with the salinity and also varied significantly at same salinity levels, which can be attributed to differences with respect to ionic composition and their respective ability to conduct electric current. Significant differences were also recorded with respect to TA of water in different aquaculture units, but no specific changes with respect to salinity were observed. Although, at higher salinity levels, the overall salt concentration in terms of Na^+, K^+, Ca^{+2}, Mg^{+2}, SO_4^{-2} and Cl^{-1}, was significantly high but no specific variation trend was observed with respect to concentration of individual ions. Water quality in terms of ionic composition also differed in the two village. Among cations, Ca^{+2} concentration was highest in all the units in village Shajrana followed by Mg^{+2}, except in 2 units. However, in Bahadur Khera Na^+ concentration was highest in all the units followed by Ca^{+2}, except in 1 unit. In case of anions, concentration of Cl^{-1} was higher than SO_4^{-2} in all the aquaculture units in both the villages. Significant ionic composition differences were recorded among aquaculture units with different/same salinity levels, even within the same village. It can be attributed to differences in the management practices, with respect to water source, salinity management, liming, manuring, feeding, probiotics and application of chemicals (disinfectants, mineral supplements, gypsum, alum, zeolite, oxidants etc.), followed at farmer's level.

In freshwater fish, internal salt concentrations are hypertonic to the surrounding environment, having blood salinity of approximately 9 ppt or gl^{-1} (Wurts 1995). Hence, a fresh water fish gains water continuously from its environment and loose ions through kidney (urine) and gills. Some stenohaline freshwater fishes can tolerate and grow in salinewater if its internal salt concentration remains hypertonic to the culture medium. However, when the internal salt concentration in the fresh water fish becomes hypotonic to the external medium, reverse osmoregulatory changes will force the fish to make unwanted exhaustive physiological adjustments to survive in a hypertonic environment, practically leaving very less or no energy for growth and leading to mortality if salinity tolerance level (species specific) is crossed (Mustafayev and Mekhtiev 2008). In a hypertonic environment, fresh water fish starts losing water and it leads to dehydration if not able to make compensatory adjustments. Significant decline in flesh moisture content (dehydration) and reduced food intake has been reported in fresh water fish (*Cyprinus carpio* and *Pangasianodon hypophthalmus*) exposed to high salinity waters (De-Boeck

et al 2000 and Kumar et al 2016), leading to poor growth and/or mortality due to stress. De-Boeck et al (2000) also recorded increased glycogenolysis (glycogen breakdown) in fresh water carp, *Cyprinus carpio* as a compensatory adaptation to meet high energy demand for making osmoregulatory adjustments when placed in saline water. Increased concentration of salts in an aquatic environment is reported to alter structure and function of gills (more chloride cells and increased Na^+/K^+-ATPase activity) in a fresh water fish (Azizi et al 2011), besides causing rapid and extreme modifications in the cardiac function (slowing down of heart beat), consequently leading to its death. Significant effect on the electrocardiogram (tachycardia followed by bradycardia) and blood serum mineral level have been reported in grass carp (*C. idellai*), exposed to salinity stress (4-12 g l^{-1}) for 3 weeks (Enayati et al 2013).

The freshwater carps adapt and grow in low salinities, but fish growth declines significantly under saline conditions (Chughtai and Mahmood 2012, Ansal et al 2013, Chandra and Joshi 2015). Further, salinity tolerance and growth of fresh water carps in inland saline water is species specific (Dhawan et al 2010, Islam et al 2014, Ansal et al 2016). Freshwater stenohaline carps like catla, rohu, mrigal and common carp, have been reared successfully in inland saline waters (up to 5 ppt salinity) in village Shajrana, with productivity range of 3.5 to 4.75 t ha^{-1} yr^{-1}, under different culture conditions (Dhawan et al 2016). Chandra and Joshi (2015) also produced 4.28 t of freshwater carps (catla, rohu mrigal and common carp) from 1-ha of inland saline water pond in Uttar Pradesh.

In arid and semi arid areas, salinity of water in saline water ponds is likely to rise during summers due to high rate of

Table 1. Water quality of aquaculture units in village Shajrana (district Fazilka, Punjab)

Unit	Salinity (ppt)	pH	EC (mScm^{-1})	TH (CaCO$_3$ mgl^{-1})	TA (CaCO$_3$ mgl^{-1})	Na$^+$ (mgl^{-1})	K$^+$ (mgl^{-1})	Ca^{+2} (mgl^{-1})	Mg^{+2} (mgl^{-1})	SO$_4^{-2}$ (mgl^{-1})	Cl^{-1} (mgl^{-1})
1	4.0	8.74[a]	5.86[d]	741[i]	163[b]	78[i]	53[f]	263[i]	115[g]	64[c]	493[i]
2	5.0	8.12[e]	11.60[c]	1121[h]	108[e]	122[h]	62[f]	336[h]	191[f]	85[b]	790[h]
3	6.0	8.23[d]	12.25[c]	2080[g]	136[cd]	226[e]	122[e]	1261[e]	198[ef]	64[c]	815[g]
4	7.0	8.22[d]	15.60[bc]	2181[e]	97[e]	187[g]	196[d]	1218[f]	234[d]	64[c]	1435[e]
5	8.0	8.43[c]	16.57[bc]	2341[d]	206[a]	203[f]	202[d]	1407[a]	226[d]	78[b]	1102[f]
6	9.0	7.89[e]	19.04[b]	2161[f]	124[d]	252[d]	214[c]	1322[c]	203[e]	77[b]	1551[d]
7	13.0	8.71[a]	30.50[a]	2623[c]	172[b]	286[c]	343[b]	671[g]	473[c]	95[a]	2949[c]
8	15.0	8.55[b]	34.50[a]	3580[b]	166[b]	382[b]	373[a]	1344[b]	543[b]	97[a]	3368[b]
9	15.0	8.47[bc]	34.10[a]	3840[a]	146[c]	491[a]	382[a]	1286[d]	622[a]	94[a]	4279[a]

Values with different superscript in a column differs significantly (p≤0.05)

Table 2. Water quality of aquaculture units in village Bahadur Khera (district Fazilka, Punjab)

Unit	Salinity (ppt)	pH	EC (mScm^{-1})	TH (CaCO$_3$ mgl^{-1})	TA (CaCO$_3$ mgl^{-1})	Na$^+$ (mgl^{-1})	K$^+$ (mgl^{-1})	Ca^{+2} (mgl^{-1})	Mg^{+2} (mgl^{-1})	SO$_4^{-2}$ (mgl^{-1})	Cl^{-1} (mgl^{-1})
1	3.0	7.68[f]	7.43[j]	1420[h]	260[b]	592[ef]	87[de]	399[i]	248[g]	64[c]	725[h]
2	5.0	8.50[c]	15.74[d]	1400[h]	78[g]	601[e]	81[efg]	389[j]	246[g]	86[ab]	1564[c]
3	5.0	8.63[b]	10.36[i]	1600[g]	103[f]	603[e]	82[efg]	504[f]	266[f]	86[ab]	1035[g]
4	5.0	8.67[b]	13.33[f]	1730[f]	108[f]	601[e]	84[ef]	332[k]	339[e]	79[b]	1305[d]
5	5.0	8.27[d]	11.78[h]	2720[c]	81[g]	600[e]	81[efg]	590[d]	517[c]	79[b]	1215[e]
6	5.0	7.73[f]	10.74[i]	1650[g]	281[b]	603[e]	81[efg]	525[e]	273[f]	86[ab]	1025[g]
7	5.0	8.45[c]	11.53[h]	1180[i]	217[cd]	608[e]	81[efg]	326[k]	208[h]	79[b]	1240[e]
8	5.0	8.16[d]	12.63[g]	1450[h]	185[d]	543[f]	72[g]	483[g]	235[g]	86[ab]	1314[d]
9	6.0	8.11[d]	13.80[e]	2180[d]	321[a]	688[d]	498[b]	441[h]	423[d]	86[ab]	1210[e]
10	6.0	7.91[e]	13.05[fg]	1420[h]	248[bc]	412[g]	75[fg]	441[h]	238[g]	94[a]	1179[f]
11	8.0	8.97[a]	16.34[c]	1790[e]	183[d]	1483[c]	94[d]	809[c]	239[g]	86[ab]	1564[c]
12	13.0	7.61[f]	24.50[b]	3660[a]	321[a]	6490[a]	410[c]	966[b]	655[a]	95[a]	2949[a]
13	14.0	8.74[ab]	29.20[a]	3450[b]	146[e]	5333[b]	1577[a]	1071[a]	578[b]	86[ab]	2734[b]

Values with different superscript in a column differs significantly (p≤0.05)

evaporation. Hence, freshwater carps can be reared well in ponds with 1-2 ppt salinity, while ponds with 3-4 ppt salinity can also be used for rearing fresh water carps, subject to maintaining salinity levels ≤ 5 ppt. Further, in aquaculture ponds with salinity levels >5 ppt, large volume of freshwater is required for diluting saline water for maintaining salinity levels ≤ 5 ppt, which it is not recommended as an economically and ecologically viable approach on long term basis for areas already affected by dual problem of underground salinity and water logging. Addition of freshwater from canals or any other underground source will further aggravate the problem of water logging in the region. Further, drainage of saline water is also a serious matter of concern, which may lead to social conflict with respect to land use and degradation. During the present survey of aquaculture units established in salt affected waterlogged villages, only 10 aquaculture units, including 02 units with < 5 ppt salinity and 08 units with 5 ppt salinity, were suitable for freshwater carp culture, subject to maintaining salinity levels ≤ 5 ppt. While rest of the 12 aquaculture units with salinity levels >5 ppt, shall be used for culturing brackish water species, as salinity in such ponds is expected to rise to detrimental levels over a period of time.

CONCLUSION

Sustainability of fresh water carp culture in inland saline water ponds depends on the factor that salinity is maintained below 5 ppt. In Shajrana and Bahadur Khera villages (District Fazilka), salinity of only 9% of the aquaculture units (3-4 ppt) was suitable for fresh water carp culture. Productivity of fresh water carps in 36% of the aquaculture units (5ppt) is not expected to remain sustainable on long term basis and rest of the units with salinity levels >5 ppt (6-14 ppt) are not suitable for any profitable carp culture practices. Hence, for long term sustainability, brackish water finfish/ shellfish culture shall be taken up in aquaculture units with ≥5 ppt.

REFERENCES

Ansal MD, Dhawan A and Singh G 2013. Productivity of freshwater carps in inland salt affected water logged areas of Punjab, India- A field study. *Indian Journal of Ecology* **48**(2): 284-289.

Ansal MD, Dhawan A, Singh G and Kaur K 2016. Species selection for enhancing productivity of freshwater carps in inland saline water of Punjab- A field study. *Indian Journal of Ecology* **43** (Special issue 1): 45-49.

APHA 2012. *Standard Methods for the Examination of Water and Wastewater* 22nd Edn. American Public Health Association, Washington, D. C. pp 1360.

Azizi A, Kochanian P and Peyghan R 2011. Chloride cell morphometrics of common carp, *Cyprinus carpio,* in response to different salinities. *Comparative Clinical Pathology* **20**: 363-367.

Bhatt D, Kaur VI, Ansal MD and Kumar V 2018. Salinity tolerance of freshwater shubunkin Gold Fish, *Carassius auratus* (Linn.): Suitability for rearing in Inland saline water. *Indian Journal of*

Ecology **45**(4): 876-880.

Boyd CE and Tucker CS 1998. Pond aquaculture water quality management. Kluwer Academic Publishers, Boston, London.

Chandra S and Joshi KD 2015. Growth and survival of carps in salt affected ponds under different treatment. *Journal of the Inland Fisheries Society of India* **47**(1): 36-42.

Chughtai MI and Mahmood K 2012. Semi-intensive carp culture in saline water logged area- A multi- locational study in Shorkot (District Jhang), Pakistan. *Pakistan Journal of Zoology* **44**(4): 1065-1072.

De-Boeck G, Vlaeminck AG, Van-Der LA and Blust R 2000. The energy metabolism of common carp (*Cyprinus carpio*), when exposed to salt stress: An increase in energy expenditure or effects of starvation? *Physilogical and Biochemical Zoology* **73**(1): 102-111.

Dhawan A, Kaur K, Ansal MD and Singh G 2009. Inland saline waters in Punjab: Water chemistry and suitability for farming major carps. *Fishing Chimes* **29**(5): 24-27.

Dhawan A, Kaur K, Ansal MD and Singh G 2010. Inland saline water aquaculture- Major breakthrough achieved in Punjab. *Fishing Chimes* **30**(3): 10-11.

Dhawan A, Ansal MD, Singh G and Kaur K 2016. Aquaculture in inland salt affected water logged areas of Punjab. *In: Proceedings of Indian Ecological Society-International Conference-Natural Resource Management: Ecological Perspectives* (Volume 2, Eds. Peshin R, Dhawan A, Risam KS and Bano F) held on 18-20 February, SKUAST-Jammu. pp 957-58.

Enayati A, Peyghan R, Papahn AA and Khadjeh GH 2013. Study on effect of salinity level of water on electrocardiogram and some of blood serum minerals in grass carp, *Ctenopharyngodon idella*. *Veterinary Research Forum* **4**(1): 49-53.

Gholampoor TE, Imanpoor MR, Shabanpoor B and Hosseini SA 2011. The study of growth performance, body composition and some blood parameters of *Rutilus frisii kutum* fingerlings at different salinities. *Journal of Agricultural Science and a Technology* **13**: 869-876.

Islam M, Ahsan DA, Mandal SC and Hossain A 2014. Effect of salinity changes on growth performance and survival of rohu fingerlings, *Labeo rohita* (Hamilton, 1822). *Journal of Coastal Development* **17**(1): 379-384

Jain AK 2007. Sustainable Inland Saline Water Aquaculture Development-Issues of Concern. *Fishing Chimes* **27**(7): 10-14 & 53.

Kültz D 2015. Physiological mechanisms used by fish to cope with salinity stress. *The Journal of Experimental Biology* **218**: 1907-1914

Kumar MU, Ansal MD and Kaur VI 2018. Salinity tolerance and survival of freshwater Carp, *Labeo rohita* Ham. (Rohu) in Inland saline water. *Indian Journal of Ecology* **45**(4): 872-875.

Kumar AV, Harikrishna AK, Reddy NK, Chadha AM and Rani B 2016. Effect of salinity on proximate composition of *Pangasianodon hypophthalmus* reared in inland saline water. *International Journal of Zoology Studies* **1**(3): 19-21.

Kumari A, Ansal MD, Singh P and Shanthangouda AH 2018. Evaluation of aquaculture units established in salt affected areas of district Sri Muktsar Sahib, Punjab. *Indian Journal of Ecology* **44**(3): 632-636.

Mandal AK, Sharma RC, Singh G and Dagar JC 2010. *Computerized database on salt affected soils in India*. Technical Bulletin CSSRI/KARNAL/2/2010.pp-28. Indian Council of Agriculture, Central Soil Salinity Research Institute, Karnal, Haryana.

Minhas PS and Bajwa MS 2001. Use and management of poor quality waters for the rice wheat based production system. *Journal of Crop Production* **4(**1): 273-306.

Mubarik MS, Ismail A, Hussain SM, Jabeen F, Samiullah K, Yaqub S, Ahmad S, Feroz K, Khan MT, Nazli S and Ahmad B 2015. Survival, growth and body composition of *Cyprinus carpio* under different

levels of temperature and salinity. *International Journal of Biosciences* **6** (10): 132-141.

Mustafayev NJ and Mekhtiev AA 2008. Changes of the serotonergic system activity in fish tissues during an increase of water salinity. *Journal of Evolutionary Biochemistry and Physiology* **44**(1): 69-73.

Pathak MS, Reddy AK, Harikrishna V, Dhage SD and Shisodiya KK 2013. Inland saline aquaculture in India: Status and prospects.

International Journal of Pharmaceuticals, Chemical and Biological Sciences **3**(3): 993-1000.

Singh G, Ansal MD and Kaur VI 2018. Salinity tolerance and survival of freshwater Carp, *Cyprinus carpio* Linn. in inland saline water. *Indian Journal of Ecology* **45**(3): 598-601

Wurts WA 1995. Using salt to reduce handling stress in channel catfish. *World Aquaculture* **26**(3): 80-81.

Effect of Jasmonic Acid on the Physiological Properties and Yield in the Maize Hybrid under Salt Stress

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Abstract: Field experiment was carried out on the maize (*Zea mays* L.), in the autumn to find out the effect of jasmonic acid(JA)in mitigating salt stress for hybrid maize. The four levels of saline irrigation water (1.2, 2, 4, and 6 ds.m^{-1}) and four JA concentrations (0 , 5, 10 and 15 mg l^{-1}). Increase in salt stress caused a significant increase in the effectiveness of the antioxidant enzyme (CAT and SOD) and a significant decrease in chlorophyll content and total yield. Spraying JA in turn caused the significant increase in the effectiveness of the antioxidant enzyme (CAT and SOD) and the significant increase in the total content of chlorophyll and yield.

Keywords: Salt stress, Jasmonic acid, CAT, SOD, Chlorophyll, Maize

Zea mays L. is ranked first in the world in terms of economic production and third in importance after rice and wheat as maize is used primarily in grain for animals especially poultry feed and processed in industries for human food and nutrition. In Iraq the autumnal season as the most productive, as the increase in temperatures and increased evaporation in this season and has complex salinity problems (Flagella et al 2002). The salinity caused the reduction of different growth indicators such as chlorophyll content and total yield, and it was mainly due to the metabolic disorder processes such as photosynthesis and respiration and proteins synthesis, carbohydrates and absorption of ions. Maize plants in general are sensitive to salinity, but the effect of salinity is at 6 leaves (30 days after planting), as well as at the stage of 10 leaves (60 days after planting). This growth stage determine the length of ear and the number of grains in it and therefore suggesting addition of JA plants maize in these two stages (6 and 10 leaves) because jamonic acid (JA) increases the viability of the plant to tolerate the stress of saline. The salt stress increases JA levels in the plant and indicates that JA has a role in reducing the effects of salt stress and foliar spraying JA helps plants to overcome salinity, because JA works to regulate the mechanics of construction and opening the closure of the stomata (Moons et al 1997, Javid et al 2011). However, maize cultivation in Iraq still suffers from poor field practices and methods of using growth regulators as characterized by the process of adding JA followed by random and non-adoption modern technologies supported by scientific knowledge and to increase productivity of maize. The present study was planned to used JA effectively at various level of salinity in water to increase productivity.

MATERIAL AND METHODS

Field experiment was carried out on the maize (*Zea mays* L.) in the autumn season of the year 2017, at Al Qasim Green University, southern Babylon Governorate in Iraq. Random soil samples were taken from the depths of (0-40cm) and observed for chemical and physical properties in (Table 1) .In order to find out the effect of Jasmonic acid (JA) in mitigating salt stress for hybrid maize (34N84), factorial experiment with in randomized complete block design in three replicates was conducted. The two factors represent the first factor of four levels of saline irrigation water, which were 1.2, 2.4 and 6 ds.m^{-1} . The second factor represents four JA concentrations of 0 (control), 5, 10 and 15 mg l^{-1}. The plants were irrigated three times with river water until the plants reach the age of 30 days (stage 6leaves) after which irrigation was the saline water according to the levels mentioned. Foliar sprayed for JA were carried out at two times, 30 and 60 days of the emergence .Total chlorophyll was measured using a Spad apparatus in stage the female flowering (William and Jemison 2006).The yield was recoded Alsahoeke basis (1990). Fresh leaves were selected randomly for the purpose of assessing the effectiveness of enzyme superoxide dismutase (SOD) by using the method proposed by Marklund and Marklund (1974). As well Fresh leaves were selected randomly for the purpose of assessing the effectiveness of enzyme catalase (CAT) by using the method proposed by Aebi (1983).

RESULTS AND DISCUSSION

Effectiveness of superoxide dismutase (SOD): There was significant increase in effectiveness of the SOD enzyme with increased salinity. The average increase of the effectiveness

of the enzyme was 3.93 unit gm^{-1} with salinity level of 1.2ds m^{-1} and increased to 9.30 units gm^{-1} with salinity level of t 6 ds m^{-1}. The difference among different salinity level were significant. Results of the study were consistent with previous studies of Ali (2011) and Al-Samurai and Al-Obeidi (2015). The effectiveness of the SOD enzyme increased with increase in concentration of JA from 6.44 to 7.23 unit gm^{-1} 5 and 15 mg l^{-1} but difference were not significantly but was higher as compared to control (5.77 unit gm^{-1}). The interaction between salinity levels of irrigation and the foliar spraying of JA significantly affected the effectiveness of the SOD enzyme, being highest with JA level 15 mg l^{-1} and the irrigation water leve 6 ds m^{-1} (10.53 unit gm^{-1}). However, there was no significant difference with JA @ 5 and 10 mg l^{-1} with the salinity of irrigation water 6 ds m^{-1}. There was increase in the effectiveness of SOD enzyme with the increasing salinity of irrigation water levels and concentration of JA. Results of the study were consistent with the results indicated by Abrizand Golezan 2018), where they increase effectiveness SOD enzymein was observed with the increase in the salinity of irrigation water and the JA concentration.

Effectiveness of catalase (CAT): There was significant increase in effectiveness of the CAT enzyme with increased salt stress and maximum was when salinity level of irrigation water was 1.2 ds.m^{-1}(19.31 unit gm^{-1}) and increased to 73.13 unit.gm^{-1} with salinity of 6 ds.m^{-1} (Table 3). Results of the study were consistent to earlier studies (Kaye et al 2011, Al-Yesari and Al-Musawi 2016). This may be due to fact that increase levels the salinity led to increase in generation of H_2O_2 at plant cell, which activate the enzyme CAT, which has a defensive line to face H_2O_2. The effectiveness of CAT enzyme with increased with increase in concentrations of JA from 45.87 to 51.88) unit gm^{-1} with spraying JA in levels 5 and 15 against 40.35 mg l^{-1} in control. Similar results were documented by Majidand Akbar (2009). The interaction between the salinity levels of irrigation water and the foliar spraying JA was significant. The effectiveness of the enzyme CAT was significantly high in JA @ 15 mg l^{-1} and the irrigation water level 6 ds m^{-1} (79.21 unit gm^{-1}) as compared to remaining combination. The enzyme CAT in the treatment of control was low (12.56 unit gm^{-1})at salinity level of 1.2 mg l^{-1}. Abriz and Golezan (2018) also observed   the high effectiveness of the enzyme CAT in conjunction with the increase in the salinity of irrigation water and the concentration of the plant JA in soybean.

Chlorophyll content of leaves: The foliar spraying of JA @ 5 mg l^{-1} resulted in significantly higher chlorophyll content (53.89 units pad) as compared to 2.5 and 15.0 mg l^{-1} but was at par with 10 mg l^{-1}. Kovac and Ravnikar (1994) observed that JA led to an increase cytokinin,the chlorophyll pigment

Table 1. Chemical and physical properties of soil

Property	The value
Electrical conductivity	2.2 ds m^{-1}
pH	7.7
Soluble cations	
K	167.3 mg kg^{-1}
N	47.1 mg kg^{-1}
P	16.7 mg kg^{-1}
Soil components	
Sand	153 g kg^{-1}
Silt	291 g kg^{-1}
Clay	556 g kg^{-1}
Texture soil	Clay

Table 2. Effect of salinity and jasmonic acid on effectiveness of the enzyme SOD on maize (unit gm^{-1})

Jasmonic acid (mg l^{-1})	Salinity level in irrigation water (ds m^{-1})				Average
	1.2	2	4	6	
0	3.25	4.90	6.62	8.30	5.77
5	3.95	5.66	7.30	9.01	6.48
10	4.00	5.70	7.32	9.38	6.60
15	4.50	6.13	7.75	10.53	7.23
Mean	3.93	5.60	7:25	9.30	

CD (p=0.05) = Salinity 1.23 ; Jasmonic acid 0.93 ; Interaction (JXS)=1.90

Table 3. Effect of salinity and jasmonic acid on effectiveness of the enzyme CAT on maize

Sprayed levels of Jasmonic acid (mg l^{-1})	Salinity level in irrigation water (ds m^{-1})				Average
	1.2	2	4	6	
0	12.56	33.27	47.99	67.57	40.35
5	18.28	38.96	53.94	72.29	45.87
10	20.11	39.31	54.02	73.43	46.72
15	26.30	42.21	59.80	79.21	51.88
Mean	19.31	38.44	53.94	73.13	

CD (p=0.05) = Salinity 3.01 ; Jasmonic acid 2.67 ; interaction (JXS) = 5.22

Table 4. Effect of salinity and JA on chlorophyll in maize (spad)

Jasmonic acid levels (mg l^{-1})	Salinity level in irrigation water (ds m^{-1})				Average
	1.2	2	4	6	
0	52.50	45.85	34.53	30.23	40.78
5	65.70	62.79	49.56	37.52	53.89
10	64.70	60.50	48.17	37.25	52.66
15	58.55	52.48	40.07	37.93	47.26
Mean	60.36	55.40	43.08	35.73	

CD (p=0.05) = Salinity 4.07; Jasmonic acid 2.13; Interaction (JxS) = 5.08

content. El-Sayed et al (2014) mentioned that spraying of olive JA led to a the chlorophyll content increase in plant leaves .The interaction between JA and the salinity levels was significant being higher in JA concentration 5 mg l^{-1}with salinity level of 1.2 ds m^{-1}.The total chlorophyll content decline

Table 5. Effects of different salinity levels of added jasmonic acid overlap on total yield (tons ha^{-1})

Sprayed Jasmonic acid levels (mg l^{-1})	Salinity level in irrigation water (ds m^{-1})				Average
	1.2	2	4	6	
0	6.70	5.99	4.78	1.72	4.80
5	10.01	9.61	9.17	3.92	8.18
10	9.78	9:47	8.17	3:22	7.66
15	8.09	7.49	6.17	2:47	6.05
Mean	8.64	8.14	7.07	2.83	

CD (p=0.05) = Salinity 0.34; Jasmonic acid 0.28; Interaction (JXS) = 0.56

in maize plant with increased salinity of irrigation water. Low chlorophyll content with increasing the level of irrigation water salinity explains that sodium ion works to reduce the elements absorption necessary to a molecule synthesis of chlorophyll such nitrogen and magnesium elements during the process of absorption elements from the roots. Cha-um and Kirdmanee (2009) observed that chlorophyll content decrease in stress saline plants due to the nitrogen withdrawal necessary for the construction of chlorophyll in favor of the production of proline and low magnesium concentration (Borsani et al 2001).

Yield: Spray of JA @ 5 mg l^{-1} gave significantly higher yield (8.18 tons ha^{-1}) followed by 10 mg l^{-1} while the lowest yield was in control (4.80 tons ha^{-1}) (Table 5). These results are consistent with the results of earlier workers (El-Sayed et al 2014, Golezani and Mahootchi 2015). The the salinity and spraying JA has a significant effect on yield , with the highest with JA 5 mg l^{-1} at the salt level 1.2 ds m^{-1}(10.01 tons ha^{-1}). The lowest was 1.72 tons ha^{-1} in control at salinity level of 6 ds.m^{-1} but spraing JA concentration 5 mg l^{-1} resulted in significant higher yield at this level of higher salinity (6 ds m^{-1}) which was 3.92 tons ha^{-1}.Similar results were reported by Sheteawi (2007). The salinity levels of irrigation water resulted in decline in yield. The use of saline water in the irrigation process has a negative effect on theyield of agricultur al crops (Irshad et al 2009). This is due to decline in absorbed elements nitrogen, potassium and Magnesium which reflected negatively on the process of photosynthesis.

REFERENCES

Abriz FS and Golezan K 2018. How can salicylic acid and jasmonic acid mitigate salt toxicity in soybean plants? *Ecotoxicology and Environmental Safety* **147**: 1010-1016.

Aebi H 1983. Catalase *in Vitro*. *Methods of Enzymology* **105:** 121-126.

Ali Q 2011. *Exogenous use of some potential organic osmolytes in enhancing drought tolerance in maize (Zea mays* L.). Ph.D. Thesis. University Faisalabad.

Al-Yesari JWM and al-Musawi AN 2016. Effect of potassium and calcium in the reduction of stress confusion saline for some varieties of wheat and its relationship with some physiological and biochemical indicators. *Karbala Magazine* **14**(14): 107-115.

Al-Samurai II and Al-Obeidi ZHH 2015. The effect of Alsaleslk acid in antioxidant enzyme activity and proline in maize under the strain NaCl. *Diyala Journal of Agricultural Sciences* **7**(2):143-152.

Al-sahoeke MM 1990. The ministry of higher education and scientific research improved the production of yellow corn in Baghdad University.

Borsani O, Valpuesta V and Botella MA 2001. Evidence for a role of salicylic acid in the oxidative damage generated by NaCl and osmotic stress in *Arabidopsis* seedlings. *Plant Physiology* **126**: 1024-1030.

Cha-um S and Kirdmanee C 2009. Effect of salt stress on proline accumulation, photosynthetic ability and growth characters in two maize cultivars. *Pakistan Journal of Botany* **41**: 87-98.

El-Sayed MO, El-Gammal OHM and Salama ASM 2014 .Effect of ascorbic acid, proline and jasmonic acid foliar spraying on fruit set and yield of Manzanillo olive trees under salt stress. *Scientia Horticulturae* **176**: 32–37.

Flagella ZV, Cantore M, Giuliani M, Tarantion ED and Caro A 2002. Crop salt tolerance: Physiological, yield and quality aspects. *Rec. Res. Dev plant Biol.* **2**: 155-186 .

Golezani KG and Mahootchi AHZ 2015. Improving physiological performance of safflower under salt stress by application of salicylic acid and jasmonic acid. *Walia* **31**: 104-109.

Javid MG, Sorooshzadeh A, Moradi F, Sanavy SAM and Allahdadi I 2011. The role of phytohormones in alleviating salt stress in crop plants. *Australian Journal of Crop Science* **5**(6): 726-734.

Jemison J and Williams 2006. Potato study project. Report Water quality office University of Main cooperation Extension . http:www. Vmexmain.ed.

Kaye Y, Golani Y , Singer Y, Leshem Y, Cohen G, Erectin M, Gillaspy G and Levine A 2011. Inositol polyphosphate 5-phosphatase 7 regulates production of reactive oxygen species and salt tolerance in Arabidopsis. *Plant Physiology* **157**: 229-241.

Kovac M and Ravnikar M 1994. The effect of jasmonic acid on the photosynthetic pigments of potato plant grown in vitro. *Plant Sciences* **103**: 11-17.

Majid NA and Akbar N 2006. A possible role for methyl jasmonate in affecting superoxide dismutase and catalase activities under pq-induced oxidative stress in maize seedlings. *Journal of Biological Sciences* **6**: 55-60.

Mansour N 2006. *Alleviating the Negative Impact of Brackish Water and Reclaimed Wastewater on Viciafaba Plants through Treatment with Jasmonic Acid.* M.Sc. Thesis. University Birzeit-Palestine.

Marklund S and Marklund M 1974. Involvement of the superoxide anion radical in the antioxidation of pyrogallol and a convenient assay for superoxide dismutase. *European Journal of Biochemistry* **47**: 469-474.

Moons AE, Prinsen GB and Montagu M 1997. Antagonistic effects of abscisic acid and jasmonates on salt stress inducible transcripts in rice roots. *Plant Cell* **12**: 2243-2259.

Noriega G, Cruz DS, Batlle A, Tomaro M and Balestrasse K 2011. Hemeoxygenase is involved in the protection exerted by jasmonic acid against cadmium stress in soybean roots. *Journal Agronomy Crop Science* **197**: 296-301.

Reiss C and Beale SI 1995. External calcium requirements for light induction of chlorophyll accumulation and its enhancement by red light and cytokinin pre-treatment in excised etiolated cucumber cotyledons. *Planta* **196**: 635- 641.

Sheteawi AS 2007. Improving growth and yield of salt stressed soybean by exogenous application of jasmonic acid and ascobin. *International Journal of Agriculture and Biology* **3**: 473-478.

Assessing Rice Growers' Knowledge on Plant Protection Measures in Sub-tropics of Jammu and Kashmir

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Abstract: Plant protection plays a vital role in modern agriculture. In the absence of adequate plant protection measures, the positive contribution of improved seeds, fertilizers and irrigation to output could completely nullify and farmers may incur heavy losses. Thus, a study was carried out on 120 rice growing farmers of Jammu district of Jammu and Kashmir state to find out the knowledge of farmers regarding plant protection practices. The results show that majority of the farmers (93%) possessed knowledge about herbicides. Only three and seven percent of the rice growers had knowledge of insecticides and fungicides, respectively. Thirty seven percent of the rice growers had applied recommended dosages of herbicide butachlor, whereas, the insecticide use was negligible (3%). In the present study, only education was found as the independent variable, which affects the knowledge of the respondents regarding plant protection. Thus training programmes related to plant protection to improve the knowledge of the farmers regarding plant protection practices, should be conducted.

Keywords: Plant protection, Knowledge, Herbicide, Pesticide, Insecticide

Rice (*Oryza sativa*) is one of the most important food crops of India in term of area, production and consumer preference. Among the rice growing countries, India has the largest area under rice in the world (43.38 million ha) with a total production of 104 million tonnes during 2015-16 and it stood next only to China in the world with respect to production (Anonymous, 2016-17). Rice crop plays a significant role in livelihood of people of Jammu and Kashmir (J&K) state. It is the staple food and second important crop of the state (Trag and Rather 2013). In J&K state, rice is grown in an area of 304.50 thousand ha with an annual production of 6466 thousand quintals. The average yield of rice in the State is 21.24 q ha^{-1} (DES, 2016-17). Rice in the state is grown under different agro-climatic conditions and the crop is damaged by more than 100 species of insect pests of which about dozen are of significance in India (Manjunath 2010). Insect pests and diseases cause considerable damage to potential agricultural production. Evidences indicate that pests cause 25 per cent loss in rice (Dhaliwal et al 2010) and the damage caused by major and minor pests of rice is largely controlled by the different natural enemies. So, it is essential that the farmers should have the knowledge about insect pests, diseases and weeds of rice and natural enemies of insect pests so that they could be able to identify pests and their natural enemies to effective use of plant protection practices. Therefore, the present study was undertaken to find out the knowledge of farmers regarding different plant protection practices in rice crop in the sub- tropical Jammu district.

MATERIAL AND METHODS

Multi-stage sampling method was employed for selection of villages and rice growers of Jammu and Kashmir state in Jammu district. All the four agricultural sub-divisions of the Jammu district were taken for the present study. From each sub-division, a proportionate sample of villages with respect to area under rice was drawn, thus selecting twelve villages. Out of each selected village, ten rice growers were selected randomly without replacement for the study. Thus a total sample size of the respondents was 120. Data were collected by personally interviewing the sampled farmers and analyzed using appropriate statistical tools. Linear regression model (Backward elimination method) was applied to find out that which factor affects the knowledge of farmers about plant protection practices. Age, education, family size, farming experience, operational land holding, extension contacts, and distance of village from different places such as market, pesticide shop, fertilizer shop, agriculture office, seed store and Sher-e-Kashmir University of Agricultural Sciences and Technology of Jammu (SKUAST-Jammu) variables were identified and these identified variables were selected to study the impact of these on knowledge of farmers regarding plant protection practices. Knowledge includes those behaviour and test situations which emphasized the remembering either by recognition or recall of ideas, materials and phenomenon (Bloom 1956). A score of 1 was given for having knowledge a particular technology and a score of zero for no knowledge.

RESULTS AND DISCUSSION

The mean age of the respondents was 48.58 years and the mean education was 7.68 years i.e. studies upto 8th class standard. Majority (47%) of the respondents studied upto matriculation level and only 18 percent were illiterate. According to the Census data 2011, Jammu district has the literacy rate of 83.45 percent which is the highest among the 22 districts of J&K state. The results are in conformity with the census data 2011 and findings of Peshin et al (2013) that 81.67 percent respondents were literate in the sampled area. The average farming experience of the respondents was 32.27 years. In farm family, children right from their childhood helps parents in farm activities and gradually practices it on regular basis. With regards to family size, the average total family size was 5.60 that means ca. 6 members per household. This may be due to increased awareness about the family planning in rural areas. The average landholding of the samples farmers was 2.14 ha, which was approximately completely irrigated (2.13 ha). However, the average land holding of the sampled farmers was double the average landholding of Jammu district which is 0.96 ha (DES 2013-14). Majority of the respondents was marginal and small famers. This is in conformity with the national level where 90 percent of the farmers belong to marginal and small category (Parsad 2011) and also the state level data as more than 85 per cent of the farmers in J&K belongs to marginal category (DES 2013-14). The input retailers namely fertilizer, pesticide and seed were available to the respondents within 5 km radius. Total average distance of the village from SKUAST-Jammu was 27.33 km (Table 1).

Progressive farmers belong to innovators and early adopters category. The majority of the respondents had extension contact with the progressive farmer. Progressive farmers favourably influence the diffusion process, are more susceptible to innovations and react first to change for innovation. Further, 57 per cent of the respondents had contact with extension officer, 64 per cent with progressive farmers, eight per cent with scientists of SKUAST- Jammu and 36 per cent with private agency. Rodent was identified by all the respondents while 88 per cent of the respondents identify grasshopper. Leaffolder, brown plant hopper, stem bores, green leaf hopper and rice hispa were identified by 84, 65, 59 and 26 per cent of the respondents, respectively. Majority (88%) of the respondents identified false smut disease. About brown leaf spot (77%), bacterial leaf blight (73%), sheath blight (48%) and blast (36%) of the respondents had knowledge as diseases in rice crop. In case of weeds of rice, respondents had knowledge about kharsu (22%), motha (49%), dilla (83%), sawank (82%) and nadi (65%) as weeds of rice crop.

Table 1. Descriptive statistics of the sampled farmers

Parameters	Statistics
Mean age (years)	48.58±1.15
Mean education (formal number of schooling years)	7.68±0.37
Education level (%farmers)	
Illiterate	18
Primary	4
Middle	17
Matriculation	47
10+2	12
Graduate and above	2
Mean farming experience (years)	32.27±1.15
Average family size	5.60±0.34
Average operational land holding (ha)	2.14±0.29
Categorization of farm size (%farmers)*	
Marginal (<1 ha)	36
Small (1-2 ha)	33
Semi- medium (2-4 ha)	19
Medium (4-10 ha)	10
Large (>10 ha)	2
Average irrigated land holding (ha)	2.13±0.29
Average unirrigated land holding (ha)	0.01±0.01
Average distance of village from (km)	
Main market	4.17
Fertilizer shop	3.59
Pesticide shop	4.17
Agriculture office	4.67
Seed store	4.67
SKUAST- Jammu	27.33

*Categorization of farm size as per MOA (2014)

Table 2. Extension contact of the farmers

Parameters	Total (n=120)
Extension contact (% farmers)*	
Extension officer	57
Progressive farmer	64
Scientist of SKUAST- Jammu	8
Private agency	36

*Multiple Responses

Regarding knowledge about resistant varieties, only six per cent of the respondents reported Ratna variety as insect pest/ disease resistant and 28 per cent of the respondents reported Basmati-370 as resistant variety. In case of knowledge of the respondents regarding seed treating chemicals and their dosages, only 7 per cent respondents had knowledge about seed treating chemical (Bavistin) out of which 75 per cent respondents reported (2-2.5g/kg seed) the recommended dose of that chemical.

Further, 52 per cent of the respondents reported that

Table 3. Knowledge of the farmers regarding insect pest of rice

Parameters*	Knowledge (n=120)
Insect pest	
Rodent (*Mus musculus*)	100
Grasshopper (*Hieroglyphus banian*)	88
Leaf folder (*Cnaphalocrocis mainsails*)	84
Brown plant hopper (*Nilaparvata lugens*)	65
Stem bores (*Sciropophaga incertulas*)	63
Green leaf hopper (*Nephotettix virescens*)	59
Rice hispa (*Dicladispa armigera*)	26
Diseases of rice	
False smut (*Ustilaginoidea virens*)	88
Brown leaf spot (*Bipolaris oryzae*)	77
Bacterial leaf blight (*Xanthomonas oryzae*)	73
Bacterial leaf streak (*Xanthomonas oryzae*)	48
Sheath blight (*Ryzoctonia solani*)	47
Blast (*Pyricularia greisea*)	36
Weeds of rice	
Kharsu (*Echinochloa colonum*)	22
Motha (*Cyperus rotundus*)	49
Dilla (*Cyperus iria*)	83
Sawank (*Echinochloa crus galli*)	82
Nadi (*Euphorbia hirta*)	65

*Multiple responses
Figures are percentages and rounded upto nearest whole number

Table 4. Knowledge of the farmers regardingplant protection

Parameters	Total (n=120)
Benefits of seed treatment	
Disease infection is less on plant	52
Insect infection less on plant	42
Seed germination well	31
Seed treating chemical	
Bavistin	7
Dose (2-2.5g/kg seed)	75
Natural enemy	
Spider	88
Lady bird beetle	2
Dragon fly	60
Herbicide	94
Butachlor 5% GR (machete)	82
Dose (30kg ha^{-1})	37
2,4-D 38% EC (Agni, not recommended)	50
Bispyribac sodium 10% SC (Nominee gold, not recommended)	21
Insecticide	
Fipronil 5% SC against stem borer (Regent, not recommended)	3

Table 5. Regression model of socio-economic factors affecting knowledge of plant protection practices in rice

Knowledge	Variable	Regression coefficient	F- value	100*R^2 (%)
Model	Constant	27.96 (0.01)	2.45 (0.04)	9.70
	Education	0.25 (0.01)		

Figures in parentheses are p- value

seed treatment reduces disease infestation in rice crop, 42 per cent of the respondents reported that seed treatment reduces insect infestation in rice crop which is scientifically wrong. Only 12 per cent respondents reported spider as a natural enemy. Dragon fly was identified by 60 per cent of the respondents. None of the respondents were able to report lady bird beetle and dragon fly as natural enemy. Majority (82%) of the respondents in Jammu district, reported butachlor as recommended chemical for weed control. Only 50 percent and 21 per cent respondents, respectively reported 2,4-D and bispyribac sodium as herbicide for weeds of rice crop, but these herbicides are not recommended by SKUAST-Jammu. A small percentage (3%) of the respondents had knowledge about fipronil as insecticide used against stem borer of rice crop, but fipronil is also not recommended by SKUAST-Jammu. The major source of information about pesticides was pesticide retailers.

To find out that which factors affect the knowledge of farmers about plant protection practices, the linear regression model (Backward elimination method) was applied. The model applied has F-value= 2.45, which was significant at p=0.04. The result shows that R^2 value was 0.097 which indicates that there is 9.70 per cent variation in the knowledge explained by the variables selected for the analysis. The variables education significantly affected the knowledge of the farmers regarding plant protection measures. The probable reason might be that the plant protection measures being complex in nature could be understood better by persons having higher education level. It is an established fact that an educated person is in a better position to gather information, better understanding capacity and interpret even complex information related to his enterprises. The findings are in consonance with the findings of Balasubramani (1997) and Raghavendra (1997), who found that there was a significant and positive relationship between education and knowledge level.

CONCLUSION

The respondents had good education level, high level of farming experience, were having marginal and small land holding but poor extension contact with scientists of SKUAST-

Jammu and medium level of knowledge regarding plant protection measures. Only education was found as the independent variable, which affects the knowledge of the respondents regarding plant protection. Training programmes or modules of the department of agriculture and SKUAST-Jammu should focus on seed treatment, pesticide and natural enemy complex in the rice eco-system so that pesticide load (insecticides and fungicides) could be maintained at current low level. Extension services should also conduct training programmes for pesticide retailers who are not trained about proper handling storage and selling of pesticide.

REFERENCES

Anonymous 2012. Rice profile.http://agricoop.nic.in/imagedefault/trade/Rice%20profile.pdf. (accessed on December 2012).

Balasubramani 1997. *Study on knowledge and adoption behaviour of rubber growers in Belthangaditaluk 9 of Dakshina Kannada district.* M. Sc. (Agri.) Thesis, Univ. Agric. Sci., Bangalore, Karnataka (India).

Bloom B S 1956. *Taxonomy of Educational Objectives*, Longman, New York

DES 2011-12. Digest of statistics. Directorate of Economics and Statistics, Planning and Development Department, Govt. of Jammu and Kashmir.

DES 2013-14. Economic survey, J&K 2013-14. Directorate of Economics and Statistics, Government of Jammu and Kashmir.

Dhaliwal GS, Jindal V and Dhawan AK 2010. Insect pest problems and crop losses: Changing trends. *Indian Journal of Ecology* **74**:1-7.

Gupta BB, Salgotra RK and Bali AS 2010. Status Paper on Rice in Jammu and Kashmir.Division of Plant Breeding & Genetics, SK University of Agricultural Sciences & Technologyof Jammu (SKUAST-J). pp. 1-20.

Manjunath T 2010. *A Study on Knowledge and Adoption of Plant Protection Measures by Paddy Growers of Raichur District*. M. Sc. (Agri.) thesis, University of Agriculture Science, Dharwad, Karnataka, India.

Peshin R, Sharma R, Gupta V and Ajrawat B 2013. Study on Impact of the Government Intervention in Procurement of Rice. Division of Agricultural Extension education, SKUAST-Jammu.

Prasad C 2011. Basic issues, experience and futurology of agricultural extension system in India-implication for developing countries.*Conference on Innovative Approaches for Agricultural Knowledge Management: Global Extension Experiences*. November 9-12, New Delhi.

Raghavendra H N 1997. *A study on knowledge and adoption behaviour of arecanut farmers of South Canara district, Karnataka state.* M. Sc. (Agri.) Thesis, University of Agriculture Science., Bangalore, Karnataka (India).

Schonherr S and Mbugua ES 1974. New Extension Methods to Speed Up Diffusion of Agricultural Innovations. Discussion paper No. 200. Institute for Development Studied of Ndirobi, Kenya.

Yogananda HG 1992. *A study on knowledge level, adoption behaviuor and training needs of coconut growers.* M. Sc. (Agri.) Thesis, University of Agriculture Science, Bangalore, Karnataka (India).

Vegetative Propagation of an Endangered Tree Species
Tecomella undulata

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Abstract: The study was carried out to elucidate the effect of different methods of propagation and IBA concentrations on rooting of *Tecomella undulata* (Sm.) Seem cuttings. Rooting success in IBA 6000 ppm was (35.72%), it was higher compared to control and IBA 4000 ppm. Percent survival in air layering was (11%), whereas, in root suckers it was (27.78). The coppice shoots emerged well on stumps of one year old seedlings during March.

Keywords: Endangered species, Medicinal tree, Mist chamber, Rooting factors, Stems cutting

Tree with medicinal value are of prime importance all over the world because of great economic value. *Tecomella* is an indigenous tree of India and belongs to family Bignoniaceae. This small tree is widely distributed up to an altitude of 1200 m in Arabia, Southern Pakistan and North-West India. *Tecomella* is an agroforestry tree species, because of its deep root system, it absorbs soil moisture and nutrients from deep soil profile. *Tecomella* tree occurs both on the flat and undulating areas and sometimes also in the ravines. Rohida grows better on well-drained soil having pH in the ranges 6.5 to 8.0. It can with stand in the area where rainfall varies from 150 to 500 mm annually and temperature as high as 50˚C and extremely low temperature (0˚C to -2˚ C). One of the important features is that this tree is a strong light demander and withstands extreme drought, frost and wind. Defoliation occurred from the first week of November to end of March. It acts as a wind break and helps in stabilizing shifting sand dune. The wood of this tree is excellent source of firewood as well as charcoal. Due to its secondary metabolites, this tree has to cure different diseases (Patel et al 2013). The Ministry of Environment and Forests had notified this species as endangered in Rajasthan and on the verge of extinction in the state of Punjab under the section 38 of the biological diversity act 2002 (18 of 2003) and only two plants are left of this species in Punjab State, which means it is near extinction Singh et al (2014). The natural regeneration of this tree is very poor, therefore cannot be supplemented with artificial regeneration (Planting nursery raised seedlings). Because of its poor seed viability, dormancy, seed infertility, improper harvest from the tree, lack of uniformity and resemblance to mother tree, loss of valuable germplasm, high rate of cross-pollination leads to loss of desirable silvicultural traits. *In vitro* propagation of *Tecomella undulata* using seedling explants and mature explants has been reported to be limited rooting potential, difficulties in culture and field establishment using mature explants, remain the major bottlenecks (Kalia et al 2014). Macro propagation methods are still preferred over micro-propagation techniques because of low cost and less complexity. Thus, there is a need of improvement in its multiplication technique for its conservation and to give boost to planting of this valuable tree and economically viable (Saggoo et al 2016, Kumar et al 2018) through cuttings and better knowledge of root induction in cuttings. Keeping in view, the limitation in micro-propagation of rohida, present study attempted to standardize the method of vegetative propagation and effect of concentration levels of IBA on rooting of cuttings and mini-cutting.

MATERIAL AND METHODS

The study was carried out during 2016 -2017 at Punjab Agricultural University, Ludhiana. The experimental site is located at an altitude of 247 m above mean sea level in the central zone of Punjab and it lies between 30°-50'N latitude and 75°-52'E longitude. The climate of this area is sub-tropical to tropical. Average annual rainfall 700 mm and relative humidity is 70.5%. The mean maximum temperature during summer month between May and June was 37.5 ˚C whereas; mean minimum temperature during winter month December and January was 19.7 ˚C in 2016. The cuttings with 0.5 -1.0 cm diameter and 10-12 cm length having 2-3 nodes were collected from fresh growth of tree and planted during the first week of January. These cuttings were treated with growth regulator IBA (Indole-3-butyric acid) 4000 and

6000 ppm and control (untreated) was also kept. Auxin was applied at lower portion of cuttings and then placed in mist chamber which was maintained at 40 ± 2° C and relative humidity of 85 ± 2 %. Treated cuttings were immediately planted in root trainers, which were filled with vermi-compost. 2/3rd length is buried in rooting media and 1/3rd remains exposed with at least one bud above media level in trays portion to produce shoot. The standard practises of nursery rising were followed. The data on plant parameters were collected in the last week of March. Different methods of vegetative propagations in the present study were included viz., mini cuttings, air layering, root suckers, cuttings, and rootstock growth. It was evaluated in completely randomized design with 6 replications for cuttings and 3 replications for other methods. Statistical analysis of data was done as per the procedures laid down for CRD (completely randomized design). Analysis of variance, critical difference (CD) of various components was calculated for the presentation and interpretation of results of the study.

RESULTS AND DISCUSSION

All parameters presented in Table 1 differed significantly within different treatments except number of shoots emerged. Sprouting percentage (%) was significantly higher in control (61.9%) compared to other treatments. Higher sprouting success of branch cuttings under control is may be due to congenial and more controlled environment especially relative humidity and temperature and auxin. As cuttings were taken from apical portion they showed higher results compared to basal portion for new shoots production of *Paphiopedilum orchid* (Udomdee et al 2012) were apical part of propagules has shown higher length as compared to basal portion. Number of shoots emerged were non-significant. Average shoot length (cm) and number of leaves per cutting were also significantly differed. Higher shoot length and number of leaves/cutting was in IBA 4000 ppm, 6000 ppm as compared to control. Collar diameter was significantly higher in IBA 6000 ppm, whereas, IBA 4000 ppm and control were at par. Variation in collar diameter of the number of shoots is seems to be depended on the initial diameter of cutting planted, whereas, Kang et al (2015) reported suitability of 1.0-1.5 cm cutting size for sprouting and growth in nursery. Similarly, average root length (cm) and number of roots per cutting was significantly higher in IBA 6000 ppm but were at par with in control and IBA 4000 ppm. Rooting percentage was significantly higher in IBA 6000 ppm (35.72%) than IBA 4000 ppm and control (which were statistically at par). Adventitious roots induction in tree species is highly variable in vivo as well as in vitro, thus it's a major problem in plantlet regeneration. IBA was effective in root induction of *T. undulata* reported by (Tyagi 2013) reported that in difficult to root species basal application of auxin increase in auxin concentration. It is due to lack of auxin receptors in these cells that would give rise to adventitious root formation. *T. undulata* rooting is easy from seedling/juvenile explants as compare to mature trees (Varshney and Anis 2011). Higher rooting percentage in IBA 6000 ppm was because of the effect of rooting hormone, whereas, non-rooting of mini cuttings was due to rotting under misting conditions. In many species thickness of stem cuttings influences rooting response viz. quality and quantity of roots emergence due to differences in carbohydrate reserves. Stem cuttings of *T. undulata*, ranging from 1.0 to 1.5 cm thickness were rooted. Stem cutting with lower or higher thickness than this middle range (1.0-1.5 cm) did not rooted (Tyagi 2013). The poor performance of thin cuttings is also attributed to the reason that the cuttings are still under maturity and may be devoid of sufficient food material for induction of roots and shoots. Reserve food material plays a vital role in root shoot induction and growth. The high temperature and humidity inside polyhouse is favourable to induce rooting in stem cuttings. It was needed to understand the growth and physiological behaviour of trees, to know the effect of tree physiology on some of the common practices applied in mature tree management. The application of auxin at cutting base to stimulate meristem-matic differentiation for promoting

Table 1. Effect of IBA on different parameters on cuttings of *Tecomella undulata*

Parameters	Treatments			CD (p=0.05)
	Control	IBA 4000 ppm	IBA 6000 ppm	
Sprouting percentage (%)	61.90	42.86	35.72	10.07
Number of shoots emerged	1.83	2.00	2.00	N.S.
Average shoot length (cm)	4.67	10.17	11.0	2.13
Number of leaves per cutting	8.33	10.67	11.5	2.10
Collar diameter (mm)	1.03	1.36	1.88	0.33
Average root length (cm)	0.96	1.08	2.08	0.39
Number of roots per cutting	3.17	3.50	5.67	0.99
Rooting percentage (%)	19.05	21.43	35.72	9.53

Table 2. Effect of IBA on different parameters of minicuttings and growth of remaining rootstock after different days of *Tecomella undulata*

Parameters	Control	IBA 500	IBA 1000	CD (p=0.05)
	Growth hormone levels (ppm)			
Greener cuttings	10.67	1.67	1	0.96
No. of leaves	12.67	4.67	2.67	3.53
Size of cutting (cm)	3.83	2.17	1.17	0.58
Stem base diameter (mm)	2.83	1.38	0.703	0.67
	Root stock (days after taking minicuttings)			
	10	20	30	
Number of shoots	3.17	4.33	5.00	1.21
Number of leaves	11.83	16.17	20.00	3.92
Collar diameter (mm)	1.27	1.79	2.11	0.60
Average shoot length (cm)	6.50	7.33	9.67	1.98

rooting is probably the best way in all kind of cuttings.

The perusal of result presented in Table 2 revealed that mini cuttings taken from nursery raised seedlings in January remained most active in growth in control than as compared to IBA 500 and IBA 1000 treatment and higher significant differences were recorded with respect to Greenness of the cuttings, appearance of new leaves (number), increase in size and stem diameter in control than IBA growth hormone level used. Root stock of the nursery raised seedlings kept in the nursery were observed for the plant parameters after 10, 20, and 30 days of taking mini cuttings and data is presented in Table 2. it is observed that after 20 days of taking cuttings there is a increase is noticed in number of new shoots, new leaves and collar diameter and average shoot length in IBA treated rootstock than control but it was not significant (except no. of new leaves) among the value recorded after 10 and 20 days of taking mini cuttings. However, these differences become significant in IBA 1000 treated rootstock after 10 day and 30days of taking mini cuttings. Root suckers and air layering method of vegetative propagation were other way for propagation where some success was achieved. In root suckers, per cent survival was 27.78 per cent after 60 days of planting, whereas, in air layering it was only 11 per cent after 60 days of planting. The plant parameters viz., collar diameter, average shoot length and per cent survival of root suckers recorded significant results after 60 days after planting.

CONCLUSION

Rooting in *Tecomella undulata* was obtained in cuttings followed by root suckers and air layering. Because of hard to root species higher success was not recorded but it opens a new opportunity both for researchers and foresters in future for large scale cultivation of this valuable tree.

REFERENCES

Kalia RK, Rai MK, Sharma R and Bhatt RK 2014. Understanding *Tecomella undulata*: an endangered pharmaceutically important timber species of hot arid regions. *Genetic Resources and Crop Evolution* **61**: 1397- 1421.

Kang JJ, Zhao WZ, Zhao M, Zhang Y and Yang K 2015. The cutting reproduction techniques of *Salix oritrepha* and its application on degraded grasslaws restoration. *Journal Soil and Water Conservation* **70**(1): 358-360.

Kumar S, Shamet G S, Kumari N and Hegde N 2018. Rooting response of *Acer acuminatum* cuttings to IBA, girdling and season. *Indian Journal of Ecology* **45**(4): 806-809.

Patel A, Rathod D, Shrimali G, Rami E and Patel I 2013. Study on qualitative and quantitative estimation of *in vivo* and *in vitro* tissues of *Tecomella undulata* (Sm.) Seem. *International Journal of Advances in Pharmaceutical Research* **4**(8): 2088-2092.

Saggoo MIS, Navdeep K and Gill A 2016. Economically valuable *Tecomella undulata*-An endangered tree of arid zone. *International Journal of Science* **2**: 8-13.

Singh A, Jerath N, Laddar SS, Singh G and Luna RK 2014. *Tree Directory of Punjab*. Punjab Agricultural University, Ludhiana and Punjab State Council for Science and Technology, Chandigarh, pp184.ISBN No. 978-81-930085-0-8

Tyagi H 2013. *In vitro, Ex vitro rooting and hardening studies in Ailanthus excelsa Roxb. and Tecomella undulata (Sm.) Seem*. Ph.D. Thesis. Forest Research Institute (Deemed) University Dehradun, Uttarakhand.

Udomdee W, Wen PJ, Chin SW and Chen FC 2012. Shoot multiplication of *Paphiopendilum* orchid through in vitro cutting methods. *African Journal of Biotechnology* **11**: 14077-14082.

Varshney A and Anis M 2011. Improvement of shoot morphogenesis in vitro and assessment of changes of the activity of antioxidant enzymes during acclimation of micropropagated plants of Desert Teak. *Acta Physiologiae Plantarum* **34**: 859-867.

Variability in Secondary Metabolites during Developmental Stages and Seasons in *Corbichonia decumbens* and *Withania coagulans* from Indian Thar Desert

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Abstract: The present study was carried out to evaluate the variations in the secondary metabolites during different developmental stages and seasons in two important medicinal plants, *viz. Corbichonia decumbens* and *Withania coagulans* from the Indian Thar desert. In *C. decumbens*, maximum amount of total alkaloids were observed during fruiting, whereas, total phenols in vegetative stage. In *W. coagulans*, rainy and summer seasons were found to be suitable for maximum accumulation of total alkaloids and phenols, respectively.

Keywords: Corbichonia decumbens, Indian Thar desert, Secondary metabolites, *Withania coagulans*

Medicinal plants are source for a wide variety of natural antioxidants and are used for the treatment of diseases throughout the world (Rafieian-Kopaie and Baradaran 2013). Some traditional medicines are highly equipped with more qualities in therapeutical basis, majority of the people in developing countries have resorted to the use of medicinal plants as an alternative treatment (Daniel and Krishnakumari 2015). Herbal medicine is based on the premise that plants contain natural substances that can promote health and alleviate illness (Balakumar et al 2011). *Corbichonia decumbens* Forssk. (Family: Lophicarpaceae) is a prostrate, glabrous, succulent and annual plant found throughout India in cultivated and wasteland areas. This plant is commonly distributed in Africa in rocky or sandy dry hot areas up to 1000 m altitude. An infusion of the root is used in biliousness, emetic, tonic and gonorrhoea (Kumar et al 2013). The plant is used in kidney stone problems (Katewa and Galav 2005). *W. coagulans* (Stock) Dunal (Family: Solanaceae) is common throughout Pakistan and also in North-West India and Afghanistan (Vaibhav et al 2013). The plants are used to treat nervous exhaustion, disability, insomnia, wasting diseases, failure to thrive in children, impotence, diabetes, etc. (Mathur and Agrawal 2011).

The medicinal value of the plants lies in presence of some chemical substances that produce a definite physiological action on the human body. The most important of these bioactive constituents of the plants are alkaloids, tannins, flavonoids and phenolic compounds. Secondary metabolites are synthesized by the plants as part of the defense system (Phan et al 2001) which fall under the category of large group of plant secondary metabolites. They are pharmacologically active organic compounds found in plants produced from amino acid and shows a broad-spectrum antibacterial activity under biotic stress. Production of secondary metabolite is administrated by both genomic and ecological factors (Tewari et al 2014). The present investigation was aimed to understand an optimum time for harvesting maximum amount of secondary metabolites in terms of total alkaloids and phenols in *C. decumbens* and *W. coagulans* from the Indian Thar desert as leaves of *C. decumbens* are used in kidney stone problem, whereas, *W. coagulans* in diabetes.

MATERIAL AND METHODS

Plant samples of *C. decumbens* were collected from rocky and stony habitats of different stages,*viz.* vegetative, flowering and fruiting from Beriganga, Jodhpur (26°23'-73°3') during 2016 & 2017. The plants of *W. coagulans* were cultivated in the botanical garden of J.N.V. University Campus, Jodhpur (26°50'- 73°4') and leaf samples were collected in their different seasons, winter (December-February), rainy (July-September), and summer (April-June) for analyses of various parameters. Acid-base titrimetric method was used to estimate total alkaloids as suggested by Debnath et al (2015). Total phenols were estimated by Folin-Ciocalteau reagent (Bray and Thorpe 1954). This estimation was based on the principle that phenols react with phosphomolydic acid in Folin-Ciocalteau reagent in alkaline medium and produce blue coloured complex (molybdenum blue). The standard was prepared with caticol phenol.

RESULTS AND DISCUSSION

In *C. decumbens,* total alkaloid contents varied from 0.756 to 1.593 per cent during different growth stages, being

highest in fruiting stage (Table 1). Verma and Kasera (2007) observed higher amount of total alkaloids during flowering stage in leaves of *Asparagus racemosus* and *Sida cordifolia*. The phenolic contents varied significantly during different physiological stages, being higher in vegetative stage than in fruiting stage. The increased quantity of total phenols might be attributed to defense mechanism (Parashar and Lodha 2007), when plants are in developmental stages, there may be chances of pathogen attacks and to save from them under biotic stresses plants produce secondary metabolites. Kale (2010) observed maximum amount of total phenols 44.2 mg g^{-1} in *Convolvulus microphyllus* during flowering stage. However in the present studies, the maximum amount of total phenols were observed during vegetative stage, as plants are in juvenile stage as compared to other stages. The maximum values of total alkaloids and phenols during fruiting and vegetative stages (rainy season) may be due to maximum rainfall as compared to other seasons (Table 3). Rainy season promote maximum accumulation of total alkaloid and phenols due to fluctuations in temperature and relative humidity. The total alkaloids in *W. coagulans* during three seasons ranged from 1.797 to 3.820%, being maximum during rainy season (Table 2). Rainy season has positive impact on plant growth as well as the formation of alkaloids. Alkaloid synthesis increases with progressive maturity. It reaches to highest concentration at flowering stage. Sahoo et al (2012) and Kale (2010) observed highest values of total alkaloids in *Grewia tenax* and *Datura metel* during summer and rainy seasons, respectively. In the present findings, maximum total alkaloids were observed during rainy season as compared to other seasons, which were supported by the findings of Kale (2010). The occurrence of maximum rainfall during rainy as compared to other seasons also favours to its maximum accumulation. The phenolic contents varied according to season, maximum during summer followed by winter and minimum in rainy season (Table 2). Water stress can stimulate the accumulation of phenolic contents during growth stages of the plants. Verma and Kasera (2007), Swami et al (2008) and Gehlot and Kasera (2013) observed maximum total phenols during summer season in *Sida cordifolia*, *Convolvulus microphyllus* and *Phyllanthus amarus*, respectively. Similarly, Soni and Kasera (2018) observed maximum amount of total phenols during June (summer season) in *Arisaema tortuosum*. In the present studies, maximum amount of total phenols were reported in summer season, which was accordance with observations of above researchers. The summer (dry) season condition favouring high accumulation of total phenols may be to higher values of maximum temperature as compare to other seasons (Table 3).

Table 1. Variability in secondary metabolic products in *C. decumbens* leaves during different developmental stages

Products	Stages			CD
	Vegetative	Flowering	Fruiting	
Total alkaloids (%)	0.783	0.756	1.593	0.87*
Total phenols (mg g^{-1})	9.2683	8.3683	7.06165	7.64**

** Significant at (P < 0.01) level.

Table 2. Variability in secondary metabolic products in *W. coagulans* leaves during different seasons

Products	Seasons			CD
	Winter	Summer	Rainy	
Total alkaloids (%)	1.797	1.7415	3.8205	NS
Total phenols (mg g^{-1})	9.663	10.02	8.33125	NS

NS = Non-significant.

Table 3. Mean values of meteorological data (2016 & 2017) during three seasons at Jodhpur

Parameters	Seasons		
	Rainy	Winter	Summer
Minimum temperature (°c)	20.90	10.18	18.23
Maximum temperature (°c)	36.85	31.59	42.24
Minimum relative humidity (%)	36.40	21.45	16.56
Maximum relative humidity (%)	81.93	76.55	60.90
Mean evaporation (mm day^{-1})	7.52	5.09	14.17
Wind velocity (km h^{-1})	70.35	0.075	22.87
Total rainfall (mm)	173.00	0.20	43.50
Sunshine (h day^{-1})	9.69	8.98	10.07

Source: Meteorological Section, CAZRI, Jodhpur

CONCLUSIONS

The growth stages and seasons affect significantly for production of secondary metabolites. Favourable climatic conditions are believed to stimulate the secondary metabolic synthesis. The leaves of *C. decumbens* accumulated maximum amount of total alkaloids during September-October (fruiting stage), while phenols in July (vegetative stage). Rainy and summer periods are suitable for maximum production of alkaloids and phenols in *W. coagulans*, respectively.

REFERENCES

Balakumar S, Rajan S, Thirunalasundari T and Jeeva S 2011. Antifungal activity of *Ocimum sanctum* Linn. (Lamiaceae) on clinically isolated dermatophytic fungi. *Asian Pacific Journal of Tropical Medicine* **8**: 654-657.

Bray HG and Thorpe WV 1954. Analysis of phenolic compounds of interest in metabolism. *Methods of Biochemical Analysis* **1**: 27-52.

Daniel G and Krishnakumari S 2015. Quantitative analysis of primary and secondary metabolites in aqueous hot extract of *Eugenia uniflora* (L.) leaves. *Asian Journal of Pharmaceutical and Clinical Research* **8**: 334-338.

Debnath B, Jashim Uddin M, Patari P, Das M, Maiti D and Manna K 2015. Estimation of alkaloids and phenolics of five edible Cucurbitaceous plants and their antibacterial activity. *International Journal of Pharmacy and Pharmaceutical Science* **7**: 223-227.

Gehlot M and Kasera PK 2013. Variability in primary and secondary metabolites during different seasons in *Phyllanthus amarus*. *Indian Journal of Plant Physiology* **18**: 169-171.

Kale VS 2010. Variable rates of primary and secondary metabolites during different seasons and physiological stages in *Convolvulus*, *Datura* and *Withania*. *Asian Journal of Experimental Biological Science* **SPL**: 50-53.

Katewa SS and Galav PK 2005. Traditional herbal medicines from Shekhawati region, Rajasthan. *Indian Journal of Traditional Knowledge* **4**: 237-245.

Kumar S, Balasubramaniam V and Jagathes UG 2013. Preliminary phytochemical screening and antimicrobial activity of *Corbichonia decumbens* Forssk. (Molluginaceae). *Research Journal of Pharmaceutical Biological and Chemical Science* **4**: 1098-1103.

Mathur D and Agrawal RC 2011. *Withania coagulans*: a review on the morphological and pharmacological properties of the shrub. *World Journal of Science Technology* **11**: 30-37.

Parashar A and Lodha P 2007. Phenolics estimation in *Foeniculum vulgare* infected with Ramularia blight. *Annals of Plant Protection Science* **15**: 396-398.

Phan TT, Wang L, See P, Grayer RJ, Chan SY and Lee ST 2001. Phenolic compounds of *Chromolaena odorata* protect cultured skin cells from oxidative damage: Implication for cutaneous wound healing. *Journal of Biological Pharmaceutical Bulletin* **12**: 1373-1379.

Rafieian-Kopaie M and Baradaran A 2013. Plants antioxidants: From laboratory to clinic. *Journal of Nephropathology* **2**: 152-153.

Sahoo KP, Kasera PK and Mohammed S 2012. Secondary metabolites produced during different season in some arid medicinal plants. *Asian Journal of Plant Science and Research* **6**: 650-652.

Soni A and Kasera PK 2018. Evaluation of secondary metabolites in three tuberous medicinal plants during different months from south eastern part of Rajasthan. *Journal of Pharmacognosy and Phytochemistry* **7**: 474-477.

Swami A, Kasera PK and Mohammed S 2008. Primary and secondary metabolites produced during different seasons and physiological stages in Shankhapushpi (*Convolvulus microphyllus*). *Indian Journal of Plant Physiology* **13**: 91-94.

Tewari JC, Kaushish S, Pareek K and Tewari P 2014. Variability in limonoid and oil content of neem in different eco-climatic regions of Rajasthan. *Indian Journal of Ecology* **41**: 290-296.

Vaibhav A, Singh OP and Tiwari SK 2013. *Withania coagulans* – An overview with special reference to diabetes mellitus. *Indian Journal of Research* **7**: 1-6.

Verma V and Kasera PK 2007. Variation in secondary metabolites in some arid zone medicinal plants in relation to season and plant growth. *Indian Journal of Plant Physiology* **12**: 203-206.

Diversity of Insects in Okra Agro-ecosystem at Gazipur in Bangladesh

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Abstract: Diversity and occurrence of insect pest, predator and pollinator associated with okra *Abelmoschus esculentus* L. were observed at Gazipur in Bangladesh during May to September 2016. Insects in the okra agro-ecosystem belonged to 29 species, in 24 families under 10 different taxonomic orders. The pest, predator and pollinator insect species revealed the highest occurrence in the order Hemiptera, Coleoptera and Lepidoptera, respectively. The relative abundance of the insect pest varied from 0.9 to 35.7%, predator from 1.7 to 26.0% and pollinator from 2.7 to 34.8%. Among the pests, aphid, white fly, and okra shoot and fruit borer were found as major pests. The aphid, ant and lemon butter fly depicted maximum abundance as pest, predator and pollinator, respectively.

Keywords: *Abelmoschus esculentus,* Insect, Pest, Predator, Pollinator

In Bangladesh, Okra *Abelmoschus esculentus* L. is cultivated throughout the year and is attacked by a number of insect pests from seedling to maturation of fruits. Insect infestation is the prime and the most limiting factor in the successful cultivation of okra. Number of insect species associated with okra agro-ecosystem differed from country to country and from region to region. Rachana et al (2009) reported that a total of 37 insect species attacked okra plant, whereas Mallick et al (2016) observed 72 insect species as the pest of okra.

Other than pests, many insect species forage in the okra field and they play vital roles in the agro-ecosystem as predators, decomposers, parasitoids and pollinators. Honey bees, bumble bees, ants, butterflies and many other pollinating insects forage in the okra field due to its attractive golden yellow flowers containing nectars (Bajiya and Abrol 2017, Nandhini et al 2018). Bilal and Satti (2012) observed 9 insect species under 4 families in 4 orders as predator in the okra agro-ecosystem in Northern Sudan. In the present study diversity and occurrence of the insect pest, predator and pollinator prevailing in okra agro-ecosystem illustrating their relative abundance was observed.

MATERIAL AND METHODS

The study was conducted at Bangabandhu Sheikh Mujibur Rahman Agricultural University (BSMRAU), Gazipur, Bangladesh during May to September 2016. The site is located at 25°25′ North latitude and 89°5′ East longitude,

which is in the middle of Bangladesh. Annual mean maximum and minimum temperatures, relative humidity and rainfall in the study area are 36.0 and 12.7° C, 65.8% and 237.6 cm, respectively.

Cultivation of okra: Seeds of okra *Abelmoschus esculentus* variety BARI OKRA-1 were sown on 26 May 2016 in 35 × 40 m plot. The spacing from plant to plant was 40 cm and from line to line was 50 cm. Regular intercultural operations such as weeding, irrigation etc were done on the basis of need and insect pest management was not adopted. Fertilizers were applied at the rate of 90-30-60-15 kg/ha N, P, K, and S as urea, triple super phosphate (TSP), muriate of potash (MoP) and gypsum, respectively (Ahmed et al 2013). Half of urea and all other fertilizers were used as basal. Remaining urea was applied around okra plant as top dress in two equal split at 3rd and 5th weeks after sowing followed by irrigation.

Insect collection, identification and categorization: Insects were captured using sweeping net having 30 cm diameter ring and 1.5 mm mesh, and attached with a 2 m long rod. A vacuum suction sampler was also used to capture very small insects. Insects were collected at weekly interval from seedling to last harvest of okra. Every collection date, both sweep net and vacuum suction sampling were done 30 times. The collected insects were brought from the experimental field to the Entomology Laboratory of BSMRAU and stored in a freezer for a few hours to kill, then mounted on points, dried and morphotyped. For identification, the insects were compared with the specimens in a labeled collection

and compared with pictures or descriptions. The identified insects were categorized as pest, predator and pollinator and their relative abundance were calculated.

Statistical analysis: Chi statistic was applied to find out significant difference in the occurrence of insect species in different taxonomic orders. All the analyses were performed using IBM SPSS 21.0 (IBM SPSS statistics 21, Georgia, USA).

RESULTS AND DISCUSSION

The insects (pest, predator and pollinator) in the okra field belonged to 29 species in 24 families under 10 different taxonomic orders. The insect pests were under 12 species in 12 families under 5 different taxonomic orders. Abundance of the pest species varied from 0.9 to 35.7% (Table 1). Aphid was the most abundant (35.7%) followed by whitefly (35.4%) and fruit borer (6.7%) and they were found as major pests. Occurrence of the pest species among the taxonomic orders ranged from 8.3 to 41.7% with significant differencs (χ^2 = 17.4). The highest number of pest species occurred in the order Hemiptera. Bhatt et al (2018) reported that a total of 17 species of insects caused damage to okra at Pantnagar, Uttarakhand, India, whereas, Mandal et al (2007) observed 13 species of insect pest in okra agro-ecosystem. The present findings showed agreement with Bhatt et al (2018) who reported that the order Hemiptera represented the highest abundance.

Ten species of insects were found as predator and they belonged to 9 families under 6 different taxonomic orders (Table 2). Abundance of the predator species varied from 1.7 to 26.0%. Ant was the most abundant (26.0%) predator followed by lady bird beetle (25.8%) and ground beetle (13.8%). The dragon fly was least abundant. Occurrence of the predator species among the orders varied from 10.0 to 30.0% and the results did not differ significantly (χ^2 = 2.0). Bhatt et al (2018) observed that the predator insects in the okra agro-ecosystem were under four orders namely Coleoptera, Lepidoptera, Hemiptera and Dictyoptera. The abundance of predator mostly depends on the availability of their prey sources and abiotic components of the environment. But the pest species and their population dynamics are related to crop or variety, their growth stages and other biotic and abiotic components of the environment.

The reproductive system of okra is a mixture of cross- and self- pollination and insects play a significant role in the fertilization of flowers. In the present study, in total 8 species of insects in 5 families under 3 taxonomic orders were observed as pollinators and their relative abundance varied from 2.7 to 34.8% (Table 3). Lemon butterfly was the most abundant pollinator (34.8%) followed by honey bee (15.4%), giant swallow tail butterfly (13.9%) and sulphur butterfly (11.2%). Occurrence of the pollinator species among the orders varied from 12.5 to 50.0% and differed significantly (Table 3; χ^2 = 21.2). The order Lepidoptera revealed the highest occurrence (50.0%) followed by Hymenoptera (37.5%) and Diptera (12.5%).

Nandhini et al (2018) reported that the flower-visiting insect pollinators of okra in Bengaluru region, Karnataka, India are in the order Hymenoptera. They also reported that honeybees *Apis* spp. were the most dominant visitors, which constituted 41.8 % of the total insect pollinators.

CONCLUSION

This study revealed that various insect species belonged to different orders were pest, predator and pollinator in the okra agro-ecosystem in Bangladesh, and their occurrence differed significantly.

Table 1. Insect pests associated with okra agro-ecosystem at Gazipur in Bangladesh

Pest insects, their species, species abundance, pest status and family					Order and occurrence of species	
Name	Species	Abundance	Pest	Family	Order	Occurrence
Short horned grasshopper	*Stenobothrus rubicundulus*	2.2	Minor	Acrididae	Orthoptera	16.7
Long horned grasshopper	*Tettigonia sp.*	3.2	Minor	Tettigoniidae		
Thrips	*Thrips tabaci*	4.0	Minor	Thripidae	Thysanoptera	8.3
Whitefly	*Bemisia tabaci*	35.4	Major	Aleyrodidae	Hemiptera	41.7
Aphid	*Aphis gossypii*	35.7	Major	Aphididae		
Jassid	*Amrasca biguttula biguttula*	2.7	Minor	Cicadellidae		
Scale insect	*Aonidiella aurantii*	1.7	Minor	Diaspididae		
Pentatomid bug	*Boisea trivittata*	0.9	Minor	Pentatomidae		
Epilachna beetle	*Epilachna dodecastigma*	2.5	Minor	Coccinellidae	Coleoptera	25.0
Blister beetle	*Hycleus lugens*	2.4	Minor	Meloidae		
Red pumpkin beetle	*Raphidopalpa foveicollis*	2.5	Minor	Chrysomelidae		
Okra shoot and fruit borer	*Leucinodes orbonalis*	6.7	Major	Crambidae	Lepidoptera	8.3

Table 2. Insect predators associated with okra agro-ecosystem at Gazipur in Bangladesh

Predator insects, their species, species abundance and family				Order and occurrence of species	
Name	Species	Abundance (%)	Family	Order	Occurrence (%)
Dragon fly	*Anax imperator*	1.7	Aeshnidae	Odonata	20.0
Damsel fly	*Ceriagrion glabrum*	5.9	Coenagrionidae		
Preying mantid	*Mantis religiosa*	3.8	Mantidae	Dictyoptera	10.0
Pirate bug	*Orius insidiosus*	3.0	Anthocoreidae	Hemiptera	10.0
Green lacewing	*Chrysoperla carnia*	9.9	Chrysopidae	Neuroptera	10.0
Lady bird beetle	*Coccinella septempunctata*	25.8	Coccinellidae	Coleoptera	30.0
Tiger beetle	*Cicindela hudsoni*	4,4	Carabidae		
Ground beetle	*Calosoma scrutator*	13.8			
Porter wasp	*Vespula vulgaris*	5.7	Vespidae	Hymenoptera	20.0
Ant	*Formica rufa*	26.0	Formicidae		

Table 3. Insect pollinators associated with okra agro-ecosystem at Gazipur in Bangladesh

Pollinator insects, their species, species abundance and family				Order and occurrence of species	
Name	Species	Abundance (%)	Family	Order	Occurrence (%)
Honey bee	*Apis mellifera*	15.4	Apidae	Hymenoptera	37.5
Carpenter bee	*Xylocopa micans*	9.3			
Paper wasp	*Vespula valgaris*	2.7	Vespidae		
Giant swallow tail butter fly	*Papilio cresphontes*	13.9	Papilionidae	Lepidoptera	50.0
Swallow tail butter fly	*Papilio troilus*	5.4			
Lemon butter fly	*Papilio demoleus*	34.8			
Sulphur butter fly	*Phoebis sennae*	11.2	Pieridae		
Hover fly	*Ceriana vespiformis*	7.3	Syrphidae	Diptera	12.5

REFERENCES

Ahmed F, Islam MN, Sarker MAI, Alom MS and Mannaf MA 2013. Study on intercropping leafy vegetables with okra (*Abelmoschus esculentus* L.). *Bangladesh Journal of Agricultural Research* **38**: 137-143.

Bajiya MR and Abrol DP 2017. Flower-visiting insect pollinators of mustard (*Brassica napus*) in Jammu region. *Journal of Pharmacognosy and Phytochemistry* **6**: 2380-2386.

Batt B, Joshi S and Karnatak AK 2018. Biodiversity of insect pests and their predators on okra agroecosystem. *Journal of Pharmacognosy and Phytochemistry* **7**: 84-86.

Bilal NAA and Satti AA 2012. The major predators and their seasonal abundance in okra fields at Elgorair Scheme, Northern Sudan. *International Journal of Science and Technology* **4**: 271-276.

Mallick S, Chand P and Mandal SK 2016. Tolfenpyrad 15% EC, a new pyrazole insecticide, against sucking pests of okra and its impact on natural enemies. *Indian Journal of Entomology* **78**: 51-55.

Mandal SK, Sah SB and Gupta SC 2007. Management of insect pests on okra with biopesticides and chemicals. *Annals of Plant Protection Sciences* **15**: 87-91.

Nandhini E, Padmini K, Venugopalan R, Anjanappa M and Lingaiah HB 2018. Flower- visiting insect pollinators of okra [*Abelmoschus esculentus* (L.) Moench] in Bengaluru region. *Journal of Pharmacognosy and Phytochemistry* **7**: 1406-1408.

Rachana RR, Manjunath M, Gayathridevi S and Naik MI 2009. Seasonal incidence of red spider mite *Tetranychus neocaledonicus* Andre and its natural enemies. *Karnataka Journal of Agricultural Sciences* **21**: 213-214.

Evaluation and Performance of CERES-Wheat DSSAT v4.6 Model for Growth, Development and Yield in Southern Bihar

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Abstract: The DSSAT model v4.6 was calibrated and validated for wheat (cv. HD2733, GW322, K307) using experimental data (2015-2017) of Bihar Agricultural University, Sabour, Bhagalpur (25°50' N latitude and 87°19' E longitude) with two dates of sowing (timely sown, 23 November; late sown, 15 December). The simulated values of growth, development and yield (anthesis, physiological maturity, maximum leaf area index and grain yield) were close to measured parameters for both the years of study. The root mean square error (RMSE) values ranged from 2.70-2.97, 0.34-0.36, 2.34-3.08 and 318-343 for anthesis, LAI, physiological maturity and grain yield, respectively. *D*-index, R^2 and error percentage values were also in acceptable range between simulated and observed values for different phenophases, LAI and grain yield during both years. Based on these results, it can be concluded that the model was very robust in predicting the critical phenological growth stages and yield of different cultivars of wheat under different sowing environment.

Keywords: Crop growth model, DSSAT, Wheat, Simulation, Calibration, Validation

Bihar is potentially an important wheat growing state, but it contributes only 5.8 percent towards national production from an area of 2.25 million ha with a productivity of 2225 kg ha⁻¹ (DSE 2015). This clearly indicates that in spite of considerable improvement in genetic potential of the crop, productivity is very poor in the state than Punjab (4307 kg ha⁻¹) and Haryana (4213 kg ha⁻¹). In Bihar, about 80 % of the crop is grown under irrigated condition and due to vagaries of monsoon the year-to-year yield fluctuations are more. The productivity of wheat is curtailed due to biotic and abiotic stresses. Weather is one of the important factors, which affects all stages of wheat growth and finally the yield. Recently, crop modeling and system analysis have also been viewed as potential tool to quantify the agronomic management practices, effects of climate, seasonal weather condition, soil environment, management and genotype as well as their interaction on crop growth, yield, resource-use efficiency and environmental impacts (Shamim et al 2012). These tools after validation and calibration for particular regions can be used to optimize crop management practices (MacCarthy et al 2012), to compute the gaps between potential and actual yields and to determine likely environmental and climate change impacts on crop growth and yield (Mahdi and Haque 2018).

The DSSAT v4.6 model package incorporates models of 42 different crops with new tools that facilitate the creation and management of experimental, soil, and weather data files. DSSAT v4.6 also includes improved application programs for seasonal, spatial, sequence and crop rotation analyses that assess the economic risks and environmental impacts associated with irrigation, fertilizer and nutrient management, climate variability, climate change, soil carbon sequestration, and precision management. In Bihar, studies on crop simulation modeling of have been rarely attempted. Hence, to fill this gap of research, the present investigation has been carried out with objectives to calibration and validation of DSSAT v4.6 model to predict wheat growth, development and yield based on field experimental data and to development of the varietal genetic coefficients for running DSSAT v4.6 CERES wheat model.

MATERIAL AND METHODS

The experimental data (2015-17) of Bihar Agricultural University, Sabour, Bhagalpur comprising two dates of sowing (D1: timely sown, 23 November; D2: Late sown, 15 December) and three ruling wheat varieties viz., HD2733, GW322 and K307 were used in this study. The package and practices for cultivation of wheat was followed as per the recommendation of Bihar Agricultural University. The measured parameters such as, grain yield, biological yield, leaf area index, plant height, 100 seed weight, days to anthesis and days to maturity and N content in straw and grain were provided for the model as observed data for the calibration of model. The genetic coefficients of wheat were estimated by repeated interactions until a close match between simulated and observed phenology and yield was

obtained in respective treatments. The values of genetic coefficients were derived from calibration of the model. For evaluation of calibrated genotypes, the simulated dates of anthesis and physiological maturity as well as yield and yield components were compared with the observed data. Different statistic indices were employed, including, coefficient of determination (R^2) (Eq. 1) to test the goodness of fit between observed and simulated values, Root Mean Square Error (RMSE) to measure the coincidence between measured and simulated values (Eq. 2) (Loague and Green 1991), Mean Absolute Error (MAE) (Eq.3) to measure how close simulations are to the eventual outcomes. The D-index, an index of agreement (Eq. 4) (Willmott et al 1985) to make cross-comparisons between model runs was applied to evaluate the model performance.

$$R^2 = 1 - \frac{\sum\limits_{i=1}^{n} (X_{obs_i} - X_{sim_i})^2}{\sum\limits_{i=1}^{n} (X_{obs_i} - \overline{X}_{obs_i})^2} \qquad (1)$$

$$RMSE = \sqrt{\frac{\sum\limits_{i=1}^{n} (X_{obs_i} - X_{sim_i})^2}{n}} \qquad (2)$$

$$MAE = \frac{\sum\limits_{i=1}^{n} (X_{obs_i} - X_{sim_i})}{n} \qquad (3)$$

$$d = 1 - \sqrt{\frac{\sum\limits_{i=1}^{n} (X_{obs_i} - X_{sim_i})^2}{[\sum\limits_{i=1}^{n} |(X_{obs_i} - \overline{X}_{obs_i})| + \sum\limits_{i=1}^{n} |(X_{sim_i} - \overline{X}_{sim_i})|]^2}} \qquad (4)$$

Where X_{obs_i} is observed values and X_{sim_i} is modeled values at time/place *i*.

RESULTS AND DISCUSSION

Days to anthesis: The average observed duration to anthesis were 84.66 days, whereas, the average days to anthesis simulated by model were 85.5 days for wheat crop sown on time during both years of study. Under late sown condition, the observed duration to reach anthesis was 76.66 days, whereas, average days to attain anthesis as simulated by model was 77.5 days. Higher temperatures prevailing during March might have caused this early anthesis and reduction in days to reach anthesis under late sown conditions (Dettori et al 2011). The average values for RMSE,

index of agreement (D-stat) and R^2 for anthesis date were 2.70-2.97, 0.92-0.77 and 0.95-0.81, respectively. The error percentage between observed and simulated values was also within 10%. This indicates that model performed good in simulating the days to anthesis with regard to measured values during both year of study (Table 2).

Maximum leaf area index (LAI): The average observed maximum LAI was 4.08 and the simulated LAI was 4.1 for the timely sown crop. Under late sown conditions, the average observed maximum LAI was 3.76 and the simulated LAI was 3.56. The average values for RMSE, index of agreement (D-stat) and R^2 for LAI were 0.34-0.36, 0.74-0.69 and 0.80-0.78 respectively. The error percentage between observed and simulated values was also within 10% (Table 2). This indicates that model performed well in simulating the LAI with regard to measured values during both year of study.

Physiological maturity: The average observed duration to physiological maturity were 125.16 days, whereas, the average days to physiological maturity simulated by model were 126.16 days for wheat crop sown on time during both years. Under late sown condition, the observed duration to reach physiological maturity was 114.66 days, whereas, average days to attain anthesis as simulated by model were 113.66 days. The average values for RMSE, index of agreement (D-stat) and R^2 for anthesis date were 2.34-3.08, 0.93-0.94 and 0.87-0.93, respectively. The error percentage between observed and simulated values was also within 10% confirms that model performed well in simulating the days to physiological maturity with regard to measured values during both years (Table 2).

Grain yield: During the two years of study, the observed average yield for timely sown wheat for three cultivars under study was 4342.16 kg ha^{-1}, while simulated average grain yield by the model was 4377.83 kg ha^{-1}. Under late sown conditions, the observed average yield was 3748.33 kg ha^{-1}, while simulated average grain yield by the model was 3734.33 kg ha^{-1}. The average values for RMSE, index of

Table 1. Genetic coefficients of different cultivars of wheat

Variety	P1V	P1D	P5	G1	G2	G3	PHINT
HD 2733	01	50	750	25	50	3.0	75
GW 322	01	55	650	22	45	4.0	72
K 307	02	43	640	25	45	4.0	73

P1V	: Days at optimum vernalizing temperature required tocomplete verbalization.
P1D	: Percentage reduction in development rate in a photoperiod10 h shorter than the optimum relative that optimum.
P5	: Grain filling (excluding lag) period duration (GDD).
G1	: Kernel number per unit canopy weight at anthesis (g^{-1}).
G2	: Standard kernel size under optimum condition (mg).
G3	: Standard non-stressed dry weight (total, including grain) of asingle tiller at maturity (g).
PHINT	: Phyllochron interval (GDD).

Table 2. Simulated and observed days to anthesis, physiological maturity, leaf area index and grain yield of wheat cultivars under different dates of sowing

Cultivar	Date of sowing	Days to anthesis				Error (%)	Days to physiological maturity				Error (%)	Leaf Area Index				Error (%)	Grain yield (kg ha⁻¹)				Error (%)
		2015		2016			2015		2016			2015		2016			2015		2016		
		Sim	Obs	Sim	Obs		Sim	Obs	Sim	Obs		Sim	Obs	Sim	Obs		Sim	Obs	Sim	Obs	
V1	D1	86	84	83	86	2.93	127	125	129	125	2.4	4.6	4.2	3.9	4.2	8.33	4424	4750	4658	4830	5.2
	D2	75	76	80	77	2.60	113	114	116	116	0.43	3.8	3.9	3.4	3.8	6.54	4300	4140	3988	4210	4.6
V2	D1	88	83	85	85	3.01	125	124	128	126	1.15	4.3	4.1	3.8	4.0	4.93	4523	4370	4154	4440	5.0
	D2	76	77	79	76	2.61	112	114	116	115	1.30	3.7	3.8	3.4	3.7	5.36	3763	3600	3480	3640	4.5
V3	D1	87	85	84	85	1.76	123	125	124	126	1.59	4.1	3.8	3.9	4.2	7.51	4489	4170	4019	4260	6.6
	D2	75	77	80	77	3.24	111	114	115	115	1.31	3.5	3.6	3.6	3.8	4.01	3622	3410	3253	3490	6.5
Statistics																					
RMSE		2.70		2.97			3.08		2.34			0.34		0.36			343.9		318.2		
D-stat		0.92		0.77			0.93		0.94			0.74		0.69			0.81		0.89		
R²		0.95		0.81			0.93		0.87			0.80		0.78			0.52		0.70		

agreement and R^2 for grain yield were 318-343, 0.81-0.89 and 0.52-0.70, respectively. The error percentage between observed and simulated values was also within range of 3.56-7.64 (Table 2), which indicated the reasonably very good agreement between simulated and observed grain yields.

Genetic coefficients of varieties: For the present modeling study, wheat varieties HD2733, GW322 and K307 have been calibrated as per Hunt's method (Hunt 1993). The genetic coefficients will be further used for model validation and different simulation application purpose (Table 1).

CONCLUSION

The DSSAT v4.6 model proved to be valuable tool in predicting the critical phenological growth stages and yield of different cultivars of wheat under different sowing environment. This shows the robustness of DSSAT model. Therefore, the validated DSSAT can further be used for applications such as prediction of crop growth, phenology, potential and actual yield, performance of wheat under climate change study, etc. The model may also to be used to improve and evaluate the current package and practices of wheat growth management to enhance wheat production.

REFERENCES

Dettori M, Cesaraccio C, Motroni A, Spano D, and Duce P 2011. Using CERES-Wheat to simulate durum wheat production and phenology in Southern Sardnia, Italy. *Field Crop Research* **120**:179-188.

Directorate of Statistics and Evaluation 2015. Planning and Development Department, Government of Bihar.

Loague K and Green RE 1991. Statistical and graphical methods for evaluating solute transport models: overview and application. *Journal of Contaminant Hydrology* **7**(1-2): 51-73.

MacCarthy DS, Vlek PLG and Fosu-Mensah BY 2012. The response of maize to N fertilization in a sub-humid region of Ghana: Understanding the processes using a crop simulation model. In improving soil fertility recommendations in Africa using the Decision Support System for Agro--technology Transfer (DSSAT), pp. 61-75. Springer Netherlands.

Mahdi SS and Haque M 2018. Calibration and Validation of CERES-Wheat (DSSAT v4.6) Model for Wheat under Irrigated Conditions: Model Evaluation and Application, *Indian Journal of Ecology* **45**(3): 555-559.

Shamim M, Shekh AM, Pandey V, Patel HR and Lungaria MM 2012. Simulating the phenology, growth and yield of aromatic rice cultivars using CERES-Rice model under different environments. *Journal of Agro Meteorology* **14** (1): 31-34.

Willmott CJ, Ackleson SG, Davis RE, Feddema JJ, Klink KM, Legates DR, Donnel J and Rowe CM 1985. Statistics for the evaluation and comparison of models. *Journal of Geophysical Research: Oceans* **90**(C5): 8995-9005.

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