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Elaboration of Sustainable Forest Model for Community Forest Management in Nghe An Province, Vietnam

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Abstract: The main trend in sustainable forest management is to use the forests to perfectly accomplish their environmental conservation role parallel with supplying forest products to fulfil communities' requirements. However, forests handed over to the local community are commonly found poor and require driving solutions to make them more stable and productive. The question is how to use the forest in sustainable management. The paper presented the methods for estimating forest products and benefits use based on the so-called sustainable forest model. The sustainable forest model is limited to stem number-diameter distribution (*N*/DBH distribution), which follows probability density functions. Meyer function is opted to be used in this research because it can make a rather good simulation of *N*/DBH distribution having the shape of decreasing curves. The results showed that the proposed *N*/DBH distribution of the sustainable forest model of group II and III has $N = 276 \cdot e^{-0.096D}$; $N = 164 \cdot e^{-0.063D}$ (respectively). This forest model will help identify the benefit levels to the community, make suitable and straightforward planning of wood exploitation, and reduce the costs by comparing the number of trees of the researched forests with that of the model.

Keywords: Diameter distribution, Ideal forests model, Meyer function, Sample forest model, Sustainable forest management

Forestry business practice requires maintaining a certain level of forest sources with the desired structure; this is the principle and an essential condition to assure non-degradation and continuous and better growing of exploited forests. The development of scientific bases for forestry business is necessary to deal with the issues mentioned above. One of the outstanding requirements is to study and propose forest structures and models to support identifying the way to exploit and use forest resources efficiently. The existing researches have so far proposed the "standard forest model" (Linh 2015), "sample forests model" (Dinh 2012), "ideal forests model" (Roth 2004), "oriented forests model" (Quan 2004, Pham 2008), "sustainable forest model" (Bao Huy 2007). These are the models of forests having high productivity and quality with reasonable structures. The current condition of even average and rich natural forests can hardly reach such a mentioned state, the typical characteristics are that the forest structure is disturbed, requiring adjustment to become stable. Forests handed over to the local community are commonly found poor and require driving solutions to make them more stable and productive (Roth 2004). To build up standardized and sustainable models of forests, forest researches in the world during the recent decades have been changing from qualitative to quantitative with a series of probability density functions used by many researchers to simulate the structures and the relationship among quantities in the forest structures (Aigbe and Omokhua 2014, Lima et al 2017). The standard forest structure is limited to the *N*/DBH structure (Stem number-diameter distribution), which follows probability density functions. The so-called negative exponential model is frequently used as a standard of comparison for natural and mixed stands managed on a polycyclic cutting system and as an aid in designing cutting schedules in such stands (Due to the ability to represent natural forest stands, negative exponential functions resembling ideal natural forests, similarly providing protection and production functions are prepared for each forest type separately (Roth 2004). However, scientists commonly recognize no perfect model of forests (Wang and Rennolls 2005). Depending on each succession stage, an established forest structure model may exhibit high applicability or is not suitable for the actual forest situation and should be improved accordinglyand the established forest structure model should be flexibly adaptive to the practical forest state. This trend is being applied in this research to build up sustainable forest models with aims to build a sustainable forest structure model to lead the different forest states to achieve higher productivity, ensure biodiversity, and protect and provide firewood for community life.

MATERIAL AND METHODS

Study area: The study area is a mountainous district located in the southwest of Nghe An province, coordinates 19°18'28" N 104°28'36" E. Nghe An is directly affected by the tropical monsoon climate. The average temperature varies from 23-25°C; the highest temperature in July: 39-41°C; the lowest temperature in January: 8oC. The average rainfall is 1450 mm but unevenly distributed in space and time, the rainy season accounting for 80% of total annual rainfall. The area of community forest in the study area is 62 ha (17 % of the total forest area). Community forest includes forest state of group II (66.7 % of the total area of community forest) and forest state of group III (33.3 %), the average DBH diameter of 14.6 cm, 17.7 cm; the average tree height of 10.3 m, 13.2 m; the average stand basal area of 8.25 $m^2 \cdot ha^{-1}$, 12.8 $m^2 \cdot ha^{-1}$; the average stand volume of 42.6 $m^3 \cdot ha^{-1}$, 84.8 $m^3 \cdot ha^{-1}$ (respectively).

Data collection: Three input variables, namely basal area, diameter-class width, and the number of trees in the respective diameter-classes, are necessary to model stem number-diameter distributions (Roth 2004). The respective data sets have been obtained via forest inventory, using a systematic random sampling design with sample plots of 1000 m^2. Fifteen sample plots were chosen, and all trees above 6 cm diameter were considered for measurement. Tree growth data collected on trees with DBH ≥ 6 cm in all sample plots include diameter at breast height (DBH). As far as the ideal stand model is concerned, sample plots have to be located in areas where the present forest condition satisfies the postulation stated above. Thus, rivers, roads, clearings for shifting cultivation, or special edaphic forest formations not representative of the forest type should not be located within the sample plots (Gimaretcarpentier et al 1998).

Methodology: In this research, the sample/sustainable forest structure model is shown in *N*/DBH distribution having the shape of decreasing curves, "the inverted J-shaped form" (McCarthy and Weetman 2006). Meyer function is opted to be used in this research because it can make a rather good simulation of *N*/DBH distribution having the shape of decreasing curves. The sample forest model having *N*/DBH distribution following the decreasing rule of Meyer function has the form: $N = \alpha \cdot e^{-\beta . D}$, where *N* is frequency per hectare in diameter-class; *D* is the centre of each diameter-classes at breast height; e is the base of the natural logarithm; α, β is estimated regression coefficients. The sustainable forest model with the same shape as the sample forest model has the form: $N = \alpha' \cdot e^{-\beta . D}$, with $0 < \alpha' < \alpha$. The purpose is to find out the reasonable value of α'.

Elaboration of the sample forest structure model: Regarding each forest state group, the structure of sample plots is developed based on the data collected on the

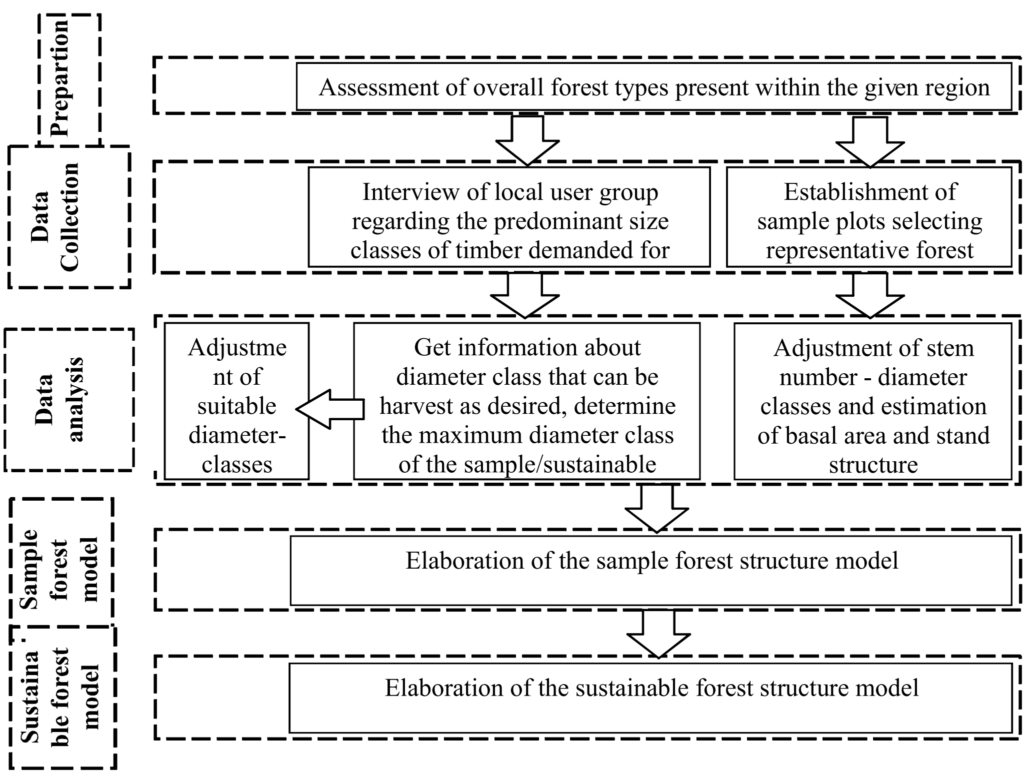

Fig. 1. The sequence of tasks necessary to determine suitable sustainable models for respective forest types

distribution of trees having diameters of the currently three best sample plots (the largest forest volume). Meyer function is used to manipulate the *N*/DBH distribution of wood trees having ≥ 6 cm. The result of identifying Meyer function may go in the following two directions:

Direction 1: At least one of the 3 sample plots sees the compliance of empirical *N*/DBH distribution with theoretical distribution. In this case, the sample plots which is most suitable for the Meyer function will be chosen as the sample forest model.

Direction 2: The empirical *N*/DBH distribution of all 3 sample plots is not in line with the theoretical *N*/DBH distribution; this can be explained as due to the disturbance of tree layers' structures. In this case, *N*/DBH distribution will be manipulated according to Meyer function based on maintaining the number of trees in the upper DBH class and the distribution of tree layers at the reserve/adjacent/mature ratio =1/3/5 (Dinh 2012). This ratio can calculate the starting diameter class of trees required for making the equation. Therefore, the increasing of trees' diameters to manipulate the distribution by Meyer function can increase the compliance of theoretical *N*/DBH distribution with the empirical *N*/DBH distribution. After selecting the Meyer function, the trees with smaller diameters will be adjusted to align with the theoretical distribution.

Elaboration of the sustainable forest structure model: A sustainable forest model is the one that has the same shape as the sample forest model having the Meyer equation in the form: $N = \alpha' \cdot e^{-\beta . D}$

To build up a sustainable forest model, it is required to identify the suitable position of *N*/DBH curves (or the reasonable value of α'). This value is not necessarily fixed but can be changing within a specific range depending on forest management requirements and utilization. This range is called the 'stability threshold' in this research. The "stability threshold" varies from α_1 to α_2. This is the value range that can assure reasonable forest capital for forest regeneration and development. The 'stability threshold' can be identified. The stability threshold is identified based on the changing range of forest volume. The forest volume's changing range is from (M_1, G_1) to (M_2, G_2) with M_1, G_1 being the minimum volume and the minimum basal area of sample plots of each forest state; M_2, G_2 being the maximum volume and the maximum basal area of sample plots of each forest state. The value α of the Meyer equation of the sample forest model will be changed until: (1) The volume of theoretical forests reach the value of (M_1, G_1) and then $\alpha = \alpha_D$; (2). The volume of theoretical forest model reaches the value of (M_2, G_2) and then $\alpha = \alpha_T$. The value α_T is taken as the upper value of the stability threshold $\alpha_2 = \alpha_T$.

The lower value α_1 of the stability threshold is identified by $\alpha_1 = \max(\alpha_D, \alpha_{KT})$, where: α_D is the value which forests reach the lower limit of the changing range of its volume. As α_D is the value calculated for forest states having the lowest volume, so $\alpha_1 > \alpha_D$. α_{KT} is the value in which the largest adjustment of existing forests to stable forests ensures logging intensity (logging intensity is based on regulation 40/QĐ-BNN-2005 for the broadleaf forest, semi-deciduous forest: is allowed to exploit forests but not lower than the limit of 35 % of the volume).The sustainable forest model can be simulated in the equation: $N = \alpha' \cdot e^{-\beta . D}$, with α' being in the range (α_1, α_2). In this research, value α' is proposed to set up a sustainable forest model and must satisfy two requirements:

- α' must be within the stability threshold (α_1, α_2).
- α' must satisfy the requirement that forest volume must not be less than the current average level. Based on the value α_{TB} at which forests reach the average volume level, we have $\alpha' \geq \alpha_{TB}$. Depending on the good or bad state of forests, α_1 may be bigger or smaller than α_{TB}; in other words, α_{TB} may be within or out of the stability threshold.

As such, a sustainable forest model should have α' satisfying: $\alpha' = \max(\alpha_1, \alpha_{TB})$. This is not the best value but only the value assuring forest stability; this value can be gradually upgraded and fixed at a suitable level within the stability threshold, depending on forest states and management targets.

RESULTS AND DISCUSSION

Sample forest model of forest state of group II: Three best sample plots of group II have been chosen to manipulate *N*/DBH distribution by Meyer exponential function (Table 1). In all 3 sample plots, the Meyer function has a very high correlation coefficient (R > 0.95). However, existence of Meyer function (*N*/DBH) distribution having diameter bigger than 6 only one sample (plot No. 9). This is also the sample plot selected as the sample forest model for group II. Although the remaining 2 sample plots have *N*/DBH

Table 1. Meyer equation of sample forest model of group II

Sample plot No	Volume (m^3 ha^{-1})	Equation	R	χ^2 calculated	χ^2 test	Conclusion
9	73.632	$N = 439.058 \cdot e^{-0.096D}$	0.992	7.71	15.51	Passed
7	48.625	$N = 365.622 \cdot e^{-0.095D}$	0.976	20.88	9.49	Types
2	44.109	$N = 422.569 \cdot e^{-0.106D}$	0.981	29.44	11.1	Types

structures which cannot assure the existence of Meyer function, and can observe that the gap of χ^2-calculated and χ^2-test is minor and this means that forests of group II all have *N*/DBH distribution asymptotic (nearly suitable) to the decreasing rules of Meyer function.

The forest state of group II having *N*/DBH distribution following the decreasing rule of Mayer function have the following equation: $N = 439.058 \cdot e^{-0.096D}$; and is also the existing equation that has the highest correlation coefficient: $R = 0.992$ (Table 1). In the selected pattern, the Meyer function makes a perfect simulation of empirical *N*/DBH distribution. The gap between the empirical and theoretical number of trees of each diameter-classes is minor. Three best sample plots of forest state of group III have been chosen to describe *N*/DBH distribution with Meyer exponential function (Table 2).

Sample forest model of forest state of group III: The three best sample plots simulated by Meyer function are listed in Table 3. The *N*/DBH distribution of 2 sample plots cannot satisfy the equation's existence, the gap between χ^2-calculated and χ^2-test is rather significant and confirms that there is no compliance with the Meyer function when describing the empirical *N*/DBH distribution of these 2 sample plots. This has proven that the disturbance of the *N*/DBH structure of the best forests in group III is better than that of group II's best forests. The natural forests are reaching a better and better state, and the natural elimination process will gradually make *N*/DBH structures change to a more stable state with the succession of tree layers gradually reaching stability (Leiva et al 2012, Carretero and Alvarez 2013). The sample forest model of group III with *N*/DBH distribution following the decreasing rule of Meyer function has the equation: $N = 253.339 \cdot e^{-0.063D}$; this is also the existing equation that has the highest correlation coefficient: $R = 0.990$ (Table 3).

The distribution results of 610 trees (forest state of group II) and 644 trees (forest state of group III) in the empirical diameter classes and their evaluation with Meyer probability function at 4 cm DBH class interval and empirical DBH frequencies shows that there are more trees in the lower DBH classes than in the upper DBH classes(Tables 2 and 4). This pattern indicates more trees in the lower DBH class that is sufficient to replace trees in the upper DBH class in the future (i.e. when the big trees are harvested or when they die). This is consistent with previous reports for two other tropical rainforests (Boubli et al 2004, Bobo et al 2006). The implication of this is that the forests are still undergoing regeneration and recruitment, which are vital indicators of forest health and vigour (Jimoh et al 2012). *N*/DBH distribution illustrates the balanced state among regeneration, growth, development, and natural elimination, assuring the succession of forest tree generation, creating the stability of forest stand output, and helping calculate the number of trees in each diameter-class for planning silviculture treatment (Leiva et al 2012, Carretero and Alvarez 2013). Information on the current diameter distribution of a forest stand can be used to indicate whether the density of smaller trees in a stand is sufficient to replace the current population of larger trees (Rubin et al 2006, Aigbe and Omokhua 2014) and allows prediction of its future structure, which provides even better supporting sustainable forest management (Podlaski 2006, 2008).

Sustainable forest model for forest state of group II: A sample forest model is the one that has the best forest state and assures the success of diameter classes and also illustrates forest tree generations' succession by having a

Table 2. Empirical and theoretical N/DBH distribution of forest state of group II

Diameter size-class (cm)	8	12	16	20	24	28	32	36	40	44	48	52
Empirical frequency	197	117	90	63	47	33	27	17	10	7	3	3
Theoretical frequency	204	139	95	64	44	30	21	14	9	6	4	3

Table 3. Mayer equation of sample forest model of group III

Sample plot No	Volume (m^3 ha^{-1})	Equation	R	χ^2 calculated	χ^2 test	Conclusion
5	131.859	$N=253.339 \cdot e^{-0.063D}$	0.990	7.67	16.92	Passed
4	84.68	$N=220.476 \cdot e^{-0.071D}$	0.975	81.77	16.92	Types
3	80.958	$N=254.944 \cdot e^{-0.078D}$	0.968	59.58	15.51	Types

Table 4. Empirical and theoretical N/DBH distribution of forest state of group III

Diameter size-class (cm)	8	12	16	20	24	28	32	36	40	44	48	52
Empirical frequency	160	100	87	67	60	47	37	33	20	13	10	10
Theoretical frequency	153	119	92	72	56	43	34	26	20	16	12	10

similar shape to the sample model. The *N*/DBH distribution curve of the sustainable forest model has a similar shape and is lower than the sample forest model's *N*/DBH distribution curve. The issue is to find out the suitable position of the *N*/DBH curve to assure stability and required to lower value α of the equation simulating *N*/DBH distribution of sample forests ($N = \alpha \cdot e^{-\beta . D}$) to a reasonable value (α'). That rationality is decided with reasonable forest volume to assure the output (or total basal area) and the number of regenerated trees. The results of identifying the stability threshold and the reasonable value α' of the sustainable forest model of group II and *N*/DBH distribution in line with the changes of value α (Table 6). According to Table 5.

$\alpha_1 = \max(\alpha_D, \alpha_{KT}) = 276$, $\alpha_2 = \alpha_T = 426$, $\alpha_1 = \alpha_{KT} \leq \alpha' < \alpha_2$, $\alpha' = \max(\alpha_{TB}, \alpha_{KT})$, As $\alpha_{TB} < \alpha_{KT}$, then $\alpha' = \alpha_{KT} = 276$

As such, the stability threshold of the forest model of group II is within (276; 426). Value α' of the sustainable forest model proposed for forest group II is 276. The lowering the values of the *N*/DBH distribution curve of sample forest model of group II to α_{TB} and α_{KT}, *N*/DBH distributions are similar: $N\alpha_{TB} \approx N\alpha_{KT}$ (Table 6). At the same time, can observe that $\alpha_{TB} < \alpha_{KT}$, means that the calculated average volume of forests of group II has not reached a stable level. The sustainable forest model of group II has quantitative indicators within the following stable range (Table 6). Then *N*/DBH distribution of sample forest model of group II has the form: $N = 439.058 \cdot e^{-0.096D}$. The proposed *N*/DBH distribution of the sustainable forest model of group II has the form: $N = 276 \cdot e^{-0.096D}$.This is only the suggested sustainable forest model. Depending on the forest business and management strategy, a suitable value of α' can be fixed in each specific condition. If the target is to make maximum exploitation of forests to meet the current wood demand of the society, we can set α' at the minimum level. On the contrary, if like to protect forests and increase forest reserves, can increase the value of α'. Obviously, α' must always stay within the stable range to assure that the sustainable forest model can illustrate or guarantee the feasibility of driving current forest states to a steady state. The comparison of the sample forest model and sustainable forest model is shown in (Fig. 3).

Sustainable forest model of forest state of group III; The results of identifying the stability threshold and value α' of the sustainable forest model of group III and *N*/DBH distribution

Table 6. Indicators of sustainable forest model and forest models within the stability threshold of group II

Quantitative indicators	Lower stable values	Upper stable values	Proposed values for sustainable forest model
Stem number with DBH ≥ 6 cm, trees ha^{-1}	814	1256	814
Number of regenerating trees, trees ha^{-1}	416	642	416
Stand basal area, m^2 ha^{-1}	8.2	12.7	8.2
Stand volume, m^3 ha^{-1}	47.9	73.6	47.9

Table 5. *N*/DBH distribution of forest state of group II corresponds to the changing of value α

Diameter size-class (cm)	$N\alpha_{LT}$, trees ha^{-1}	$N\alpha_D$, trees ha^{-1}	$N\alpha_{TB}$, trees ha^{-1}	$N\alpha_{KT}$, trees ha^{-1}	$N\alpha_T$, trees ha^{-1}
	$\alpha = 439.058$	$\alpha_D = 158$	$\alpha_{TB} = 246$	$\alpha_{KT} = 276$	$\alpha_T = 426$
2	362	130	203	228	352
4	299	108	168	188	290
8	204	73	114	128	198
12	139	50	78	87	135
16	94	34	53	59	92
20	64	23	36	40	62
24	44	16	25	28	43
28	30	11	17	19	29
32	20	7	11	13	20
36	14	5	8	9	13
40	9	3	5	6	9
44	6	2	4	4	6
48	4	2	2	3	4
52	3	1	2	2	3
Total	1292	465	726	814	1256

$N\alpha_{LT}$, $N\alpha_D$, $N\alpha_{TB}$, $N\alpha_{KT}$, $N\alpha_T$ is frequency per hectare in diameter-class. α is the value of the Meyer equation of the sample forest model; α_D is the value which forests reach the lower limit of the changing range of its volume; α_{TB} is the value which forests reach the average volume level; α_{KT} is the value in which the largest adjustment of existing forests to stable forests ensures logging intensity; α_T is the value which forests reach the upper limit of the changing range of its volume.

with changing values of α are given in Table 7.

According to Table 7: $\alpha_1 = \max(\alpha_D, \alpha_{KT}) = 164$, $\alpha_2 = \alpha_T = 253.339$, $\alpha_1 = \alpha_{KT} \leq \alpha' < \alpha_2$, $\alpha' = \max(\alpha_{TB}, \alpha_{KT})$

As $\alpha_{TB} < \alpha_{KT}$, then $\alpha' = \alpha_{KT} = 164$

Therefore, the stability threshold of the forest model of group III is within (164; 253). The value of α' of the sustainable forest model proposed for forest group III is 164. The α_{TB} and α_{KT} are approximately equal; this means that if the average volume of the forest of group III is calculated, such results may reach the lower values of the stability threshold. Thus, the feasibility of driving forests of group III to their stable level is rather high.

The suggested stability threshold and sustainable forest model are shown in Figure 4. Then N/DBH distribution of the sample forest model of group III has the form: $N = 253.339 \cdot e^{-}$

Table 8. Indicators of sustainable forest model and forest models within the stability threshold of group III

Quantitative indicators	Lower stable values	Upper stable values	Proposed values for sustainable forest model
Stem number with DBH ≥ 6 cm, trees ha^{-1}	695	1073	695
Number of regenerating trees, trees ha^{-1}	272	420	272
Stand basal area, m^2 ha^{-1}	12.46	19.2	12.46
Stand volume, m^3 ha^{-1}	85.70	131.86	85.70

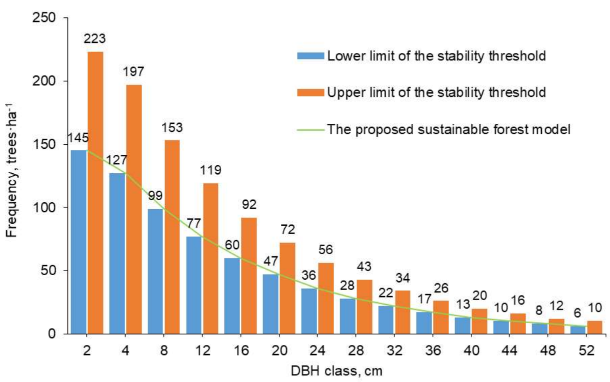

Fig. 2. Stability threshold and sustainable forest model have been proposed for the forest state of group II

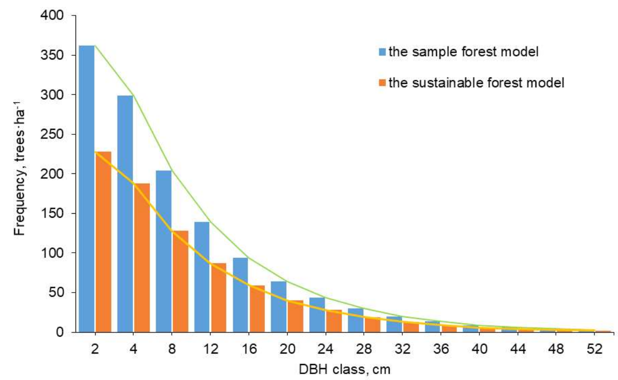

Fig. 3. N/DBH distribution of sample forest model and sustainable forest model of group II

Table 7. *N*/DBH distribution of the forest state of group III corresponds to the changing of values α

Diameter size-class (cm)	$N\alpha_{LT}$, trees ha^{-1}	$N\alpha_D$, trees ha^{-1}	$N\alpha_{TB}$, trees ha^{-1}	$N\alpha_{KT}$, trees ha^{-1}	$N\alpha_T$, trees ha^{-1}
	$\alpha = 253.339$	$\alpha_D = 102$	$\alpha_{TB} = 162$	$\alpha_{KT} = 164$	$\alpha_T = 253.3$
2	223	90	143	145	223
4	197	79	126	127	197
8	153	62	98	99	153
12	119	48	76	77	119
16	92	37	59	60	92
20	72	29	46	47	72
24	56	22	36	36	56
28	43	17	28	28	43
32	34	14	22	22	34
36	26	11	17	17	26
40	20	8	13	13	20
44	16	6	10	10	16
48	12	5	8	8	12
52	10	4	6	6	10
Total	1073	432	688	695	1073

$N\alpha_{LT}$, $N\alpha_D$, $N\alpha_{TB}$, $N\alpha_{KT}$, $N\alpha_T$ is frequency per hectare in diameter-class. α is the value of the Meyer equation of the sample forest model; α_D is the value which forests reach the lower limit of the changing range of its volume; α_{TB} is the value which forests reach the average volume level; α_{KT} is the value in which the largest adjustment of existing forests to stable forests ensures logging intensity; α_T is the value which forests reach the upper limit of the changing range of its volume.

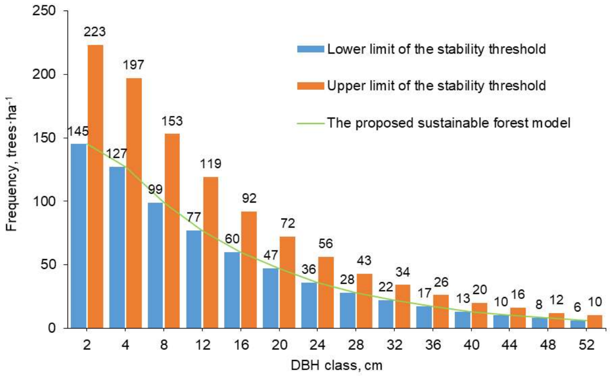

Fig. 4. Suggested stability threshold and sustainable forest model for forest state of group III

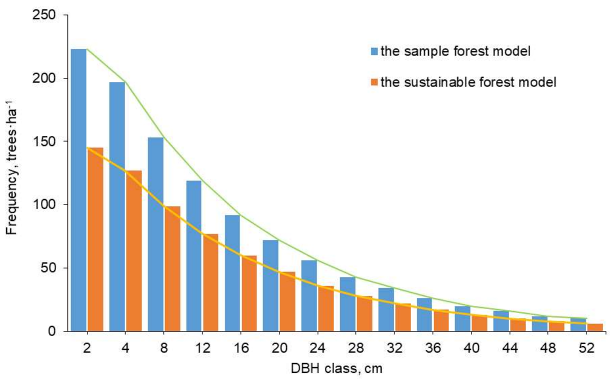

Fig. 5. *N*/DBH distribution of sample models and sustainable models for forest state of group III

$^{0.063D}$. The proposed *N*/DBH distribution of the sustainable forest model of group III has the form: $N = 164 \cdot e^{-0.063D}$.This forest model is suggestive only. Depending on the forest business and management strategy, a suitable value of *α*' can be fixed in each specific condition. The comparison of the sample forest model and sustainable forest model is shown in (Fig. 5). The decreasing speed or the slope of the curve of *N*/DBH distribution shows the advantage of site potentials (Fig. 3, 5). The practice has proven that the structure of forests of group II tends to be more disturbance than that of the forest of group III. The slope of the curve of *N*/DBH distribution of forest of group III is also less downward than that of the forest of group II because forests are reaching better and better state with the time towards stability.

CONCLUSION

The sustainable forest model will help identify the benefit levels to the community and make suitable and straightforward planning of wood exploitation, reduce the costs through comparing the number of trees of the researched forests with that of the model. The number of trees exceeding that of the model is the part that can be exploited .The number of shortage trees of each diameter size needs to be maintained and forest nourishment to reach a stable level. The sustainable forest model is a tool that helps us to manage and monitors handed over forests, meeting requirements of maintaining a sufficient number of trees with minimum diameter size-classes equivalent to that of a sustainable forest model. The task can be simply undertaken by supervising the number of trees according to required diameter size classes, which can be favorably done by management authorities and the people. According to prevailing regulations, only forest plots that have reached volume standards can be exploited. This has caused a massive obstacle due to long waiting times. Besides, it is difficult for people to be aware of exploitable forest standards. At the same time, if the number of trees with various diameter size-classes of the current forest state is compared with that of a sustainable forest model and even in young and poor forest conditions, a certain number of trees of various diameter size-classes can still be exploited to meet community demand, which can concurrently adjust such forests to a stable state with better productivity and efficiency. When comparing the sustainable forest model with the current forest plots, the community may have more opportunities to improve their knowledge of their forest plots, based on which they can not only identify the number of trees to be exploited and cultivated but also have discussions to find out suitable forest management measures given available resources.

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Influence of *Melia dubia* Spatial Configurations on Quantitative and Qualitative Performance of Hybrid Napier (*Pennisetum purpureum* x *P. americanum*) and Soil Biota Status

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Abstract: Study intended to develop suitable *Melia dubia*-hybrid Napier (HN) silvi-pasture and sole cropping systems through assessment of growth, physiology, forage yield, proximate and mineral principles of hybrid Napier under 5 years old *M. dubia* planted at 2 x 2, 3 x 3, 3 x 2, 4 x 4 and 4 x 2 m spatial configurations. Study revealed that growth, physiological attributes, fresh and dry forage production, and proximate and mineral matter principles (average of two years; three harvests in each year) were higher under silvi-pasture systems as compared to sole cropping. Among silvi-pasture, HN attained significantly maximum plant height and number of leaves under *M. dubia* (2 x 2 m)-HN, lengthiest leaf (96.76 cm) and widest leaf under *M. dubia* (3 x 2 m)-HN, and tillers under sole HN cropping system. Among studied physiological attributes, specific leaf weight was maximum in sole HN cropping, chlorophyll content index was maximum of forage from *M. dubia* (2 x 2 m)-HN system, leaf area and leaf area index was maximum for clumps under *M. dubia* (3 x 2 m)-HN system. Significantly higher total fresh and dry forage yield was obtained from *M. dubia* (2 x 2 m)-HN and *M. dubia* (3 x 2 m)-HN, respectively. Significantly maximum dry matter and crude fibre was in forage from sole cropping system. However, maximum crude protein, ether extract, nitrogen free extract, ash and nitrogen were recorded in forage from *M. dubia* (2 x 2 m)-HN system. Whereas, phosphorus and potassium was higher in forage from *M. dubia* (3 x 2 m)-HN system. Integration of HN as understory crops, increased microbial populations in all land use systems. Among different silvi-pasture systems, closest spacing had more bacterial and actinomycetes populations, while fungi were highest under sole cropping. The study divulged out that tree-crop interactions under different *M. dubia* spatial configurations were positive. Hence, HN could be adopted as intercrop for higher forage yield and better nutritive quality.

Keywords: *Melia dubia*, Agroforestry, Hybrid napier, forage, Nutritive value, Soil biota

Estimates indicated that, there is a huge deficit of green and dry fodder in India. Over the years, this deficit is showing escalating trend from 62.76% (666 million MT) in year 2010 to 64.21% (759 million MT.) in year *i.e.* 2020 (GoI 2006). This deficit is the result of shrinkage of open land for grazing, urbanization and introduction of high yield cattle, which requires feeds in large quantity and of good quality as well (Birthal and Jha 2005). Ensuring an adequate supply of reasonable quality feed and fodder to livestock is one of the major challenges faced by country where dairying is largely the avocation of poor, especially women. Land allocation for cultivation of green fodder is limited and has hardly ever exceeded 5% of the gross cropped area (GoI 2015) due to increasing pressure for growing food grains, oil seeds and pulses. Hence, available land cannot directly be brought under fodder cultivation. In this case, agroforestry based silvi-pasture systems are advocated to address these issues. Such system promises healthy environment and rich biodiversity, which is an important support system on earth for sustainability of dairy enterprise (Pathak and Roy 1994, Thakur et al 2005, 2015, Chauhan et al 2014). Besides the forage demand, the current production of raw materials for pulp and paper is 2.76 million tonnes, against the demand of 5.04 million tonnes, a shortfall of 45 per cent. The current demand is 13.2 million tonnes, which is still more staggering (Palsaniya et al 2009) and overall wood demand has been estimated more than 150 million cum (Shrivastava and Saxena 2017).

In this backdrop, development of silvi-pasture systems will not only help augment the raw material for wood-based industries but also in bridging the gap between demand and supply of quality fodder. For this the grass and tree species need to be screened based on the quantitative and qualitative evaluations which will provide insight to select compatible species. Hence, in the present study, Hybrid Napier (*Pennisetum perpureum* x *P. americanum* var. CO-3) was selected as intercrop to develop *Melia dubia*-HN based silvi-pasture systems. *Melia dubia* Cav. is indigenous to India and also found Bangladesh, Myanmar, Thailand, Mexico, Sri Lanka, Malaysia, Java, China, America, Philippines and

Australia. It is multipurpose, fast-growing species, valued for its high-quality termite and fungus resistant timber for furniture, agricultural implements and house construction, plywood and pulp wood, owing to its high pulp recovery and exceptional fibre strength as compared other raw material (Parthiban et al 2009, Sinha et al 2019, Kumar et al 2017a). It has been reported compatible agroforestry ideotype (Jilariya et al 2017, Mohanty et al 2017, Thakur et al 2019) without any allelopathic effect (Kumar et al 2017b, Parmar et al 2019). Thus, intercrops like pulse, vegetable and medicinal/aromatic plants have been evaluated with this valuable multipurpose species (Bhusara et al 2018a & b, Mohanty et al 2019, Jilariya et al 2019). But fodder intercropping studies are still lacking with respect to production, bio-physical interactions and forage quality. The study, intended to develop a compatible silvi-pasture system with appropriate spatial configuration.

MATERIAL AND METHODS

This study was carried out at the College of Forestry, Navsari Agricultural University, Navsari, Gujarat, India, during 2018-2019. Site is situated at 20.95°N latitude, 75.90°E longitude at an altitude of 10 m above the mean sea Arabian seashore. The system units of silvi-pasture systems were *M. dubia* [planted in 2014, the average growth attributes of *M. dubia* at Hybrid Napier (HN) planting-January, 2018 and at HN final harvest-November, 2019) under different spatial configurations are given in Table 1] as tree component and HN as intercrop. The experiment was conducted in randomized block design with 6 land uses *i.e.* LU_1 to LU_5=*M. dubia* at 2 x 2, 3 x 2, 3 x 3, 4 x 2 and 4 x 4 m, intercropped with HN, respectively and LU_6= sole HN, with four replications. The treatment combinations so formed are referred here as silvi-pasture (*M. dubia* + HN) systems. Healthy slips of HN, Var. CO-3, were planted at 50x50 cm spacing under each treatments (L_1 to L_6) in January, 2018. Necessary agro-techniques were followed as suggested by Pandey and Roy (2011).

Soil physico-chemical properties in silvi-pasture and sole cropping were estimated by taking samples in a zigzag manner to cover the entire treatment plot. Ten sub samples (cores) were taken randomly under each treatment and mixed together to make a representative (composite) sample. The average values of soil parameters along with estimation methods followed are presented in Table 2. Soil moisture (0-30 cm soil depth) was estimated gravimetrically using samples from all treatments and monthly data from transplanting till final harvest of HN are illustrated in Figures 1a & b. Photosynthetically active radiation (PAR) ($\mu Em^{-2}s^{-1}$) was measured fortnightly (on 9 points of each treatment, *i.e.* 3 points under the tree, 3 points between the trees, and 3 spots in the middle of tree diagonal) in each LU, using LI-COR biosciences quantum sensor (LI-190) and monthly average values is illustrated are Figures 2a & b.

Growth, physiology and yield: Growth attributes *viz*., plant height, number of tillers/clump, number of leaves/tiller, leaf length and leaf width were recorded by taking 20 random samples (n=20; 5 plants x 4 replications from each treatment). Physiological parameters *viz*., specific leaf weight [(SLW (mg/cm^2)=Leaf dry weight (mg)/Leaf area (cm^2), n=20; 5 leaf discs x 4 replications from each treatment], chlorophyll content index [using chlorophyll meter (Opti-sciences CCM 200, USA); n=20; 4 leaves x 4 replications from each treatment], leaf area (n=20; 5 leaves x 4 replications from each treatment), leaf area index [using LAI-2200C plant canopy analyzer (n=20; 5 sampling points x 4 replications from each treatment), were recorded by taking random samples. Similarly, fresh and dry HN forage yield was assessed by harvesting whole plot (n=24; 4 replications x 6 treatments) under each treatment, taking 3 harvests each year *i.e.* 2018 and 2019.

Proximate principles and mineral matter: Proximate principles (%) *i.e.* dry matter (DM), crude protein (CP), crude fibre (CF), ether extract (EE), ash content (AC) and nitrogen-

Table 1. Average growth attributes of *M. dubia* under silvi-pasture systems having different spatial configurations at Hybrid Napier planting (2018) and final harvest (2019)

Land use systems	Height (m)		GBH (cm)		Crown spread			
					North-South		East-West	
	*	**	*	**	*	**	*	**
MD (2 x 2 m)-HN	4.18	7.18	13.55	30.65	1.05	1.75	0.73	1.58
MD (3 x 2 m)-HN	6.33	9.25	21.18	42.63	1.68	2.84	1.29	1.73
MD (3 x 3 m)-HN	6.70	10.45	22.03	47.40	1.84	2.81	1.60	2.28
MD (4 x 2 m)-HN	5.50	9.50	20.48	47.35	2.08	3.61	1.23	1.75
MD (4 x 4 m)-HN	6.50	10.08	21.53	47.58	2.10	3.78	1.41	2.60

*at Hybrid Napier planting; **at Hybrid Napier final harvest; MD=*M. dubia;* HN=Hybrid Napier free extract (NFE) as well as mineral matter constituents *i.e.* Nitrogen (N), phosphorus (P), and potassium (K) were estimated by standard procedures (AOAC 2016).

Soil biota*:* The microbial population (bacteria, fungi and actinomycetes) was counted in each LU system by the standard plate count method (Seeley et al 1991) using formula: Total no. of microbes/g of soil = No. of colonies in plate/volume of aliquot plated on agar medium x dilution level.

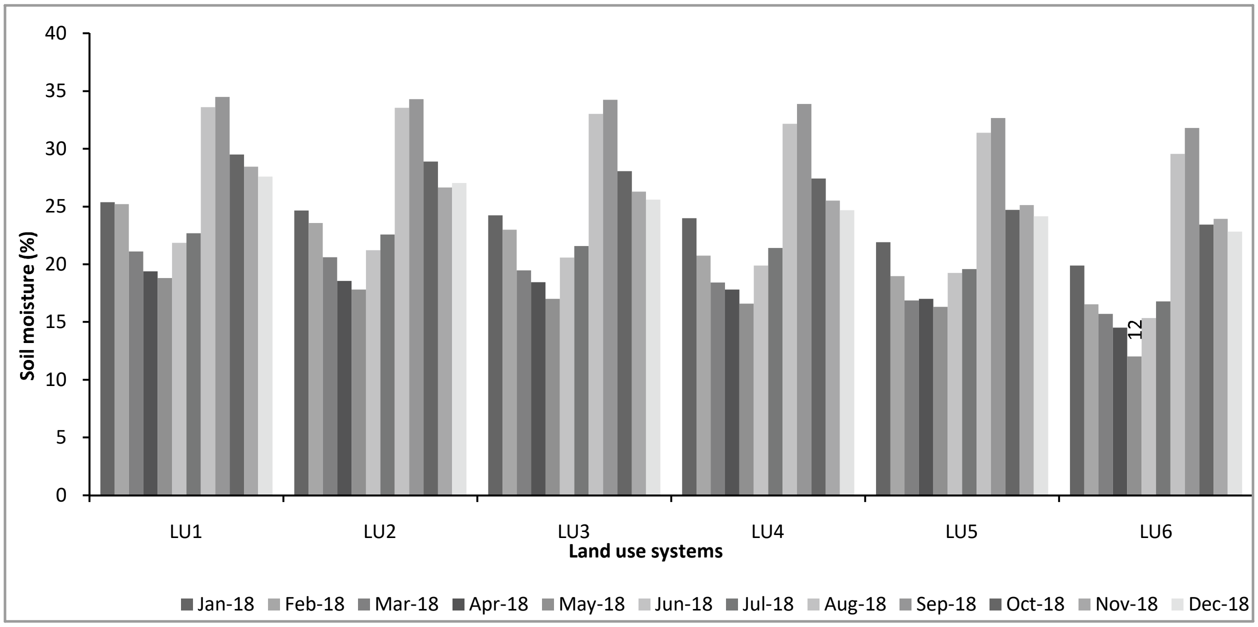

Fig. 1a. Average monthly soil moisture (%) under *M. dubia*-Hybrid Napier based silvi-pasture and sole cropping systems during Jan-2019 to Nov-19 [LU_1 = *M. dubia* (2 × 2 m)-HN, LU_2 = *M. dubia* (3 × 2 m)-HN, LU_3 = *M. dubia* (3 × 3 m)-HN, LU_4 = *M. dubia* (4 × 2 m)-HN, LU_5 = *M. dubia* (4 × 4)-HN, LU_6 = Sole HN]

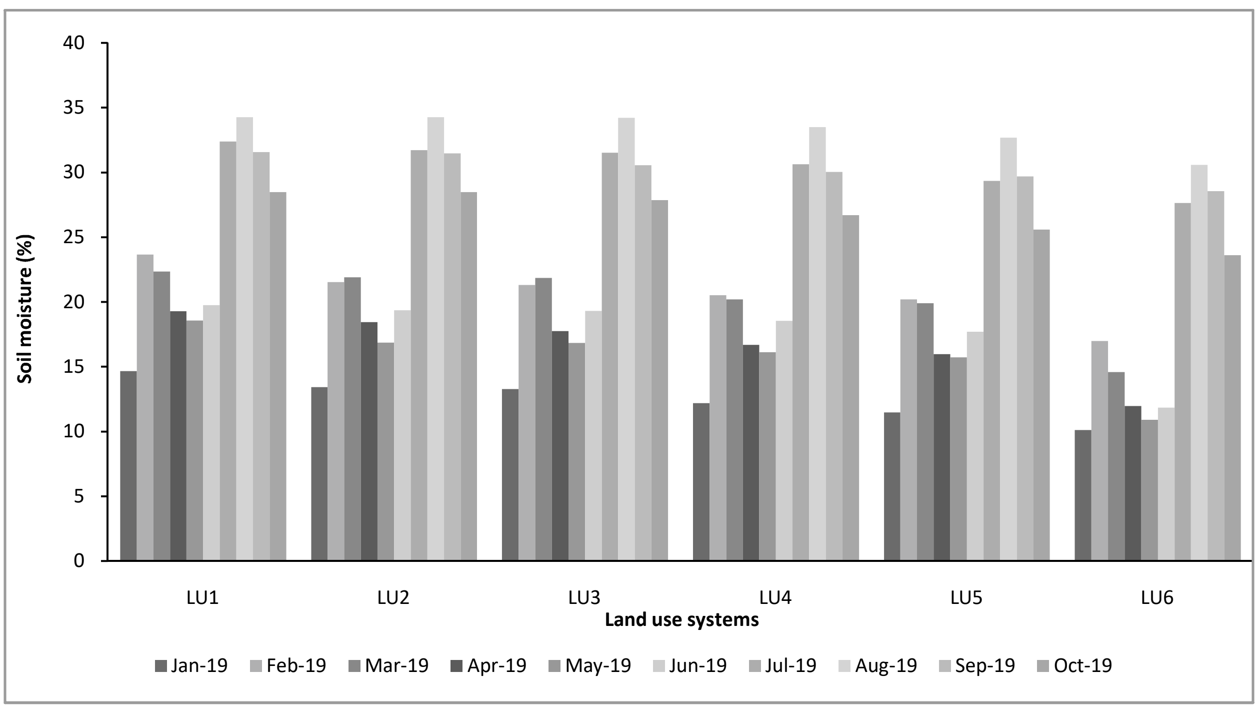

Fig. 1b. Average monthly soil moisture (%) under *M. dubia*-Hybrid Napier based silvi-pasture and sole cropping systems during Jan-2019 to Oct-19 [LU_1 = *M. dubia* (2 × 2 m)-HN, LU_2 = *M. dubia* (3 × 2 m)-HN, LU_3 = *M. dubia* (3 × 3 m)-HN, LU_4 = *M. dubia* (4 × 2 m)-HN, LU_5 = *M. dubia* (4 × 4)-HN, LU_6 = Sole HN]

Statistical analysis*:* The experimental data generated were subjected to the statistical analysis following randomized block design (RBD) and ANOVA ($Y_{ij}=\mu+a_i+b_j+eij$ where i=1,2,…….,t; j=1,2,………,n_i; Y_{ij}=response of the j^{th} individual unit (replication) belong to the i^{th} group (treatment); μ= overall mean; ai= effect of treatment i (difference with μ); b= effect of block j (difference with μ); eij= error in measurement for treatment i and block j) was constructed following Sheoran et al (1998). Duncan's multiple range test (DMRT) was used to compare the sets of means of each treatment at *P<0.05* suing WASP (Web Agri Stat Package) Developed by Ashok Kumar Jangam and Pranjali Ninad Wadekar, Indian Council of Agricultural Research complex, Goa, India.

RESULTS AND DISCUSSION

Hybrid napier growth, physiology and yield*:* Growth, physiological and yield attributes (average of three consecutive harvests per year *i.e.* 2018 and 2019) of Hybrid Napier (HN) varied significantly (*P*<0.05) under *M. dubia*-HN silvi-pasture and sole cropping land use (LU) systems (Table

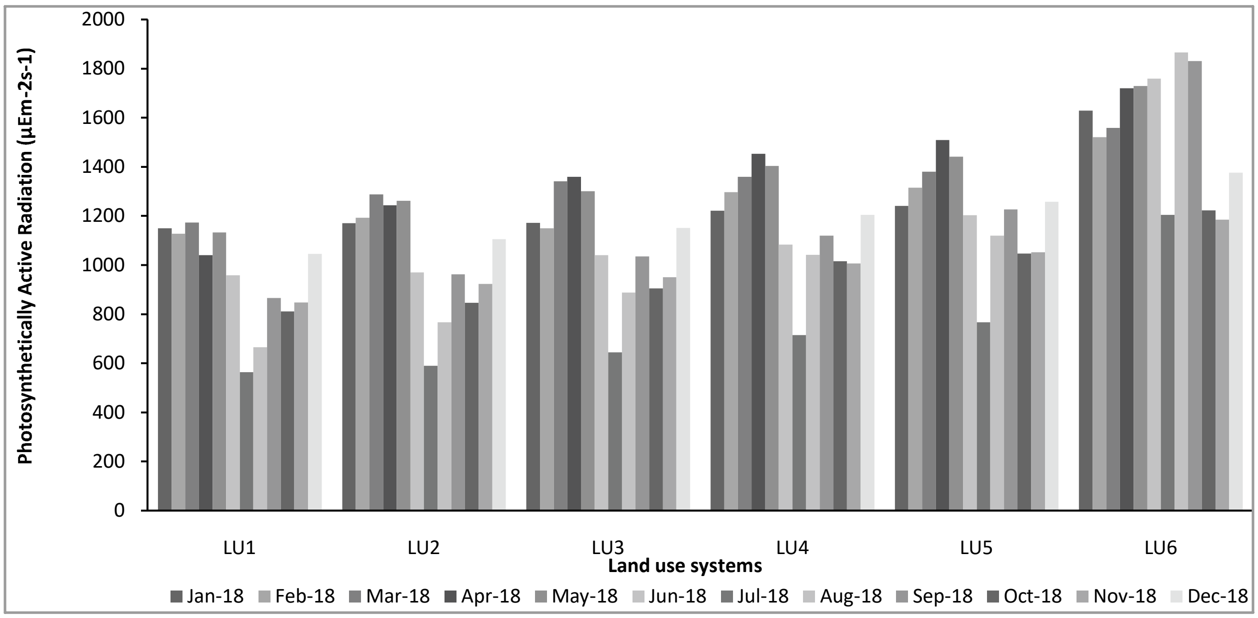

Fig. 2a. Average monthly Photosynthetically Active Radiation (PAR; µEm-2s-1) under *M. dubia*-HN based silvi-pasture and sole cropping systems during Jan-2018 to Dec-19 [LU_1 = *M. dubia* (2 × 2 m)-HN, LU_2 = *M. dubia* (3 × 2 m)-HN, LU_3 = *M. dubia* (3 × 3 m)-HN, LU_4= *M. dubia* (4 × 2 m)-HN, LU_5 = *M. dubia* (4 × 4)-HN, LU_6 = Sole HN]

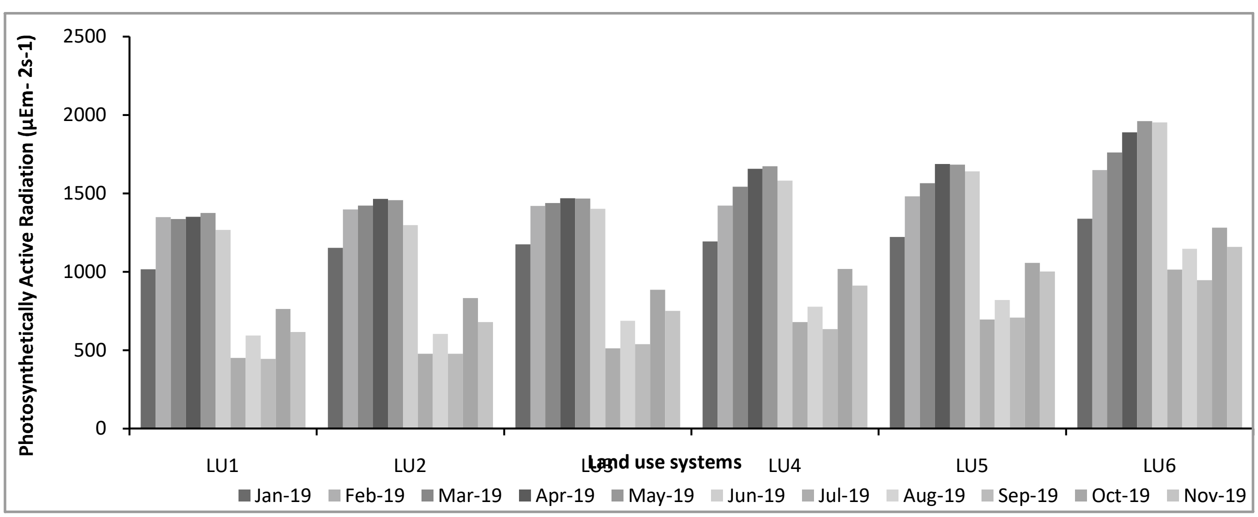

Fig. 2b. Average monthly Photosynthetically Active Radiation (PAR; µEm-2s-1) under *M. dubia*-HN based silvi-pasture and sole cropping systems during Jan-2019 to Nov-19 [LU_1 = *M. dubia* (2 × 2 m)-HN, LU_2 = *M. dubia* (3 × 2 m)-HN, LU_3 = *M. dubia* (3 × 3 m)-HN, LU_4= *M. dubia* (4 × 2 m)-HN, LU_5 = *M. dubia* (4 × 4)-HN, LU_6 = Sole HN]

3, Fig. 3a, b). Significantly superior plant height, number of tillers per clump, leaf length and leaf width of HN was under *M. dubia*-HN systems having 2 x 2 m and 3 x 2 m spatial configurations as compared other *M. dubia* geometries and sole cropping. HN attained maximum plant height (142.29 cm) and number of leaves (9.29/tiller) under *M. dubia* (2 x 2 m)-HN (Table 3). Maximum tillers (21.92/clump) were formed under sole HN cropping. Significantly lengthiest (96.76 cm) and widest leaf (3.09 cm) was developed by clumps under *M. dubia* (3 x 2 m)-HN. The study deduced that HN growth parameters were lesser under silvi-pasture systems with wider spatial configurations (Table 3).

Specific leaf weight was maximum (6.17 mg/cm^2) in sole HN cropping system (Table 4). Highest chlorophyll content index (47.08) was in forage from *M. dubia* (2 x 2 m)-HN system. Maximum leaf area (188.26 cm^2) and LAI (13.98) was under *M. dubia* (3 x 2 m)-HN, which was statistically at par with that attained under *M. dubia* (2 x 2 m)-HN system. The study indicated that SLW was least, whereas all other attributes were superior under silvi-pasture systems with narrow spatial configurations (Table 4). Fresh and dry forage productivity (t ha^{-1} $year^{-1}$) of HN was significantly (*P<0.05*) highest (122.66 t ha^{-1} $year^{-1}$) from *M. dubia* (2 x 2 m)-HN LU (Fig. 3a). Significantly maximum dry forage productivity amounting to 27.55 t ha^{-1} $year^{-1}$ was from *M. dubia* (3 x 2 m)-HN, which was at par with that provided by *M. dubia* (2 x 2 m)-HN system (Fig. 3b).

Our study indicated that growth performance of HN was better under silvi-pasture systems. It may be ascribed to partial shade (Fig. 2a, b) under different *M. dubia* spatial configurations. Antony (2016) reported that increased level of artificial shade increased plant height, leaf length, leaf width

Table 2. Average soil physico-chemical properties (0-30 cm depth) under *M. dubia*-Hybrid Napiersilvi-pasture systems and sole cropping

Land use systems	pH[!]	Electrical conductivity (dSm^{-1})[#]	Organic carbon (%)[$]	Nitrogen (kg ha^{-1})*	Phosphorus (kg ha^{-1})[!!]	Potassium (kg ha^{-1})**
At HN planting (January, 2018)						
T_1	7.70	0.29	0.79	246.38	11.26	504.08
T_2	7.65	0.24	0.77	236.77	10.96	504.76
T_3	7.52	0.24	0.74	224.86	10.90	508.48
T_4	7.52	0.23	0.70	212.46	10.96	510.86
T_5	7.50	0.24	0.67	212.00	10.70	512.10
T_6	7.34	0.33	0.57	230.57	13.99	615.89
At HN final harvest (November, 2019)						
T_1	7.39	0.26	0.82	229.74	10.62	477.13
T_2	7.37	0.22	0.81	220.30	10.92	482.41
T_3	7.33	0.19	0.80	217.11	10.80	495.76
T_4	7.28	0.16	0.77	203.84	10.80	501.35
T_5	7.26	0.16	0.74	189.76	10.38	515.64
T_6	7.32	0.13	0.66	189.37	9.02	550.83

T_1= *M. dubia* (2 x 2 m)-HN, T_2= *M. dubia* (3 x 2 m)-HN, T_3=*M. dubia* (3 x 3 m)-HN, T_4=*M. dubia* (4 x 2 m)-HN, T_5= *M. dubia* (4 x 4 m)-HN, T_6= Sole HN; [!]Potentiometric method;[#]supernated liquid suspension of 1:2.5 soil water ratio method; [$]Walkley and Black's rapid titration method; *Alkaline potassium permanganate method; [!!]Olsen's method; **1 N NH_4OAC Extraction method

Table 3. Growth performance of hybrid napier (HN) under *M. dubia*-HN based silvi-pasture and sole cropping systems

Land use systems	Plant height (cm)	Number of tillers $clump^{-1}$	Number of leaves $tiller^{-1}$	Leaf length (cm)	Leaf width (cm)
MD (2 x 2 m)-HN	142.29^{a}	20.16^{b}	9.29^{a}	94.64^{ab}	2.97^{b}
MD (3 x 2 m)-HN	138.46^{ab}	21.66^{a}	9.14^{ab}	96.76^{a}	3.09^{a}
MD (3 x 3 m)-HN	134.28^{b}	15.17^{d}	8.89^{bc}	93.29^{bc}	2.83^{c}
MD (4 x 2 m)-HN	121.09^{d}	20.52^{b}	8.73^{c}	87.46^{d}	2.68^{d}
MD (4 x 4 m)-HN	127.62^{c}	19.15^{c}	8.92^{bc}	93.49^{bc}	2.86^{c}
Sole HN	126.98^{cd}	21.92^{a}	8.99^{bc}	91.35^{c}	2.80^{c}
SEm (±)	1.86	0.30	0.08	0.79	0.03

T_1= *M. dubia* (2 x 2 m)-HN, T_2= *M. dubia*(3 x 2 m)-HN, T_3= *M. dubia* (3 x 3 m)-HN, T_4=*M. dubia* (4 x 2 m)-HN, T_5= *M. dubia* (4 x 4 m)-HN, T_6= Sole HN; Means with different superscript letter in the same column indicate significant difference (*p<0.05*) according to Duncan's Multiple Range Test and leaf area index, whereas, number of tillers, number of leaves, and fodder yield of six cultivars of HN (CO-3, CO-4, Suguna, IGFRI-3, DHN-6 and PTH) were reduced under shade. In contrary, growth and yield in our study was higher under natural shade of *M. dubia*. DeBruyne et al (2011) reported that grass forage yield was greater under black walnuts and honey locusts tree canopy than under 70 per cent shade cloth (artificial shade). This indicate that, tree canopy shade increases forage fresh/dry biomass (Soares et al 2009, Barro et al 2012). The varying tree densities affect performance and production of under storey grasses. Earlier studies also inferred that tree canopy shade under agroforestry system favour intercrops resulting in enhanced growth and production (Gupta et al 2012, Paciullo et al 2011, DeBruyne et al 2011, Mohanty et al 2019, Thakur et al 2019).

Enhanced growth and herbage production of aromatic grasses has been reported under *M. dubia* based agroforestry systems due to beneficial effect of partial shade and better moisture availability (Thakur et al 2019, Mohanty et al 2019). Partial shade under silvi-pasture systems, moderate ambient microclimate *i.*e. air temperature, soil moisture and retention for longer time and reduction in the soil water evaporation especially due to low irradiance under closed tree spacings (Jilariya et al 2017, Thakur et al 2018). In present study these deductions are supported by available soil moisture (Fig. 1a, b) and reduced PAR (Fig. 2a, b).

Plants respond to resource limitations by allocating their biomass to those organs which are engaged in capturing these resources (Poorter et al 2012). The taller plants in silvi-pasture systems indicate a phototropism response to modify plant leaf distribution in order to help the plants receive enough light (Yang et al 2007). Under-storey plants in response to varying shade levels increase number of leaves (Rezai et al 2017). Likewise, intermediate light conditions (about 50% of full sun light) results in higher levels of biomass production in some species (Goncalves et al 2005). Similarly, in the present study decreased PAR under silvi-pasture (Fig. 2a, b) increased number of leaves, leaf length and width and leaf area due to increase in radiation use efficiency. Thus, shade increases these growth-attributes for higher light interception, which may have ultimately resulted in vegetative growth of HN under *M. dubia*-HN silvi-pasture systems.

In present study, more trees in close spatial magnitudes might have produced more litter fall, which eventually released more nutrients into the soil due to high decomposition rate under shade owing to higher moisture retaining capacity (Dodd et al 2005, Jilariya et al 2017). The availability of nutrients and moisture for longer period improve intercrop growth and yield (Wilson 1996, Scholes and Archer 1997). Increased decomposition rate of organic matter increased N availability (Wilson and Wild 1995). Higher N availability under silvi-pasture LU may be attributed to directly N fixation by microbial communities (Catchpole and Blair 1990). Soil microbes itself store significant quantities of soil carbon and nitrogen in living biomass and their death make N readily available to crops (Duxbury et al 1989). Present findings are consistent with these studies where higher organic matter, N content (Table 2) and microbial colonies (Table 6) were observed under silvi-pasture LU than sole cropping systems. Light levels increase towards saturation, quantum yields (ratio of the number of photons emitted to the number of photons absorbed) decline, due to the inability of carbon metabolism to utilize fully the light energy absorbed by the leaf of C_4 plants (Zhu et al 2010). Similar mechanism may have encountered in open plot where high sunlight did not yield biomass due to maximum light level.

Increased forage yield may also be assigned to twin facts *i.e.* water use efficiency by shaded grass and increased water availability through hydraulic lift by trees (DeBruyne et al 2011). High water use efficiency may also allow C_4 plants to

Table 4. Physiological attributes of hybrid napier (HN) under *M. dubia*-HN based silvi-pasture and sole cropping systems

Land use systems	Specific leaf weight (mg cm^{-2})	Chlorophyll content index (CCI)	Leaf area (cm^2)	Leaf area index (LAI)
MD (2 x 2 m)-HN	5.59^{c}	47.08^{a}	177.86^{b}	12.80^{b}
MD (3 x 2 m)-HN	5.64^{c}	42.45^{b}	188.26^{a}	13.98^{a}
MD (3 x 3 m)-HN	5.69^{c}	39.99^{c}	160.94^{d}	8.36^{e}
MD (4 x 2 m)-HN	5.95^{b}	36.62^{d}	142.71^{e}	9.91^{d}
MD (4 x 4 m)-HN	5.94^{b}	36.11^{d}	163.42^{cd}	10.95^{c}
Sole HN	6.17^{a}	33.28^{e}	169.08^{c}	12.77^{b}
SEm (±)	0.04	0.57	2.28	0.28

T_1= *M. dubia* (2 x 2 m)-HN, T_2= *M. dubia*(3 x 2 m)-HN, T_3=*M. dubia* (3 x 3 m)-HN, T_4=*M. dubia* (4 x 2 m)-HN, T_5= *M. dubia* (4 x 4 m)-HN, T_6= Sole HN; Means with different superscript letter in the same column indicate significant difference (*p<0.05*) according to Duncan's Multiple Range Test exhibit more flexible allocation patterns, for example allocating proportionally more biomass to shoots in moist environments (silvi-pasture systems), or to roots in dry environments (Open plot) (Taylor et al 2010). Superior growth and yield attributes of HN under silvi-pasture system in the present investigation, may be due to the fact that *M. dubia* in younger age of 4-5 years moght have created favorable microclimatic conditions. Therefore, HN performed well under different *M. dubia* spatial configurations compared to open or sole HN cropping systems.

Integration of woody and non-woody components together leads to complex interactions among themselves at various bio-physical domains such as light, space, water, nutrients, *etc*. Modifications in micro-environment by trees, directly or indirectly influence various vital physiological processes of under-storey crops (Chauhan et al 2013, Zhang et al 2014). Adaptable plants change morpho-physiological attributes in response to changing environments, including larger and thinner leaves with about three-fold increase in total chlorophyll content. The synthesis and degradation of photosynthetic pigments are associated with adaption to changing environments (Taiz and Zeiger 2002). Lower SLW in silvi-pasture systems may be ascribed to reduced irradiance (Figures 3.1a & b, 3.2) due to tree shade with fewer mesophyll cells and stomata per unit area, and more intercellular air space. Shade reduces cell wall concentration due to unavailability of photosynthates for secondary cell wall development (Fales and Fritz 2007).

The increased leaf area under shade is the result of longer leaves because of leaf elongation to capture more sun light under reduced irradiance (Kephart et al 1992, Mohanty et al 2019). Sanderson and Nelson (1995) Reducing light in a stepwise manner results in longer leaves with a larger area and lower SLW, a greater leaf elongation rate, and reduced dry matter deposition in high yield per tiller and low yield per tiller genotypes of tall fescue. These findings are in congruence with the present study.

Similar to our study, higher chlorophyll content under shade has been reported earlier (Rezai et al 2017). This demonstrate the ability of plant to maximize the light harvesting capacity under light-deficit conditions and the efficient use of light captured in photosynthesis with decreased respiration costs for maintenance (Dai et al 2009). The lower CCI in sole crops might be due to excess irradiance that caused greater degradation or photo-oxidation of chlorophyll and consequently decrease chlorophyll levels (Goncalves et al 2005). Increased leaf area and leaf area index while reduced specific leaf dry weight in shade compared to plants grown in full sun have also been reported (Lin et al 2001, Mohanty et al 2019, Thakur et al 2019). These findings are in agreement with present study. Overall, change in microclimatic condition under narrow and

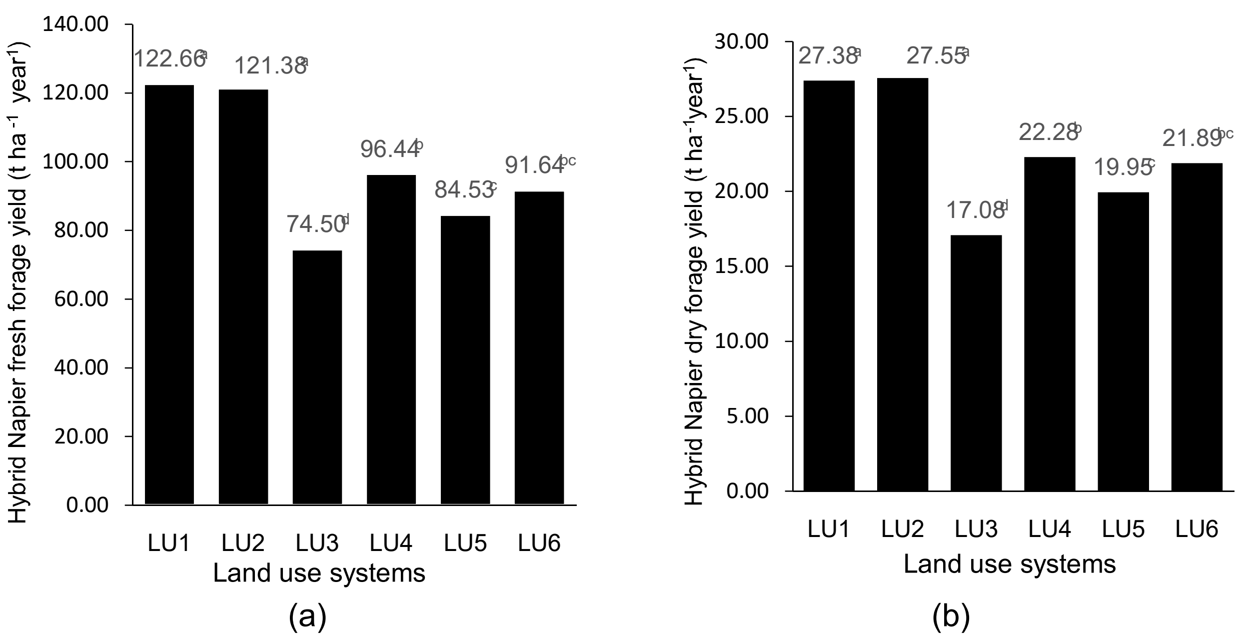

Fig. 3. Hybrid Napier fresh [a (SEm (±)= 2.57) and dry [b (SEm (±)= 2.57) forage yield (t ha^{-1}year^{-1}) under *M. dubia*-HN based silvi-pasture and sole cropping systems [LU$_1$ = *M. dubia* (2 × 2 m)-HN, LU$_2$ = *M. dubia* (3 × 2 m)-HN, LU$_3$ = *M. dubia* (3 × 3 m)-HN, LU$_4$= *M. dubia* (4 × 2 m)-HN, LU$_5$ = *M. dubia* (4 × 4)-HN, LU$_6$ = Sole HN]; Means with different superscript letter with data labels in each bar indicate significant difference (*p<0.05*) according to Duncan's Multiple Range Test

wider spatial configurations influenced the HN physiological attributes by altering PAR, moisture (Fig. 2a, b), nutrients availability and soil microbial populations (Tables 2, 6).

HN forage qualitative attributes*:* Results on HN forage qualitative attributes (average of three consecutive harvests per year *i.e.* 2018 and 2019), evinced that forage proximate principles namely dry matter (DM), crude protein (CP), crude fibre (CF), ether extract (EE), ash content (AC), nitrogen free extract (NFE), N (nitrogen), P (phosphorus) and K (potassium) experienced significant ($P<0.05$) influence of silvi-pasture and sole HN cropping systems (Table 5). Significantly maximum DM and CF to the tune of 23.89 and 31.39%, respectively was obtained in HN forage from sole cropping system. However, maximum CP (9.36%), EE (2.19%) and AC (14.25%) was recorded in HN forage harvested from *M. dubia* (2 x 2 m)-HN system. Similarly, NFE content was also maximum (47.23%) in forage harvested from *M. dubia* (2 x 2 m)-HN (Table 5). Maximum forage N (1.50%) content was in samples from *M. dubia* (2 x 2 m)-HN system. Whereas, P and K percentage (0.21 and 3.82%, respectively) was in forage from *M. dubia* (3 x 2 m)-HN LU.

The ranges of DM, CP, CF, EE, N and P of HN (var. CO-3) forage in the present study are in agreement, while ash and K contents are higher to those reported by Antony and Thomas (2014). Low pasture quality impairs the productivity of ruminant livestock and present study suggested that integration of HN under *M. dubia* silvi-pasture systems not only increased the overall DM production but also increased CP, EE, ash, N, P and K content. Higher NDF *i.e.* total fibre levels (cell wall) are advocated to slower forage digestion rate and result in lower voluntary intake (Ball et al 2001), dry matter intake and energy content (Saha et al 2017). Therefore, lower crude fibre in forage from silvi-pasture system is better while considering forage quality in intercrops.

Sanderson and Nelson (1995) found that reduced light result in reduced dry matter deposition in high yield per tiller and low yield per tiller genotypes of tall fescue. CP contents of 10% is sufficient for medium level of production from ruminants (Subba 1999) and the present study indicated higher CP in silvi-pasture system which may decrease the cost of additional concentrated feeds to the animals. The lower amount of CP or N content in sole cropping systems may be due to the low soil moisture availability (Fig. 1a, b) that directly affects the mineral nutrition of plants by mechanisms (Lemaire and Gastal 2009). Higher N availability under silvi-pasture may also be due to direct effect of N fixation in the under-storey grass by microbial communities (Catchpole and Blair 1990). Many other researchers have also reported higher CP or nitrogen content (irrespective of nitrogen fertilization) under shady environmental condition (Cruz 1997, Guenni et al 2008), which are in accordance with the present investigation. The higher moisture availability under agroforestry systems boost rapid organic matter breakdown and increase N availability (Wilson 1996, Thakur et al 2019). The eventual availability of more N availability to HN under *M. dubia* tree canopy might have increased N content of intercrops as compared to the sole grown crop. Apparently in present study, the better fertility status (Table 2) and microbial populations (Table 6) are evident to support these inferences.

Ether extract contains crude fat which is high density source of energy and alcohols, waxes, terpenes, steroids, pigments, ester, aldehydes, and other lipids (Ball et al 2001). In present study it was higher in forage under *M. dubia* silvi-pasture than sole cropping systems. Increased EE may be due to higher availability of nitrogen due to high decomposition and N cycling rate under silvi-pasture induced the pigments amount in plants and that, ultimately, increased the EE percent in silvi-pasture (Barros 2010). Forage quality

Table 5. Proximate principles and mineral content (%) of hybrid napier (HN) under *M. dubia*-HN based silvi-pasture and sole cropping systems

Land use systems	DM	CP	CF	EE	AC	NFE	N	P	K
T_1	22.19^{e}	9.36^{a}	26.98^{f}	2.19^{a}	14.25^{a}	47.23^{a}	1.50^{a}	0.20^{a}	3.77^{ab}
T_2	22.51^{d}	9.13^{b}	27.85^{e}	2.03^{b}	13.98^{ab}	47.02^{a}	1.46^{b}	0.21^{a}	3.82^{a}
T_3	22.71^{cd}	8.43^{c}	28.62^{d}	1.92^{c}	13.94^{ab}	47.09^{a}	1.35^{c}	0.19^{a}	3.69^{ab}
T_4	22.91^{c}	8.22^{c}	30.05^{c}	1.81^{d}	13.75^{bc}	46.16^{b}	1.32^{c}	0.18^{b}	3.60^{b}
T_5	23.40^{b}	7.93^{d}	30.62^{b}	1.80^{d}	13.49^{c}	46.17^{b}	1.27^{d}	0.17^{b}	3.36^{c}
T_6	23.89^{a}	6.83^{e}	31.39^{a}	1.52^{e}	13.11^{d}	47.15^{a}	1.09^{e}	0.15^{c}	3.24^{c}
SEm (±)	0.08	0.06	0.15	0.03	0.12	0.22	0.01	0.004	0.06

T_1= *M. dubia* (2 x 2 m)-HN, T_2= *M. dubia*(3 x 2 m)-HN, T_3=*M. dubia* (3 x 3 m)-HN, T_4=*M. dubia* (4 x 2 m)-HN, T_5= *M. dubia* (4 x 4 m)-HN, T_6= Sole HN; DM=Dry matter; CP=Crude protein; CF=Crude fibre; EE=Ether extract; AC=Ash content; NFE=Nitrogen free extract; N=Nitrogen; P=Phosphorus; K=Potassium; Means with different superscript letter in the same column indicate significant difference (*p<0.05*) according to Duncan's Multiple Range Test of grasses increased by shade with a small decrease in fiber concentration, an increase in digestibility, and a large increase in N concentration. Under shaded conditions, leaf area may be increased and leaf-area expansion may be prolonged, allowing only limited photosynthate for growth of secondary cell walls. Thus, shade may cause lower cell wall (fibre) concentration and increased forage quality (Kephart and Buxton 1993). The reduced PAR delays the maturation process of fodder grasses (Bos and Neuteboom 1998) and delays plant maturity, thereby reducing the fibre content (Pierson et al 1990). Higher cell wall content *i.e.* crude fibre decrease the *in-vitro* dry matter digestibility (O'Shea 1968). Therefore, higher HN CF content under sole cropping systems may impair the DM intake and lower the feed conversion ratio. The grasses under silvi-pasture relatively have high ash content *i.e.* total minerals content as compared to sole cropping systems. It may be due to higher uptake of potassium under silvi-pasture systems, which is major part of ash. Apparently, in the present study, forage K content was higher under silvi-pasture systems compared to sole crop. Previous studies have reported higher uptake of K (Guenni et al 2008) and P (Belsky 1992, Cruz 1997) by plants under shade which are in consistence with our study. NFE content of forage grasses is directly affected by CP, CF, EE, and AC of the grasses. Therefore, increase in these proximate principles decreases the NFE content of the forage grass. Higher NFE content in HN under silvi-pasture systems indicate it as energy rich source (Sukhadiya et al 2020).

Fungal population (cfu; colony forming units/g of soil): Fungal population (two years average of each season) was minimum (0.25 x 10^6 cfu/g) in *M. dubia* 2 x 2 m configuration among different spatial configurations (before planting HN in *M. dubia* plantations and open filed later HN sole crop systems) (Table 6). Fungal population increased with increase in *M. dubia* spacing and was maximum (3.25 x 10^6 cfu/g) in open field. After HN intercropping, similar trend was observed in all the seasons *viz*., summer, monsoon and winter. Maximum fungal population count of 3.88, 2.88 and 3.75 x 10^6 cfu/g was observed in summer and monsoon under HN sole cropping and in winter under *M. dubia* (4 x 4 m)-HN LU, respectively. *M. dubia* (2 x 2 m)-HN silvi-pasture system showed minimum fungal count of 0.38, 0.88 and 1.50 x 10^6 cfu/g in three seasons, respectively. However, it increased from summer, monsoon to winter season.

Bacterial population (cfu/g): Bacterial population, before HN planting, was maximum (61 x 10^7cfu/g) in 2 x 2 m *M. dubia* spatial configuration. It was in decreasing order with increase in spatial arrangement of *M. dubia* and minimum (4 x 10^7

Table 6. Soil microbial population (cfu/ml) under *M. dubia*-HN based silvi-pasture and sole cropping systems

Types of microbes	Land use systems	At HN planting	Average seasonal (2018-19) variation in microbial population after HN planting		
			Summer	Monsoon	Winter
Fungi population x 10^6 (cfu/g)	T_1	0.25	0.38	0.88	1.50
	T_2	1.25	1.50	1.00	2.25
	T_3	1.25	1.75	1.13	2.25
	T_4	1.50	1.75	1.38	2.38
	T_5	2.00	2.25	2.00	3.75
	T_6	3.25	3.88	2.88	3.50
Bacterial population x 10^7 (cfu/g)	T_1	61.00	144.88	300.00	187.13
	T_2	57.00	117.50	267.38	173.75
	T_3	38.75	116.13	241.00	100.38
	T_4	27.00	78.13	166.63	88.63
	T_5	21.75	66.63	141.75	47.63
	T_6	4.00	40.25	105.75	16.75
Actinomycetes population x 10^6 (cfu/g)	T_1	4.00	10.50	4.38	30.75
	T_2	3.00	8.13	4.25	19.13
	T_3	2.75	3.13	3.50	14.25
	T_4	1.00	2.25	1.13	6.75
	T_5	0.75	1.25	1.00	4.25
	T_6	0.00	0.38	0.13	1.38

T_1 = *M. dubia* (2 x 2 m)-HN, T_2 = *M. dubia*(3 x 2 m)-HN, T_3 =*M. dubia* (3 x 3 m)-HN, T_4 =*M. dubia* (4 x 2 m)-HN, T_5 = *M. dubia* (4 x 4 m)-HN, T_6 = Sole HN cfu/g) was in open field (Table 6). Similar trend was also observed in all the seasons *viz*., summer, monsoon and winter after intercropping HN (Table 6). Bacterial population was highest (114.88, 300 and 187.13 x 10^7 cfu/g in all seasons, respectively) in *M. dubia* (2 x 2 m)-HN silvi-pasture, whereas lowest was in sole HN cropping system.

Actinomycetes population (cfu/g): Actinomycetes populations, before HN intercropping (Table 6) was maximum (4 x 10cfu/g) in *M. dubia* (2 x 2 m)-HN silvi-pasture system. Count decreased with increase in spatial configuration and no count was recorded in open field. Similar trend was observed after HN intercropping in all the seasons. *M. dubia* (2 x 2 m)-HN LU harbored highest population (10.50, 4.38 and 30.75 x 10^6 cfu/g, in three seasons, respectively) and minimum was in sole HN system. The soil microbial population study substantiated that integration of HN as understory crops, increased microbial populations in all LU systems. Further, among different seasons, fungi and actinomycetes populations were highest in winter season, while bacterial population was maximum in monsoon season. Among different silvi-pasture systems, closest spacings had more bacterial and actinomycetes populations, while fungi were highest under sole cropping. Agroforestry practices are advocated as techniques that can be used to conserve and improve soil organic matter (Ross 1993) by increasing soil microbial biomass and enhance plant residue inputs (Amatya et al 2002, Lee and Jose 2003, Mao and Zeng 2013).

Many factors *i.e.* environmental, and soil conditions; composition of the soil micro-organism population; and chemical quality of the litter affect soil organic matter decomposition rate (Swift et al 1979), which is directly proportional to the nutrient release to the soil (Dhanya et al 2013). Rates of litter and soil organic matter mineralization and nutrient availability to plants may be greater under trees, due to higher litter inputs, higher soil moisture, and lower soil and air temperatures (Menezes et al 2002). These studies are evident for the increased microbial populations obtained in the present investigations. Low population of microorganism is found in the soil with low organic matter (Bhattarai et al 2015). Thus, present study substantiates that varying *M. dubia* densities created congenial development conditions for soil biota thereby improving the soil health. Further, inclusion of HN improved the microbial populations.

CONCLUSIONS

The growth, physiological attributes, fresh and dry forage production, and proximate and mineral matter principles and qualitative attributes (average of two years; three harvests in each year) were higher under silvi-pasture systems as compared to sole cropping. Study also substantiated that integration of HN under varying *M. dubia* configurations, increased microbial populations in all LU systems. Among different silvi-pasture LU systems, closest spacing had more bacterial and actinomycetes populations, while fungi were highest under sole cropping. The study evinced out that tree-crop interactions under different *M. dubia* spatial configurations were positive and hence HN could be adopted as intercrop for better quantitative and qualitative attributes.

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Crop Productivity and Soil Properties under Agroforestry System in Kosi Watershed of Kumaun Himalaya

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Abstract: In the hilly region of Kumaun Himalaya agroforestry system is an important source of food, fodder, fuel, fibre, livelihood security, biological diversity and soil conservation. Local inhabitants are primarily dependent on agriculture along with trees maintained on margin of terraces and bunds of crop fields. This study focused on (i) productivity of paddy and wheat crops under agroforestry and sole agriculture, (ii) comparison of soil properties of different land-use sites of Kantli, Dhaniyakot and Sauraal villages situated along different altitudinal gradient in Kosi watershed. Crop yield and harvest index were recorded better under sole agriculture compared to agroforestry system. Overall, 17.8 to 32.6 % higher grain yield of paddy and 13.76 to 24.76% higher grain yield of wheat crops were recorded under sole agriculture system. Soil properties were better under vegetation compared to control site. Increases in soil organic carbon and better water holding capacity under top soil (0–15 cm) were noted under agroforestry and forest soil.

Keywords: Agroforestry, Kosi watershed, Crop productivity, Soil properties, Kumaun Himalaya

Uttarakhand, with 53,483 km^2 area, shares about 9.62% of total geographical area of Indian Himalayan Region and 1.56% of India. About 86% land of the state is mountainous and only 14% land of total reported area is available for agricultural activities of which ~55% is under rainfed with cropping intensity of 161 per cent. About 7.81 lakhs ha land area is under agriculture of which 4.43 lakhs (56.8% of total agriculture) is under hilly regions and remaining 3.37 lakhs ha is in *tarai* regions of the state. Average landholding of farmers of hilly region and *tarai* region of the state is 0.68 ha and 1.77 ha per farmer, respectively. With this smaller land hold, the state needs extra effort to feed population in coming year both for human and cattle populations. Due to increasing demands of food, fodder, fuel, timber and environmental security, Indian agriculture is facing lots of challenges such as: inclusive growth and sustainable livelihoods, agricultural growth, food security, energy security and environmental security in climate change regime. Like other parts of Himalayas, agriculture is the prime occupation of the majority of people in the Uttarakhand Himalayas (Pandey and Singh 1984) and about 70% of the population still dependent of agriculture and associated activities. Here local people have evolved agriculture with association of natural forests to meet their food, fodder and fuel wood requirement from this system. Farmers are more dependent for organic matter to support soil fertility of farms on forest resources. Here traditional cereal cultivation is done along with indigenous trees on terraced hill slopes.

Traditional AF plays a significant role in livelihood support to farmers of Kumaun Himalaya. Currently, agriculture in the Kumaun Himalaya is rainfed, less productive and subsistence. Agricultural land is fragmented with terraced slopes constituting a fragile ecosystem leading to difficulty in agricultural operations and even not sufficient to meet out the annual demand of food grain of the household. Here agroforestry practices; particularly composition and use pattern of plants seems diverse under different agro-climatic zones. AF system does not meet only some of the primary necessity of the local people but also reduce soil erosion (Guevara-Escobar *et al*. 2002, Bhatt *et al*. 2016), improve soil structure and nutrients (Schroth and Sinclair 2003, Jose 2009) through addition of litter fall. It provide sustainable land management by arresting soil degradation and productivity loss due to excessive use and reduces risk of crop failure under uncertain weather and erosion hazards (Saroj and Arora 1994, Rao 2002). At the same time, it improves sites (Maikhuri and Semwal 1997), improve microclimate (Tanga et al 2014, Singh et al 2016), such as lowering of soil surface temperature and reduction of evaporation of soil moisture through a combination of mulching and shading. Moreover, it reduces pressure from forests (Iiyama et al 2014, Verma et al 2017), conserve biodiversity (Harvey et al 2006, Jose 2009) and sequestrates carbon (Montagnini and Nair 2004, Nair et al 2009, Chauhan et al 2019).

Studies on agricultural productivity under AF system indicate higher productivity can be achieved under agroforestry system (Fagerholm et al 2016, Waldron et al 2017, Lehmann et al 2020) while in other studies reduced yield under agroforestry was recorded than the sole cropping system (Puri and Bangarwa 1992, Dufour et al 2013, Chauhan et al 2015). However, few studies also recommended higher production under AF system can be achieved by selection of appropriate tree–crop combination (Tadesse et al 2021) and proper management (Semwal et al. 2002, Broadhead et al 2003). Such practices and knowledge on spatial arrangement, temporal sequence, tree crop combination is limited and scattered in Kumaun Himalaya. In view of this, present study was conducted to understand the productive potential of hill agroforestry system and its impact on soil properties.

MATERIAL AND METHODS

Srivastava (2006) suggested that central Himalayan region can be divided into four markedly different agro-climatic zones along the elevation gradient *i.e.*, lower altitude, <800 m, middle altitude between 800 to 1500 m, higher altitude between 1500 to 2000 m and very high altitude >2000 m based on the different farming practices along the elevation zones. Thus, three study villages namely Kantli (1750 m), Dhaniyakot (1064 m) and Sauraal (839 m) were selected for the present study along the altitudinal gradients of Kosi watershed. They represent upper, middle and lower parts of Kosi watershed situated in Uttarakhand state. All the villages have terraced rainfed agriculture in hill slopes. Very smaller part of agricultural land was under irrigation condition. Climatic conditions of the watershed fall under temperate to sub-tropical zone following the classification of Köppen (1900). The watershed has three prominent seasons; summer (April-June), rainy (July-Sept) and winter (Nov-Feb). During the study period, annual air temperature ranged from a maximum of 32.1°C (June) to minimum -0.8°C (January) and the mean annual temperature was approximately 18°C. Rainfall varies from 3 mm (Nov.) to 287 mm (Aug.) across the year.

Agricultural productivity: Assessment of agricultural crops productivity under agroforestry systems and sole agriculture was estimated by taking samples of paddy (*Oryza sativa*) and wheat (*Triticum aestivum*) crops for two consecutive years from the farmer's fields. A net plot of 1.0m x 1.0m was harvested from agroforestry system as well as sole agriculture system. This sample harvest was done in 5 replicates. Harvested crop was separated into grains and straw. It was dried for 5-6 days and the produce was weighed to obtain the net yield of crops. Average crop yield data were presented in kg ha^{-1}.

Harvest index: The harvest index is used to denote the fraction of economically useful products of a plant in relation to its productivity. It was obtained by dividing economic yield (grain yield) by biological yield and expressed in percent as follows:

$$\text{Harvest index} = \frac{\text{Economic yield}}{\text{Biological yield}} \times 100$$

Soil analysis: Soil samples were collected in Z shape using augur from 3 layers (0-15 cm, 15-30 cm and 30-45 cm) up to a depth of 45 cm from agroforestry systems, forests and control sites. Uncultivated cropland without any amendment of organic manure or inorganic manure was treated as control. Three replicates samples were collected from these sites in each study village. Samples from each individual plot were thoroughly mixed to make it composite, air dried and passed through a 2 mm sieve before chemical analysis. The average

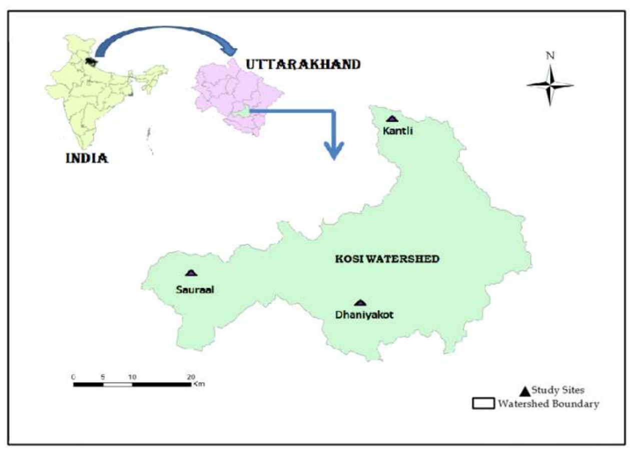

Fig. 1. Location of study sites in Kosi watershed

Table 1. Altitude, agro-climatic condition, area and population of study sites of the Kosi watershed

Village	Altitude (m)	Agro-climate	Coordinate	Total area (ha)	Nos. of total household	Population (Residing person)
Kantli	1750	High hills	N29°50'55.06" E79°33'57.14”	114.57	117	321
Dhaniyakot	1064	Mid hills	N29°29'31.48” E79°26'56.61”	128.31	212	797
Sauraal	839	Low hills	N29°32'36.84” E79°13'31.29”	260.2	100	331

values from all the depth were treated as final value. Soil pH, soil moisture content, water holding capacity and organic carbon were analysed using standard methods. Thus soil pH was measured in slurry of soil and deionized water in the ratio of 1:5. All the samples were stirred for 30 minutes and then allowed to stand for approximately 15 minutes before pH was measured using pre-calibrated digital pH meter (Jackson 1958). Soil moisture was measured using following ASTM D 2216 method by heating the 10 g air dried samples at 105°C for 24 hours. Water holding capacity was measured using Hilgard cup method (Cassel and Neilson 1986) and organic carbon was estimated using Walkley and Black (1934) method.

RESULTS AND DISCUSSION

Economic yield: Highest paddy production was recorded at Dhaniyakot followed by Kantli and Sauraal. At Dhaniyakot and Kantli sites paddy yield was relatively higher during IInd year as compared to Ist year under both land-use type. However, decrease trend of grain yield was recorded during IInd year at Sauraal site under agroforestry and sole agriculture. Yield under sole agriculture was higher at all the three study sites and during both the cropping years (Table 2). Total grain yield was 17.8 to 32.6 % higher during Ist year and 18.1 to 29.3% higher during IInd year under sole agriculture system was recorded in comparison to agroforestry system.

Wheat crop showed nearly similar grain yield pattern like paddy during both years (Table 3). Among all sites, highest wheat production was recorded at Dhaniyakot followed by Kantli and Sauraal under both the land-use systems. Per hectare wheat yield was higher under sole agriculture as compared to AF system at all the three study sites and during both the cropping years. Under sole agriculture, grain yield was recorded 24.8%, 23.9% and 22.8% higher than the agroforestry system during Ist year, while 28.8, 21 and 32 % higher under sole agriculture system respectively at Kantli, Dhaniyakot and Sauraal, respectively during second year. Under both land-use systems, increase in grain yield was observed during IInd year except AF system of Sauraal village. Lesser grain yield (4% less) was recorded at Sauraal village under agroforestry during II year. Overall, Maximum grain yield was recorded at Dhaniyakot under both the land-use type among all the study villages. Similar trend was observed in straw yield as well.

Wheat straw also showed lower yield during Ist year as compared to IInd year. Per hectare straw yield was higher under sole agriculture than the AF system under all the three study villages. It was 19.85% to 24.76% higher during Ist year and 13.76% to 22.97% higher during IInd year under sole agriculture. Overall wheat straw yield was highest at Dhaniyakot followed by Kantli and lowest at Sauraal under both the land-use types.

Biological yield: Biological yield, a sum of straw and grain yield, follows the nearly similar pattern like straw and grain yields of paddy on per hectare basis both under agroforestry and agriculture systems (Table 2). The biological yield was recorded higher during IInd cropping year under both the land-use types as compared to the biological yield of Ist year. Biological yield of paddy under sole agriculture was higher

Table 2. Grains, straw and biological yield of paddy crop under AF system and sole agriculture system in Kosi watershed

Land use system/Study sites		Paddy yield (kg ha^{-1})		
		Grain	Straw	Biological
Agroforestry System				
Kantli (1750 m amsl)	Ist Year	1189±27	1820±135.5	3009±154
	IInd Year	1245±29	2103±148	3348±174.5
Dhaniyakot (1064 m amsl)	Ist Year	1396±34	2130±75	3526±112
	IInd Year	1473±42	2285±79.5	3758±121.5
Sauraal (839 m amsl)	Ist Year	967±5	1580±19.5	2547±14.5
	IInd Year	958±4	1622±23	2580±19
Sole Agriculture				
Kantli (1750 m amsl)	Ist Year	1430±86	2120±148	3550±238
	IInd Year	1610±95.5	2431±161.5	4041±252.5
Dhaniyakot (1064 m amsl)	Ist Year	1645±45	2418±89.5	4063±135.5
	IInd Year	1740±49.5	2607±99	4347±149
Sauraal (839 m amsl)	Ist Year	1282±23	1821±29	3103±8.5
	IInd Year	1239±20.5	1883±33.5	3122±12.5

than biological yield of AF system at all the study sites and during both the cropping years. During Ist cropping year, biological yields was about 18, 15.2 and 21.8% higher under sole agriculture while IInd cropping year, biological yields were nearly 20.7, 15.7 and 21.0% higher under sole agriculture than AF systems, respectively at Kantli, Dhaniyakot and Sauraal, respectively. In addition, the highest biological yield was recorded at Dhaniyakot followed by Kantli and minimum at Sauraal during both the cropping year.

Biological yield of wheat crop also showed nearly similar pattern like paddy crop at all the three study villages and under both the land-use types (Table 3). Higher biological yields were recorded under sole agriculture as compared to AF systems. It was nearly 21.9, 22.2 and 23.9% higher under sole agriculture during Ist cropping year and 25.36, 16.74 and 23.71% higher than the agroforestry systems, respectively at Kantli, Dhaniyakot and Sauraal during the IInd cropping year. The productivity of biological yield of wheat was highest at Dhaniyakot followed by Kantli during both the cropping year. It was lowest at Sauraal under both the land-use system during both cropping year.

Harvest index (HI): Harvest index (HI) of paddy crops was higher under sole agriculture as compared to the AF system (Table 4). During Ist cropping year, HI was recorded in between 37.97 to 39.59% under AF system, while it was 40.28 to 41.31% under sole agriculture. For IInd cropping year, it was 37.13 to 39.20% under AF system and 39.69 to 40.03% under sole agriculture system in study villages of Kosi watershed. Under agroforestry system Dhaniyakot showed highest HI (39.59%) while under sole agriculture Sauraal showed highest HI of 41.31% during Ist cropping year. During IInd cropping year, Dhaniyakot had highest HI of paddy crop under both land-use systems. Harvest Index of wheat crop was recorded slightly higher as compared to paddy. It was also higher under sole agriculture as compared to agroforestry systems (Table 4). During Ist cropping year, HI was in the range of 42.05 to 42.99% under AF system and 42.59 to 43.56% under sole agriculture system. For second year, HI was 38.03 to 41.42% under AF system and 40.59 to 42.92% under sole agriculture system. Harvest Index of wheat crop under AF system was recorded higher than the sole agriculture at Sauraal during Ist cropping year. However, it was higher under sole agriculture than the AF systems of Kantli, Dhaniyakot and Sauraal village during IInd year. Overall, Dhaniyakot showed highest HI under both the land use types.

The grain, straw, biological yield and harvest index of study crops were higher under sole agriculture as compared to AF system mainly due to competition for resources *i.e.* light, nutrients, water etc. between intercropped crops and trees under agroforestry. Under agroforestry system economic yield was 17.84–32.57% lower than the sole agriculture. Bijalwan (2012) record similar findings in Grahwal Himalaya where the annual productivity of food grains under AF systems was 34.56 to 38.29% lower than the sole agriculture. However, he also observed that this reduction in food production was supplemented by fruit production from the agroforestry trees. Grain yield of both paddy and wheat crops of present study are comparable with

Table 3. Grains, Straw and Biological yield of Wheat crop under AF system and sole agriculture system in Kosi watershed

Land use system/Study sites		Wheat yield (kg ha^{-1})		
		Grain	Straw	Biological
Agroforestry System				
Kantli (1750 m amsl)	Ist Year	1294±42	1783±92	3077±142
	IInd Year	1385±48.5	1994±118.5	3379±161.5
Dhaniyakot (1064 m amsl)	Ist Year	1484±58.5	1968±142	3452±204.5
	IInd Year	1608±66	2274±162	3882±223
Sauraal (839 m amsl)	Ist Year	1021±23.5	1361±112.5	2382±91.5
	IInd Year	980±18	1597±127	2577±103
Sole Agriculture				
Kantli (1750 m amsl)	Ist Year	1615±79.5	2137±148	3752±234
	IInd Year	1784±88.5	2452±159.5	4236±253.5
Dhaniyakot (1064 m amsl)	Ist Year	1838±49	2381±97	4219±148
	IInd Year	1945±57.5	2587±109.5	4532±165
Sauraal (839 m amsl)	Ist Year	1254±19.5	1698±94.5	2952±112.5
	IInd Year	1294±21	1894±104.5	3188±123

the average grain yields of these crops of Central Himalaya (Table 5). Yields of paddy and wheat crops are also comparable with the results of Toky et al (1989), Sundriyal et al (1994) and Singh (2010). There were little variations in the crop yields, which could be attributed to various crop compositions, tree density and quantity of fertilizer used (Sundriyal et al 1994). Among three study sites crop yield under both the agroforestry and sole agriculture systems was highest at Dhaniyakot because of better agriculture practices being followed in that village than the Kantli and Sauraal. The economic yield of any crop is dependent on the yield attributing characters, which are the ultimate outcome of the contribution of the growth characters. Further, these growth characters are function of photosynthesis, a universal physiological process of capturing and transforming the solar energy into more useful chemical energy (Kudtarkar 2005).

Increase in crop productivity of paddy and wheat may be attributed to change in climate, use of high yielding verities and fertilizers. Increase in CO_2 concentration induced higher number of tillers and grain per plant that increase the rice

Table 4. Harvest index (HI) of paddy and wheat crops under agroforestry system and sole agriculture

Parameters		Harvest index (%) of crops		
		I Year	II Year	Mean
Agroforestry system				
Kantli	Paddy	39.51±1.25	37.19±1.08	38.35±1.16
	Wheat	42.05±0.59	40.99±0.46	41.52±0.53
Dhaniyakot	Paddy	39.59±0.24	39.20±0.17	39.39±0.20
	Wheat	42.99±0.81	41.42±0.74	42.20±0.78
Sauraal	Paddy	37.97±0.45	37.13±0.38	37.55±0.42
	Wheat	42.86±2.67	38.03±2.15	40.44±2.42
Sole Agriculture				
Kantli	Paddy	40.28±0.26	39.8±0.19	40.06±0.22
	Wheat	43.04±0.51	42.12±0.42	42.58±0.46
Dhaniyakot	Paddy	40.49±0.24	40.03±0.21	40.26±0.23
	Wheat	43.56±0.35	42.92±0.29	43.24±0.32
Sauraal	Paddy	41.31±0.86	39.69±0.74	40.5±0.81
	Wheat	42.48±0.98	40.59±0.87	41.53±0.94

Table 5. Grain yield of paddy and wheat (MT ha^{-1}) in Central Himalaya

Locations	Paddy	Wheat	Reference
Almora district	1.00	1.30	Sati and Deng Wei (2018)
Almora district	1.02	1.08	Mittal et al (2008)
Central Himalaya	1.41	1.52	Mukerjee et al (2018)
Uttarakhand	1.98–2.14	1.88–2.43	Tuteja (2015)
Uttarakhand	1.74	1.85	Mittal et al (2008)
Garhwal Himalaya Sole agriculture	NA	1.03–1.06	Bijalwan (2012)
Agroforestry	NA	0.59–0.66	Bijalwan (2012)
Agroforestry			
Kantli	1.22	1.34	Present study
Dhaniyakot	1.43	1.55	Present study
Sauraal	0.96	1.00	Present study
Sole Cropping			
Kantli	1.52	2.29	Present study
Dhaniyakot	1.69	2.48	Present study
Sauraal	1.26	1.80	Present study

grain yields. Additional carbohydrate in paddy plants has helped in balancing the profile of photosynthetic proteins to sustain greater photosynthetic activity (Uprety et al 2004). In their study, Attri and Rathore (2003) predicted enhancement of 29-37% in the wheat yield under climate change conditions of northwest India. Kanwal *et al*. (2019) also projected increase in the yield of rice (30-40%) and wheat (28-31%) with changing climate scenario in Kumaun Himalaya. However, Birthal et al (2014) projected decrease in average yield of rice and wheat, respectively up to 15 and 22% by 2100 with increasing temperature and rainfall for all the districts of India. The contradiction may be corroborated to the fact that a temperature rise up to 3°C at the Himalayan region may result in a better rice producing condition unlike the Gangetic and peninsular India where it may lead to heat stress.

Soil Properties

Soil pH: Soil pH of the nearby forests, particularly 0-15cm soil layers of all the three villages were slightly acidic in nature and their pH ranged between 6.20 to 6.44 (Table 6). It was followed by AF system. Further, soil pH changed from acidic to alkaline with increase of soil depths. Overall, there was not much variation in soil pH under control with increase in soil depths. For sustained cultivation of food crops such as paddy, wheat, vegetables pulses during two cropping seasons *i.e*. *Kharif* and *Rabi* seasons in a year, soil nutrients are managed by mixing decomposed organic manure in farms (Fig. 2). Organic manure is prepared with cattle dung and dried pine needles and leftover fodder leaves mixed with cattle urine as beddings (dried forest leaves, leftover fodder and unpalatable straw etc.) on floor of cattle sheds under cattle during night. When bedding is mixed with dung and urine it is kept in pits for decomposing; after complete decomposition organic manure is ready for mixing in the crop fields. Chemical fertilizer such as urea is also used during paddy and wheat cropping. Soil organic matter and regular use of organic manure may increases soil pH in acidic soils whereas use of chemical fertilizers decreases soil pH (Whalen et al 2000). Soils of Kantli and Sauraal were acidic in upper layers of 0-15 cm depth and remaining two layers *i.e.* 15 to 30 cm and 30 to15 cm were either neutral or slightly basic. Soil pH was much lower under agroforestry and forests as compared to control. Further, pH was much lower under forests compared to agroforestry. Soil pH was lower in the higher soil depths. The lower pH in 0-15 cm soil depth under tree species could be attributed to accumulation of organic matter in the soil by falling of leaves, small twigs and decomposition of below ground parts *i.e.* fine roots that subsequently produce organic acids (Gupta and Sharma 2008). Similar results were reported in agri-silviculture system by Prasadini and Sreemannarayana (2007) and Kumar et al (2008). Newaj et al (2007) also observed very nominal changes in soil pH under white siris (*Albizia procera*) based agri-silviculture system after 4 years of experimentation as compared to initial value due to very high free calcium carbonate content in the soils.

Fig. 2. Amendments of organic manure in crop fields in Kosi watershed

Water holding capacity (WHC): Water holding capacity (WHC) of soils were better under all agroforestry sites as compared to controls. However, it was best under forests as compare to agroforestry and control sites (Table 7). Further, WHC of soils under agroforestry and forests were better at Kantli (higher altitude sites) than the soils of middle altitude (Dhaniyakot) and lower altitude (Sauraal). It was also found that WHC was higher under upper soil layers (0-15 cm) than middle layers (15-30 cm) and lower layers (30-45 cm) at all the sites and all landuse types.

In present study, water holding capacity (WHC) was

Table 6. Soil pH from different soil depths of different land use types

Parameters	Kantli (1750 m amsl) Soil depth (cm)				Dhaniyakot (1064 m amsl) Soil depth (cm)				Sauraal (839 m amsl) Soil depth (cm)			
	(0-15)	(15-30)	(30-45)	Mean	(0-15)	(15-30)	(30-45)	Mean	(0-15)	(15-30)	(30-45)	Mean
Agroforestry	6.51±0.49	6.71±0.60	7.52±0.06	6.91	6.31±0.10	7.52±0.03	7.57±0.03	7.13	6.45±0.27	6.51±0.35	6.16±0.84	6.37
Forest	6.44±0.03	7.20±0.04	7.62±0.09	7.08	6.20±0.06	7.24±0.02	7.28±0.03	6.90	6.36±0.22	6.49±0.28	7.14±0.03	6.66
Control	6.79±0.28	7.01±0.38	7.60±0.19	7.13	6.68±0.03	6.67±0.02	6.70±0.02	6.68	6.56±0.49	6.89±0.17	6.93±0.01	6.79

superior under forests followed by agroforestry system and lowest at control sites. It was lowest in lower soil depths as compared to upper two soil depths. Similar results were obtained by Subba and Dhara (2017) under fruit based agroforestry systems. In his study, Felker (1978), indicated WHC of soil increases under *Acacia albida* in comparison with sites devoid of such trees. Udawatta *et al*. (2011) also reported that perennial vegetation increases infiltration rate and water holding capacity of the soil. Singh and Singh (2011) and Chauhan *et al.* (2018) also reported higher WHC of soil in woodland as compared to control. They concluded two to three folds higher soil moisture in multi-storey plots as compared to control. The effect of increased two to three folds higher is believed to be a consequence of higher topsoil organic matter content under trees in forest and agroforestry systems than the sole agriculture or monoculture system.

Soil moisture content: Soil moisture contents of forested sites were better than the soil moisture of agroforestry and control in all the sites. Soil moisture contents of agroforestry sites were higher than the control (Table 7). In middle soil depth (15-30 cm) and lower soil depth (30-45 cm) soil moisture content was higher than the upper soil (0-15 cm), particularly under forests and control sites. Among AF systems, Kantli and Sauraal villages soil has higher moisture as compared to agroforestry system of Dhaniyakot.

Higher soil moisture content of forests and agroforestry systems could be attributed to more litter production and subsequent litter decomposition under trees favouring higher soil moisture retention capacity (Vanlalhluna, 2007). The higher value of WHC and soil moisture at Kantli might also be due to oak forests, as higher amount of litter in oak forests influences the texture of soil that results in higher water retention capacity. But in case of Dhaniyakot having higher concentration of OC, yet the water holding capacity is very low. This might be due to the sandy texture of soil; sandy soil has small surface area and less pore volume subsequently retains less moisture.

Organic carbon (OC): Among agroforestry systems maximum organic carbon (OC) was observed under agroforestry system of Dhaniyakot followed by Sauraal and minimum under agroforestry system of Kantli village (Table 8). OC was recorded maximum in the upper soil depths (0-15 cm) across all the study sites and showed trend of decline in lower soil layers of 15-30 cm and 30-45 cm. OC was relatively higher under forest soils than the agroforestry soils. Both the agroforestry and forest soils had higher concentration of OC than control in general. High organic matter content (up to 30%) in organic manure is believed to increase the content of organic corban, nitrogen, phosphorus, potassium, and main cations in the soil (Han et al 2016, Sheikh and Dwivedi 2017). The organic matter of manure allows plants to use the nutrients for a long time, due to its slow decomposition, and reduces the loss of what is not utilized by the plants (Bhandari et al 2002). Potassium, and

Table 7. Water holding capacity and soil moisture (%) from different soil depths of different land use types

Parameters	Kantli (1750 m amsl) Soil depth (cm)				Dhaniyakot (1064 m amsl) Soil depth (cm)				Sauraal (839 m amsl) Soil depth (cm)			
	(0-15)	(15-30)	(30-45)	Mean	(0-15)	(15-30)	(30-45)	Mean	(0-15)	(15-30)	(30-45)	Mean
Water holding capacity (%)												
Agroforestry	53.06	52.39	52.32	52.59	52.26	50.7	50.45	51.13	49.78	48.75	48.18	48.90
Forest	55.39	54.67	53.13	54.39	54.43	52.18	52.0	52.87	51.21	52.21	51.02	51.48
Control	53.22	49.53	48.65	50.46	48.26	46.85	47.7	47.60	44.57	43.57	44.12	44.08
Soil moisture (%)												
Agroforestry	12.35	17.4	16.34	15.36	9.52	7.25	8.34	8.37	13.35	15.20	12.21	13.58
Forest	13.32	14.52	16.23	14.69	12.34	12.56	14.36	13.08	13.96	17.96	16.86	16.26
Control	5.53	6.49	8.52	6.84	8.75	7.48	7.62	7.95	8.31	11.55	11.85	10.57

Table 8. Organic carbon (%) from different soil depths of different land use types

Parameters	Kantli (1750 m amsl) Soil depth (cm)				Dhaniyakot (1064 m amsl) Soil depth (cm)				Sauraal (839 m amsl) Soil depth (cm)			
	(0-15)	(15-30)	(30-45)	Mean	(0-15)	(15-30)	(30-45)	Mean	(0-15)	(15-30)	(30-45)	Mean
Agroforestry	2.04±0.24	1.41±0.19	1.38±0.16	1.61	2.45±0.26	1.50±0.17	1.24±0.19	1.73	2.33±0.21	1.33±0.19	1.15±0.22	1.60
Forest	2.32±0.26	1.85±0.15	1.64±0.11	1.93	2.51±0.23	1.96±0.17	1.44±0.13	1.97	2.45±0.19	1.68±0.12	1.50±0.16	1.87
Control	1.42±0.15	1.22±0.19	1.02±0.14	1.22	2.20±0.20	1.15±0.24	1.05±0.11	1.46	1.32±0.13	1.22±0.14	1.08±0.11	1.20

nitrogen increased by organic manure treatment due to their high content in organic manure.

In the present study, soil organic corban (SOC) varied between 1.32 to 2.20% in upper layer of 0-15 cm under control, 2.32 to 2.51% under forest and 2.04 to 2.45% under agroforestry system. SOC in agroforestry soils, particularly uper layer, *i.e.* 0-15cm depth was higher due to manuring the crop fields with organic manure. The range of OC in soils 2.32 to 2.51% in chir pine forests were reported earlier by Goswami (2014). While in the similar agroforestry systems, Bhardwaj et al (2013) observed SOC contents ranging from 0.89 to 1.22% only. SOC was miximum under forest followed by agroforestry system. The soil enrichment in SOC content under tree based systems could be due to several factors such as addition of litter, decomposition of fine roots biomass and root exudates and its reduced oxidation of organic matter under tree shades (Gill and Burman 2002). Studies indicate addition of leaf litter favours the higher nutrient status of the soil (Uthappa et al 2015). Lower organic carbon under agroforestry system of Kantli village may be due to the agricultural practices like removal of crop residue from the field after harvesting of previous sown crop whereas at Dhaniyakot farmers do not remove the crop residues from the crop fields and plough the field along with residues. The highest SOC (%) was recorded at the surface soil layer (0-15 cm) while the lowest SOC (%) was observed for 30-45 cm soil depth. This may be attributed to the major contribution made by litter fall at surface layer. Similar variation in SOC with soil depth has also been reported by Chauhan et al (2010), Ghimire (2010) and Uthappa et al (2015). Generally, the plants have lignified cells in its parts like litter, bark, small branches, roots etc. that may leads to biochemical stabilization of organic carbon in the soil and leads to improve SOC (%) under agroforestry as concluded by Six et al (2002). Hence, one of the reasons which reveal the lower concentration of SOC under control (without vegetation) is lack of lignified cells.

CONCLUSION

Local people evolved traditional agroforestry system on terraced hilly soils to meet their food, fodder and fuel wood requirement from this system with trial and error method over a time period. Cereal cultivation along with agroforestry on terraced hill slopes of central Himalayan regions is an example of such system. This system does not meet only some of their primary necessity of the local people but also provide soil benefits. Although, crop yields and harvest index were higher under sole agriculture as compared to the agroforestry but overall profit in agroforestry is higher due to addition of tree biomass. Moreover, it provides better livelihood security, ecosystem services and biodiversity conservation than a mono-cropping system. In pure agriculture some chemical fertilizers are also used which are ecologically undesirable whereas under agroforestry for sustained cultivation of food crops during two cropping seasons in a year, soil nutrients are managed by mixing decomposed organic manure in farms. Further, better soil properties were observed under forest and agroforestry sites as compared to without vegetation site mainly due to addition of organic matter in the soil. This study is limited to only two important cereal crops of the region for a short period of two cropping years. Similar observations on other hill crops, pulses and vegetables on a longer period basis needs be carried out to understand impact of various interactions between agroforestry components. In the present scenario to feed growing population with limited resources, land area and increase in deforestation rate traditional agroforestry system would be viable option in Kumaun Himalaya which can be strengthen by suitable policies for hilly states, better management practices, proper site selection, plantation of multipurpose tree species, appropriate tree-crop combination and arrangement.

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Microsatellite Analysis of Genetic Diversity and Structure of Farmer Selected Genotypes of Tree Bean (*Parkia timoriana* (DC.) Merr) in Manipur

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Abstract: Microsatellite markers were used to analysed the genetic diveristy and structure of twenty six farmer-selected trees in the valley districts of Manipur, India. Three markers, which displayed high polymoprhic information content (88.9%) and allelic richness ranging between 14 and 16. The number of allele per locus (Na) in the pooled selected population was 5.33, number of private alleles was 0.66 and Shannon Diversity Index (I) was 1.12, indicating high diversity values. Population wise, highest values were obtained in Imphal West (Na= 3.67; number of private alleles = 1.33, I= 1.05) and lowest in Chandel (Na= 1.67; number of private alleles = 0, I= 0.24). Analysis of molecular variance indicated much of variability resided within selections (49.5%) and very less among groups (12.5%). Structure analysis revealed that selections have originated from two genepools, but with no clear-cut inclination of any selection to either genepool. The results indicate that ample genetic variation existed in the twenty farmer-selected trees and informal selections by farmers do not display any genetic deficiencies. However there is a need for an extensive genetic survey comprising of natural and planted populations across the state to enable more meaningful comparisons.

Keywords: Domestication, Genetic bottleneck, SSR, Shannon Diversity Index, *Yongchak*

Indigenous fruit tree species (IFTs) are trees with edible fruits, which naturally grow within a specific geographic location and are often characterized by limited development relative to their potential (Mabhaudhi et al 2017). Throughout the tropics, there are many IFTs that supplement nutritional demands and support family income of rural communities (Reed 2017, Ickowitz et al 2014, Vira et al 2015). Some of the IFTs have even surpassed local usage and are presently in high demand triggering widespread domestication (Mithofer 2005, Sankanur et al 2017) and introduction in farmer's fields. The maintenance of adequate amounts of genetic variation in the domesticated population is essential to allow for continued genetic gains over multiple generations (Johnson et al 2001). This is especially relevant for IFTs where the formal production system of propagation material in most species is still lacking and farmers generally use planting materials from random, unknown and often genetically narrow sources. Conflicting evidence has emerged on the level of genetic diversity harboured by planted populations across the globe. For example, microsatellite markers showed clear genetic differences between matched natural and planted populations of *Inga edulis*, an indigenous fruit of the Amazon, raising doubts over the sustainability of planted populations (Hollingsworth et al 2005). On the contrary, similar studies on Meru oak (*Vitex fischeri*) using RAPD (Lengleek et al 2006) and sheanut (*Vitelleria paradoxa*) using microsatellite markers (Kelly et al 2004) found little difference in diversity levels between agroforestry trees and the natural population stand. With natural habitats and useful resources fast depleting due to land use changes and high extraction pressure, planted populations may become sole repositories of genetic diversity for many IFTs in the near future. Further, since many of the planted populations will be the founding population for *on* and *off* farm plantation, ascertaining the level of variation and genetic structure becomes essential.

Parkia timoriana (DC.) Merr. [Syn. *Parkia roxburghii* G. Don.] is a tree that yields a fruit (henceforth referred to a pod), which is used for many culinary purposes in the North east region of India. It is commonly called Tree Bean and naturally distributed in North East India and South East Asia including Bangladesh, Burma (Myanmar), Thailand and the Malaysian region. The pods have high market value prized between 65$ to 90$ for 100 pods during its peak season (Roy et al 2016). Aside from the pods being a source of food, it is nutritional (Longvah and Deosthale 1998, Salam et al 2009), has many medicinal uses and diverse bioactivity (Angami et al 2017). In the state of Manipur Tree bean is locally known as

"*Yongchak*" and commonly consumed as a vegetable, salad or '*chutney*'. It is extensively planted in village areas, along roadsides, home gardens and agricultural lands. Based on palatability and morphological traits, traditional cultivars of tree beans have been identified (Anon 1981, Meitei and Singh 1990).

In a larger exercise aimed to initiate a domestication program of Tree Bean in Manipur, we identified farmer-selected trees in the valley districts of Manipur, India. These farmer selections were best in their respective sites for pod quality and/or pod production and the preferred choice as mother trees for propagation. Using SSR markers we assessed the genetic diversity and structure of these selected individuals to ascertain whether selection by farmers has invariably resulted in genetic deficiencies in the population. Such investigations are especially crucial in domestication programs that are in participatory mode to refine the selection procedure of good genotypes.

MATERIAL AND METHODS

The study was conducted during 2017-19 and samples were collected from the valley districts of Manipur. We randomly selected sites in six districts of the state and at each site we enquired village elders about the best tree bean trees in their area in terms of eating quality, pod characteristics and production and from where they preferred to obtain seeds for propagation. Based on consensus at each site, we located the farmer-selected trees and geo referenced their location. A total of 26 trees were located in this manner from six districts of the state (Table 1).

Leaf samples from the 26 adult trees were collected, dried in silica gel and stored at -20°C. The genomic DNA was extracted from the leaf samples (200mg) using the cetyltrimethylammonium bromide protocol (Doyle and Doyle 1987) with relevant modifications. The extraction buffer consisted of 100 mMTris, 20mm EDTA (ethylene diamine tetra acetic acid), 1.4 M NaCl and 2 % CTAB. The extracted DNA were treated with 4ul of 50mg/ul RNAse and kept at 37˚C for 30 mins. The presence of the DNA was confirmed through electrophoresis in ethidium-bromide stained 0.8% agarose gels. The DNA was quantified using a spectrophotometer at absorbance A260nm/A280nm. All the 26 samples were diluted in TE buffer to a final concentration of 50 ng/µl and stored at -20°C before amplification.

The diluted DNA (50 ng) were subjected to polymerase chain reaction (PCR) using shortlisted three nucleotide microsatellite primer pairs from *P. panurensis* (Leuttmann et al 2010); *P. bigobulosa* (Lassen et al 2014) (Table 2). The PCR amplification was carried out in 20 µL reaction containing 2.0 µL template DNA (30-50ng/ml), 2.5µL 10x PCR buffer, 2.5 ml of 2.5mM dNTP, 1.0 µL of forward and reverse primer each, 0.2 µL of 3U Taq polymerase and the final volume was made up to 20µL with nuclease free sterile water. An master cycler gradient (Eppendorf) was used with following conditions: Initial denaturation at 94°C for 4 min followed by 38 cycles of 94°C for 1 min, 46-58°C (primer specific annealing temperature) for 35 sec, and elongation at 72°C for 1 min and final extension at 72°C for 10 min. Amplified products were genotyped using ABI PRISM3130 genetic analyser (Applied Biosystems, Chromous Biotech Bangalore, India). The electropherograms were manually checked for specific artefact peaks, split peaks before scoring the alleles using Genemarker Ver 3.0.1 (www.softgenetics.com).

Genetic diversity measures were analysed at three level; individual, geographical and pooled level. The observed number of alleles, effective number of alleles, private alleles, observed and expected heterozygosity and Shannon's diversity index analysis were carried out using POPGENE V 1.31 and GenAlEx 6.502 softwares (Yeh and Boyle 1997, Peakall and Smouse 2012). Based on the tree's geographical origin, the individuals were grouped into six populations namely Imphal West, Kanpokpi, Bishnupur, Churachandpur, Kamjong and Chandel. Analysis of molecular variance (AMOVA) was also carried out to assess the genetic variance among the groups, individual trees as well as within each tree. A model-based program, STRUCTURE (Pritchard et al 2000), was used to determine the genetic relationship among the 6 populations of *P. timoriana.* In this method, fractional membership of each individual was assigned to a specific cluster (K). The program was performed under the assumptions of admixture and no admixture model with the allele frequencies correlated. The program was performed with 5,00,000 burning period with 20,00,000 MCMC runs assuming K=1 to K=8 for both the models. Ten replicates were run for each K for robust results in achieving the best possible K value. To identify the best K, Evanno's ∆K method was used in the STRUCTURE HARVESTER (Dent and VonHoldt 2012). To identify that the replicate runs were consistent and also to modify labels and colours, CLUMPAK Ver1.1 was used (Kopelman et al 2015). Principal Component Analysis (PCA) was performed to identify clusters using GENODIVE Ver 3.0 (Meirmans 2020) and plotted using Origin prob 2020 (Origin lab corp). All the files were converted using CONVERT Ver 1.3.1 (Glaubitz 2004).

RESULTS AND DISCUSSION

Three microsatellite or simple sequence repeat (SSR) markers were used to estimate the genetic diversity and structure of 26 farmer-selected trees from Manipur. The number of alleles detected was 45 and the number of alleles ranged from 14 to 16. The average value of polymorphic information content (PIC) for three primers was 88.9%, the highest being in locus PBL 21 and lowest PP9. The markers used in the study showed higher allelic richness as compared to 5 SSR markers used in *Parkia biglobosa*, which detected a total of 55 alleles ranging between 10 and 14 (Popoola et al 2020).

The diversity indices estimated for twenty six genotypes are shown in Table 3. The number of alleles per locus (Na) varied from 1.00 in 11 individuals to 1.66 in 3 individuals, with a mean of 1.30 (Table 3). The observed heterozygosity (H_o) ranges from 0 in 11 individuals to 1 in Tree No. 2 from Imphal West which also reported the highest Shannon diversity index (0.69). The zero values obtained for observed

Table 1. Details of location and GPS coordinates of 26 farmer-selected genotypes of tree bean (*Parkia timoriana*) from Manipur

Tree no.	Village	District	GPS Coordinates		
			Longitude	Latitude	Elevation (m)
T1	New Keithelmanbi	Imphal-West	N24°46'19.38”	E93°47'43.49”	802
T2	Laimanai, Langol	Imphal-West	N24°50'23.5”	E93°55'07.6	781
T3	Oinam Leikai, Pishum	Imphal West	N24°46'59.7”	E93°55'58.8”	804
T4	M S Leirak, Yaiskul	Imphal-West	N24°47'31.4”	E93°56'14.0”	786
T5	Kanglatombi, Ward 1	Imphal-West	N24°58'09.39”	E93°53'16.33”	854
T6	Kanglatombi, Ward 1	Imphal-West	N24°58'9.84"	E93°53'16.73"	854
T7	Kholep Village	Kangpokpi	N25°01'03.95”	E93°54'34.96”	982
T8	Saitu	Kangpokpi	N25°01'57.3”	E93°54'25.3”	1192
T9	Keithelmanbi,	Kangpokpi	N25°06'1.43”	E93°56'53.72”	980
T10	Keithelmanbi	Kangpokpi	N25°06'14.0”	E93°57'01.3”	980
T11	Ward 8	Bishnupur,	N24°37'38.65”	E93°45'47.6”	802
T12	Ward 8	Bishnupur,	N24°37'25.01”	E93°45'44.73”	802
T13	Ward 8	Bishnupur,	N24°37'24.85”	E93°45'45.03”	802
T14	Moirang	Bishnupur	N24°30'20.4”	E93°45'39.6”	762
T15	Zenhang Lenka	Churchandpur	N24°20'48.5”	E93°42'07.8”	807
T16	Zenhang Lenka	Churchandpur	N24°20'48.8”	E93°42'08.4”	816
T17	Rengkai Road	Churchandpur	N24°20'43.01”	E93°41'59.27”	830
T18	Elim Veng	Churchandpur	N24°20'04.3”	E93°41'47.2”	854
T19	Sampui	Kamjong	N24°53'07.1”	E94°29'10.3”	1303
T20	Sampui	Kamjong	N24°53'07.4”	E94°29'11.2”	1306
T21	Sampui	Kamjong	N24°53'06.4”	E94°29'10.2”	1312
T22	Sampui	Kamjong	N24°53'6.47"	E94°29'9.41"	1307
T23	Christian Village	Chandel	N24°18'58.80"	E93°59'3.90"	880
T24	Christian Village	Chandel	N24°19'00.8"	E93°59'01.6"	880
T25	Liwa Khulen	Chandel	N24°22'19.60"	E94° 0'40.10"	830
T26	Liwa Khulen	Chandel	N24°22'20.91"	E94° 0'39.45"	831

Table 2. Details of nuclear SSR markers used for genetic analysis of natural, planted and selected populations of tree bean (*Parkia timoriana*) from Manipur

Locus	Primer sequence along with the labeled marker	Ta (°C)	Repeat motif	Size range (bp)
PP9	VIC-F: GGGGCTTGTGTCTCTCACTG R: ACTTTGAAGGCACGAGATGG	58	(AC)8	204-262
PBL21	FAM-F: TGTTGCTTTTGCTTTTGCTG R: CCCTCTGCAGAATTGAGTCC	58	(CA)21	250-290
PRO1	VIC-F: ACTCCTGCCTTACCACATCC R: TAGCAGCCTATCGACCGC	46	(AC)8	270-310

Note: Ta- Annealing temperature, bp - base pair length heterozygosity and Shannon diversity index in 11 individuals is due to their homozygous condition at all three loci; hence genetically undifferentiated in terms of heterozygosity levels based on the primers used. However, when the individuals were analyzed as a population, Na was 5.33, number of private alleles was 0.66 and Shannon Diversity Index was 1.12. These reported diversity values were higher than those reported for species of the same genera by Jacob et al (2019) for 19 landraces of *Parkia biglobosa* from Nigeria using five SSR primers (0.49) and *Parkia speciosa* (0.96) from Malaysia using RAPD markers (Lee et al 2002). The three microsatellite markers used in the study were also able to detect larger variation as compared to 19 ISSR markers used by Thangjam (2014) for 3 populations of the same species from Manipur where the highest Shannon index was 0.19 and number of alleles 1.33. Based on only three primers, we are able to detect larger variation in the selected population and genetic diversity values momentarily indicate the absence of any genetic bottleneck event during the selection process by farmers. Tree bean is commercially propagated by seeds since there are no vegetative propagation protocols developed, and this could be one of the reasons why high genetic diversity is maintained within the selected population. However, pooled genetic variation of tree bean in the state needs to be ascertained by sampling natural as well as planted populations, which can be used as a reference point for more meaningful comparison.

The 26 selections were further divided into 6 groups based on geographical origin of the tree and genetic parameters for all groups are shown in Table 4. The number of alleles (Na) ranged from 1.67 in Chandel to 3.67 in Imphal west, which also showed the highest number of private

Table 3. Summary statistics addressing genetic diversity of 26 farmer-selected genotypes of Tree Bean (*Parkia timoriana*) from Manipur

Tree No.	Na	Ne	I	Ho	He	Obs_Hom	Exp_Hom
T1	1.00	1.00	0.00	0.00	0.00	1.00	1.00
T2	2.00	2.00	0.69	1.00	1.00	0.00	0.00
T3	1.00	1.00	0.00	0.00	0.00	1.00	1.00
T4	1.66	1.66	0.46	0.66	0.66	0.33	0.33
T5	1.33	1.33	0.23	0.33	0.33	0.66	0.66
T6	1.00	1.00	0.00	0.00	0.00	1.00	1.00
T7	1.66	1.66	0.46	0.66	0.66	0.33	0.33
T8	1.33	1.33	0.23	0.33	0.33	0.66	0.66
T9	1.33	1.33	0.23	0.33	0.33	0.66	0.66
T10	1.00	1.00	0.00	0.00	0.00	1.00	1.00
T11	1.00	1.00	0.00	0.00	0.00	1.00	1.00
T12	1.00	1.00	0.00	0.00	0.00	1.00	1.00
T13	1.33	1.33	0.23	0.33	0.33	0.66	0.66
T14	1.33	1.33	0.23	0.33	0.33	0.66	0.66
T15	1.33	1.33	0.23	0.33	0.33	0.66	0.66
T16	1.66	1.66	0.46	0.66	0.66	0.33	0.33
T17	1.50	1.50	0.34	0.50	0.50	0.50	0.50
T18	1.00	1.00	0.00	0.00	0.00	1.00	1.00
T19	1.66	1.66	0.46	0.66	0.66	0.33	0.33
T20	1.33	1.33	0.23	0.33	0.33	0.66	0.66
T21	1.33	1.33	0.23	0.33	0.33	0.66	0.66
T22	1.00	1.00	0.00	0.00	0.00	1.00	1.00
T23	1.00	1.00	0.00	0.00	0.00	1.00	1.00
T24	1.50	1.50	0.34	0.50	0.50	0.50	0.50
T25	1.00	1.00	0.00	0.00	0.00	1.00	1.00
T26	1.50	1.50	0.34	0.50	0.50	0.50	0.50

Na = No. of alleles; *Ne* = Effective No. of alleles; *I* = Shannon's Index; *Ho* = Observed Heterozygosity; *He* = Expected Heterozygosity; *Obs_Hom* = Observed Homozygosity; *Exp_Hom* = Expected Homozygosity alleles (1.33), Shannon Diversity Index (I = 1.05) and expected heterozygosity (He= 0.63). The genetic diversity parameter values were lowest from Chandel (I=0.24; He=0.13), while populations from Kangpokpi and Bishnupur were similar in their diversity values. Earlier Thangjam (2014) had estimated genetic variation of 10 individuals each from Kangpokpi and Narankonjin (Imphal West) using ISSR markers and reported allelic richness of 1.32 and 1.18 and Shannon index of 0.19 and 0.11, respectively, which were lower than values reported in our study (Table 4). This re-enforces the strength of SSR markers to detect higher rate of polymorphism and high extent of allelic diversity and therefore are excellent molecular markers in studies of germplasm characterization, genetic diversity, and genetic mapping (Powell et al 1996).

Analysis of molecular variance (AMOVA) was performed to partition the genetic variance levels among groups, among selections, and within selection (Table 5). AMOVA results showed that much of variability resided within selections (49.5%, Table 5). Significant difference among individuals (P < 0.01) was observed, which represented 38% of the total variation, whereas the variability among groups accounted for 12.5%. Low genetic differentiation between populations is a common feature among perennials (Hamrick et al 1979, Nevo et al 1984, Loveless and Hamrick 1984) primarily due to their outcrossing nature and high gene flow events (Hamrick and Godt 1996). These features are more relevant to Tree bean, which is an obligate outcrossing species since it is self-incompatible and pollinated by a bat species *Eonycteris spelaea* (Bumrungsri et al 2008), which has distance foraging flights up to 38 km (Start and Marshall 1976) promoting pollen dispersal over a large area. The lack of distinct population structure among genotypes is also demonstrated in the structure analysis. According to Evanno et al (2005), the maximum K represents the optimal number of clusters and K

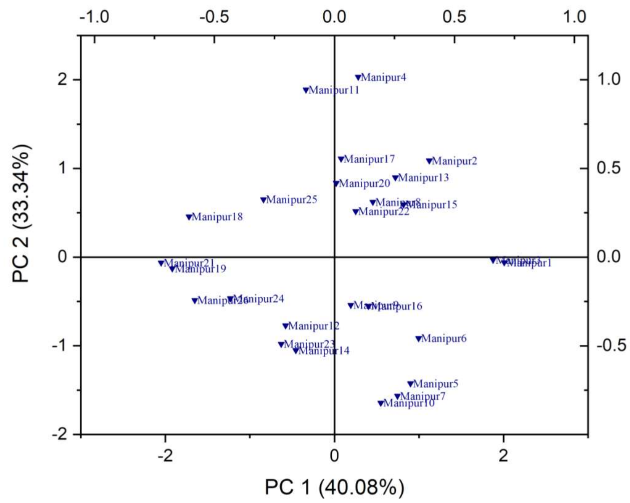

Fig. 2. Principal component analysis (PCA) for 26 farmer-selected tree bean (*Parkia timoriana*) genotypes from Manipur

Table 4. Summary statistics addressing genetic diversity 26 farmer-selected genotypes of tree bean (*Parkia timoriana*) from Manipur grouped under 6 populations based on tree origin

Population	N	Na	Ne	PA	I	Ho	He
Imphal West	6	3.66	2.60	1.33	1.05	0.33	0.63
Kangpokpi	4	2.67	2.08	0.33	0.83	0.33	0.59
Bishnipur	4	2.33	1.95	0.00	0.73	0.16	0.52
Churachandpur	4	2.66	2.21	0.66	0.84	0.36	0.62
Kamjong	4	2.00	1.60	0.33	0.56	0.33	0.42
Chandel	4	1.66	1.22	0.00	0.24	0.16	0.13

n = No. of individuals; *Na* = No. of alleles; *Ne* = Effective No. of alleles; PA = Private Allele *I* = Shannon's Index; *Ho* = Observed Heterozygosity; *He* = Expected

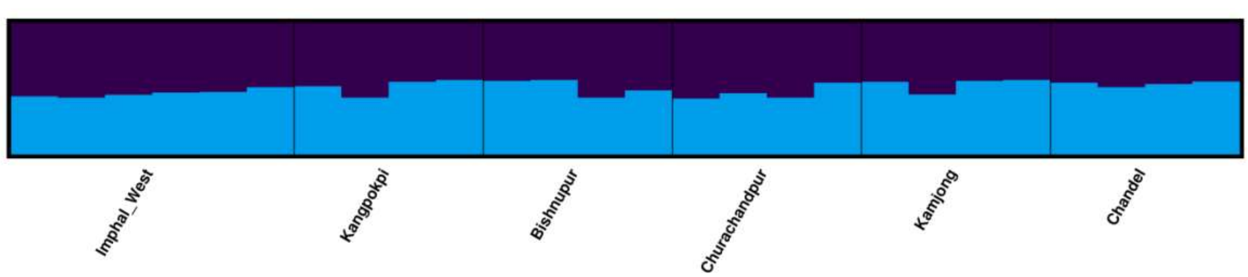

Fig. 1. Genetic structure of *Parkia* with $K = 2$ for 26 farmer-selected tree bean (*Parkia timoriana*) genotypes from Manipur under Admixture model. Each colour represents possible admixture from different lineage or cluster

Table 5. Analysis of molecular variance for 6 populations of tree bean (*Parkia timoriana*) from Manipur

Source of variation	d.f	Sum of squares	Est. variance	Total variance (%)	P-value
Among populations	5	7.27	0.12	12.50	<0.01
Among Individuals	20	15.62	0.42	38.00	<0.01
Within Individuals	26	8.00	0.42	49.50	<0.01
Total	51	30.90	0.97	100	

d.f. = Degree of freedom; P-value is base

= 2 was the largest value indicating the selections have originated from two genepools (Fig. 1), but each group a mixture of individuals from different sites. However, there was no clear-cut inclination of selections to any specific genepool, but were all mixture of both. The scatter plot along the two principle components explained 73.42% of the total variation. Grouping of selected individuals in different axis of the PCA graph was not dictated by geographical origin (Fig. 2). Past records from the print media reveal extensive cultivation of tree beans by farmers and plantations in non-agricultural lands by government and non-government agencies, which lead us to believe that large scale physical movement of propagating material across the state occurred in the past, especially within the valley areas of Manipur.

This study clearly showed that ample genetic variation is represented among the 26 farmer-selected trees from the valley region of Manipur based on only three microsatellite markers. The common perception that informal selection by farmers generally lead to genetic deficiencies in planted populations does not hold true in this case. However, due to less number of markers used we were unable to detect the diversity levels of individuals, hence a need to develop more SSR markers for the species. Extensive cultivation and plantation activities of tree beans in the state has led to routine movement of planting materials across sites eliminating major population differentiation. Tree bean is an IFT that has enormous economic potential for the farmers of the region and the selected population will play a major role in shaping the genetic future of *on* and *off* farm plantations. The selected individuals considered in the study though diverse are not sufficient to constitute a genetically sound base population for future breeding programs. Further, we are unaware whether selected individuals produce pods that meet market demand. Towards this end, it is recommended that the number of selections should be increased to meet greater breeding challenges of the future and selection should be based on refined criteria that are more market oriented.

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Tinospora cordifolia: A Valuable Plant in Ayurveda

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Abstract: *Tinospora cordifolia* commonly is a natural herbal shrub that belongs to the moonseed family Menispermaceae. The phytochemical analysis showed the presence of alkaloids, flavonoid, saponins, cardiac glycosides, steroids, carbohydrate and proteins. The aqueous extracts of *Tinospora cordifolia* were evaluated for antibacterial activity against standard pathogens i.e. *Staphylococcus aureus, Escherichia coli, Vibrio cholera, Salmonella typhi, Shigella* at concentrations 5, 10 and 20%. The 20% aqueous extract of *Tinospora cordifolia* showed an optimum zone of inhibition. *Vibrio cholera* MTCC 3906 was highly sensitive to aqueous extract followed by *S. aureus* MTCC 3160*, Salmonella enterica typhi* MTCC 734*, Shigella sonnei, Escherichia coli* MTCC 1018. *Salmonella enterica typhi* MTCC 734 was highly sensitive to methanol extract followed by *Shigella sonnei, Staphylococcus aureus* MTCC 3160*, Vibrio cholera* MTCC 3906*, Escherichia coli* MTCC 1018. These phytochemical data analysis and antibacterial activity of *Tinospora cordifolia* may be useful and may be lead to the improvement and formulation of drugs and discovery of drugs development against tested gastrointestinal tract pathogens.

Keywords: *Tinospora cordifolia,* Gastrointestinal tract pathogens, Antibacterial activity.

Ayurvedic herbs played important role in Ayurvedic treatments from ancient time to this most modern time. One of the plant known for having many medicinal use in traditional system of medicines is *Tinospora cordifolia* which belongs to the Menispermaceae family and is common climbing shrub in India (Shah and Shah 2016), extending from Himalayas down to the Southern Part of India. Root leaves and stem region of this shrub used for medicinal purposes and contain columbin, tinosporin, and tinosporin acid. The other different types of phytochemicals also identified which includes alkaloids, diterpenoids, lactones, steroids, glycosides, aliphatic compounds, polysaccharides, saponins, flavonoids, tannin. The *T, cordifolia* act as immunomodulatory, anti-microbial (Bonvicini et al 2014), anti-oxidant, hepatoprotection, diuretic, anti-neoplastic, anti-hypoglycemic, antipyretic, anti-inflammatory (Li et al 2010, Tiwari et al 2014), anti-stress, anti-hyperglycemic, anti-diabetic, and anti-tuberculosis also been reported (Sharma et al 2015). The stem preparation is used in general debility, dyspepsia, fevers, and urinary infection. The root is a powerful emetic and its aqueous extract is used for visceral obstruction, leprosy, etc. The present study is based on the use of its extract against certain types of pathogenic bacteria for anti-inflammatory activity.

MATERIAL AND METHODS

Collection of plant materials: The *Tinospora cordifolia* was collected from the Karjat Mahamandal Depo. The freshly collected stem region was then subjected to preliminary treatment, which includes washing and cutting appropriate pieces. These pieces were further dried at 54° C in the oven for 2-3 days and converted into powder form, which was further used for extract preparation.

Preparation of extract: For the preparation of hot water extract and methanol extract, hot water and methanol both were separately added to the powder at a ratio of 1:10. Hot water extract was heated in a boiling water bath to make the volume 3/4th of the original volume. The methanol extract was kept shaker at 1500 rpm for 48-72 hours. Both the extract was filtered and dried at 54°C. Then dried extract weight was determined. The extracts were stored in a cool condition to protect them from direct sunlight.

Extract quantification and sterility checking: Extract quantification was done by calculating the percent yield of the extract as:

Percent yield = weight of the extract/ weight of the total mass of the powder X 100

For preliminary sterility testing of extracts, streaking was done on a sterile nutrient agar plate and sterile potato dextrose agar plate. Then the plate was incubated and observed for growth.

Phytochemical Analysis

Alkaloids: 200mg of plant material was dissolved in 10ml of methanol and filtered. To this 2ml filtrate, 1% HCl was added and steamed, to 1ml of this filtrate, 6 drops of Dragendroff reagent were added and observed for orange precipitate.

Tannins: 200mg plant material was mixed with 10 ml of distilled water and then filtered. To this 2ml filtrate, 2ml $FeCl_3$ was added and observed for blush black precipitate.

Flavonoids: 200mg of plant material was heated with 10ml of ethyl acetate over steam and kept for 3 min and then filtered. To 4ml filtrated, 1ml of dilute ammonia solution was added and observed for yellow colouration.

Saponin: 200mg plant material mixed with 10ml of distilled water. The presence of frothing after shaking the tube confirms the presence of saponin.

Steroids (Libermann- Buchard reaction): 200mg plant material was mixed with 10ml of chloroform and filtered. To 2 ml of filtrate, 2 ml of acetic anhydride then conc. H_2SO_4 was added and observed for the development of blue-green rings (Xiong et al 2007).

Cadiac glycosides (Keller - Killani test): 200 mg plant material was mixed with 10ml of ethanol. To 2 ml of this filtrate, 1 ml of glacial acetic acid, $FeCl_3$ and conc. H_2SO_4were added and observed for greenish-blue colouration.

Carbohydrates: Fehling's Test for carbohydrates was performed for both water extract and methanolic extract.

Amino acids: The estimation was done by using Ninhydrin's Test for the presence of amino acids in both the extracts were tested.

Antibacterial study against gastrointestinal tract pathogens: Standard gastrointestinal tract pathogens such as *Escherichia coli* MTCC 1885*, Salmonella enterica typhi* MTCC 734*, Shigella sonnei, Staphylococcus aureus* MTCC 3160and *Vibrio cholera* MTCC 3906were freshly subculture on sterile Nutrient Agar slant before use for antibacterial activity.

The antibacterial activity of methanol extract and water extract of Tinospora cordifolia (stem) were tested by the agar cup method. Different concentrations of both extracts (5, 10 and 20%) were prepared by reconstituting with 25% DMSO (Rose et al 2010). 20 ml of sterile Nutrient Agar was bulk seeded with test culture (0.2 ml of 0.5 OD culture). After solidification of agar the wells were made on this plate using 6mm sterile borer (Shubha and Hiremath, 2010) and then 0.2 ml of extract (5, 10 and 20%) was added. Dimethyl sulphonic acid (25%) was used as control. The antibacterial assay plates were incubated at 37°C for 24hrs. The diameter of the inhibition zone of was measured in mm.

Table 1. Yield of water and methanol extract

Methanol extract	Yield (%)	Hot water extract	Yield (%)
TM1	11.33	TW1	12.93
TM2	11.91	TW2	12.43
TM3	11.77	TW3	11.67
TM4	12.14	TW4	12.39
TM5	11.43	TW5	12.52
TM6	11.72	TW6	12.39

Preparation of syrup: Firstly, three different concentrations of 40, 50 and 60% sugar were prepared in D/W and sterilized using an autoclave (Sivakumar et al 2011). Extract powder was added using aseptic techniques to make the final syrup concentration 10%. These mixtures were homogenized using a vortex mixer. Final syrup formulations were used for antibacterial activity against GI tract pathogens as used above.

Acid and bile stability of extract: For this acid and bile stability of extract, phosphate buffer of 2.5, 4 and 6 pH were prepared to which 0.85% bile was added. In that buffer, the extract was added to make its final concentration 10%. Antibacterial activity of the acid and bile subjected extract were determined at different time intervals (1, 2 and 3hrs) by using the agar cup method.

Anti-Inflammatory activity of extract: The anti-inflammatory activity of the extract was studied by using the inhibition of the albumin denaturation test. The reaction mixture consists of test extract within the concentration range of 200 to 800mcg/ml and 1% aqueous solution of bovine serum albumin. pH of the reaction mixture was adjusted with 1N HCl. The sample extract was incubated at 37°C for 20min and then heated to 51°C for 20 min. After cooling the mixture, turbidity was measured at 660nm. The percent of inhibition of denaturation was calculated using the following equation (Dharmadeva et al 2018):

Percent inhibition = (Abs control – Abs sample) X 100/Abs control

The aqueous extract yield was marginally higher than the methanol extract yield. This could be due to the higher polarity of water than methanol and this plant may contain more polar components. A number of different active principles including alkaloids, flavonoids, carbohydrates, saponins, steroids, cardiac glycosides and amino acids have been identified for observing its medical effect in *T. cordifolia*.

The phytochemical analysis done shows the presence of alkaloids, flavonoids, saponins, cardiac glycosides, steroids, carbohydrates and proteins (Table 2). All the phytochemicals were present except tannin. Amino acids were estimated with the help of Ninhydrin's Test which showed intense dark blue colouration, which could be due to the presence of a high concentration of amino acids. Test for steroids, flavonoids and cardiac glycosides also showed intense dark colouration *i. e.* present in abundant amounts. The larger foam formation points out the presence of a high amount of saponins. Other phytochemical tests gave light colour development which could indicate its intermediate and low presence in the extract. From the phytochemical screening, the extracts are rich in amino acid, saponin, steroids, flavonoids and cardiac glycosides. Similar results were also obtained by Sivakumar and Dhana Rajan (2011).

When tested by the well diffusion method, the aqueous extracts of leaf extracts of *T.cordifolia* were subjected for antibacterial activity against standard pathogens i.e. *S. aureus, E. coli, V. cholera, S. typhi, Shigella* at concentrations 5, 10 and 20%. as the concentration of extract increases, there was also an increase in the zone of inhibition occurs. It was found that 20% of the extract showed the highest zone of inhibition which has a 25 mm zone of inhibition against *V. cholera* MTCC 3906 was highly sensitive to aqueous extract and followed by *S. aureus* MTCC 3160*, S. enterica typhi* MTCC 734*, Shigella sonnei, E. coli* MTCC 1018 (Fig. 1).

This Figure 2 indicates as the concentration of methanol extract increases, there was also an increase in the zone of inhibition occur. The 20% of the extract showed the highest zone of inhibition and S. *enterica typhi* MTCC 734 was highly sensitive to methanol extract and showed 20 mm zone of inhibition followed by *Shigella sonnei, S. aureus* MTCC 3160*, V. cholera* MTCC 3906*, E. coli* MTCC 1018. Rose et al (2010) revealed that the maximum antibacterial activity of hot and cold methanol extracts was exhibited against *Staphylococcus aureus* when compared with standard drugs. Shanthi and Nelson (2013) observed that maximum inhibitory activity of ethanol extract of leaf of *T. cordifolia* was against *Klebsiella pneumoniae* was followed by *Pseudomonas aeruginosa* while the chloroform extract of leaf showed moderate activity against *Pseudomonas aeruginosa* and *Klebsiella pneumoniae* but was less against *E. coli.* Prajwala et al (2019) observed the antibacterial activity of *T. cordifolia* leaf extract of methanolic, ethanolic, chloroform, hexane, aqueous and acetone extract but only the methanolic extract showed the antibacterial activity against the *E. coli.* In the present study, the results of both the extract show good antibacterial activity against GI tract pathogens. In this investigation, the antibacterial activity of water extract syrup and methanol extract syrup was also evaluated against GI tract pathogens. The antibacterial activity was determined for both the extract containing syrup against GI tract pathogens. As the concentration of extract increases, there was an increase in the zone of inhibition. It and 60 and 50% extract showed the highest zone of inhibition.

In the present study acid and bile tolerance of *Tinospora cordifolia* indicated that at different pH values (2.5, 4 and 6

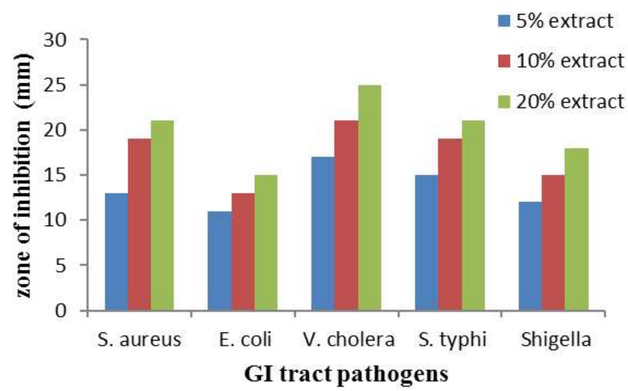

Fig. 1. Antibacterial activity of water extract against GI tract pathogens

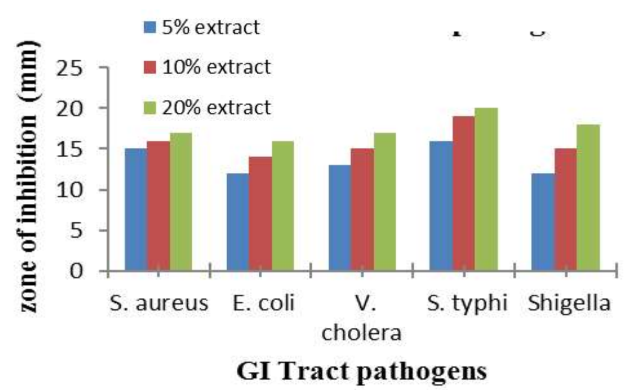

Fig. 2. Antibacterial activity of methanol extract against GI tract pathogens

Table 2. Phytochemical analysis of *Tinospora Cordifolia*

Phytochemicals	Test used	Observations/ colour	Results
Alkaloids	Dragendorff test	Reddish brown precipitate	+
Tannin	Ferric chloride test	Brown colour	-
Flavonoid	Alkaline reagent test	Green colour	++
Saponins	Foam formation	Foam	++
Carbohydrate	Molish test	Blue colour ring	+
Amino acid	Ninhydrin's test	Dark blue colour	++
Cardiac glycosides	Keller – Kiliani test	Greenish blue colour	++
Steroids	Libermann – Burchard test	Blue green ring	++

+Light colour, ++ Intense dark colour, - Negative test

Table 3. Effect of *Tinospora cordifolia* extract on protein denaturation

Concentrations (mcg ml^{-1})	Absorbance (540 nm)	% inhibition at protein denaturation
200	0.20	48
400	0.25	34
600	0.16	59
800	0.13	65
Control	0.38	--

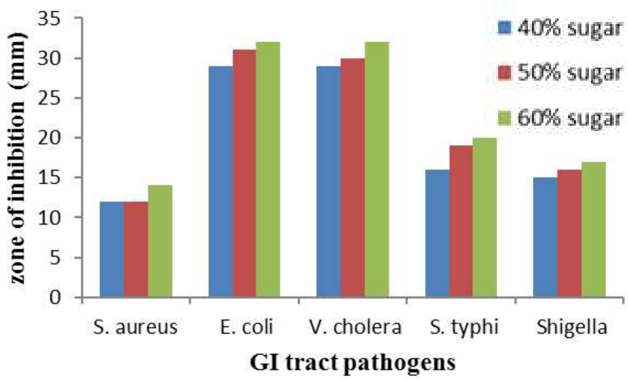

Fig. 3. Antibacterial activity of syrup (Methanol extract) against GI tract pathogens

Fig. 4. Plate showing acid and bile stability of extract at different interval

pH) high bile contain does not affect the activity of extract. The extract showed antibacterial activity against all the pathogens. When the extract activity was determined at different interval the activity of extract remained (Fig. 4). Both extract (water and methanol extract) at 600mcg/ml and 800mcg/ml showed higher inhibitory activity of protein denaturation of bovine serum albumin (Table 3).

CONCLUSION

Tinospora cordifolia may be useful due the presence of quantitative and qualitative alkaloids, flavonoid, saponins, cardiac glycosides, steroids, carbohydrates and proteins that may be lead to the improvement and formulation of drugs and discovery of drugs development against gastrointestinal tract pathogen. The 20% of the extract showed the highest zone of inhibition with 25 mm zone of inhibition against *V. cholera,* MTCC 3906 was highly sensitive to aqueous extract and followed by *S. aureus* MTCC 3160*, S. enterica typhi* MTCC 734*, Shigella sonnei, E. coli* MTCC 1018. The *S. enterica typhi* MTCC 734 highly sensitive to methanol extract and showed 20 mm zone of inhibition followed by *Shigella sonnei, S. aureus* MTCC 3160. From the present investigation, can conclude that *Tinospora cordifolia* has good antibacterial activity against gastrointestinal tract pathogens.

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Anatomical Response of Regenerated Bark in *Terminalia arjuna* (Roxb.) Wight & Arn.

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Abstract: *Terminalia arjuna* is a large tropical tree whose both original and regenerated bark is commercially exploited for medicinal purpose mainly to cure cardiac diseases. For sustainable supply of Arjuna bark, the regenerated bark of tree is usually harvested within 18-24 months with controlled wounding at different girth classes. During course of investigation, it was found that the biomass and rigidity of regenerated bark was higher than original bark in each girth-class of tree. To explore the reason for higher biomass and rigidity in the regenerated bark of Arjuna, a comparative anatomical investigation was carried out between original and regenerated bark from randomly selected trees of middle girth-class (50-75cm). Results showed that there was significantly higher proportion of phloem fibres and ray cells and lower proportion of sieve tubes in regenerated bark in comparison to original bark. Most of the fibre dimensions and ray parameters varied between original and regenerated bark and also between first and second harvest of the regenerated bark. The wounded tree gives first preference to the protection of the injured bark from surroundings rather than food conduction through sieve tubes.

Keywords: *Terminalia arjuna*, Regenerated bark, Wound, Harvesting, Bark anatomy

Terminalia arjuna (Roxb.) Wright & Arnot ('Arjuna') is a large tropical medicinal tree species of family Combretaceae. It's bark is commercially exploited for Ayurvedic medicines, primarily to cure cardiac diseases (Dhingra et al 2013, Chander and Chauhan 2014). Most bark collectors girdle the trees or sometimes harvest entire bark by means of unscientific way, which may lead to death of trees. Considering these issues, sustainable bark harvesting techniques have been developed (Pandey and Mandal 2012, Pandey 2015, Gunaga et al 2017, Anonymous 2020). During sustainable harvesting practices, outer and middle bark is generally removed longitudinally from the stem and branches by making incision of specific strip size leaving inner bark for regeneration. However, regeneration largely depend upon the age and girth of trees, depth of incision, strip size (width and length), moisture of exposed surface, method, season of harvesting and also largely by tree-to-tree variation (Pandey and Mandal 2012). Bark regrowth usually completes within 18-24 months after each harvesting in *Terminalia arjuna* (Pandey 2015).

Trees respond to bark injury with a series of chemical, anatomical and physical changes adjacent to wound surface. When tree is injured for bark collection, the injured tissue is not repaired or heals from inside out like animals (Shigo 1986). The replacement of removed bark tissues initiates with callus formation from newly formed wound cambium in the surrounding area of injury (Dickison 2000). The callus mostly grows from the peripheral parts of the wound and suberinized. Thus, trees respond to injury by compartmentalizing or creating a wall around the wounded tissue with gradual growth of new tissue (Shigo 1986, Sinha et al 2010). The harvesting of regenerated bark is important for sustainable supply of bark in *Terminalia arjuna,* since the regenerated bark is also exploited commercially for medicinal purpose. During preliminary stages of the present investigation, it was reported that bark regeneration after first harvest completed within 8-9 months in *Terminalia arjuna* trees of middle (50-75 cm) to higher girth classes (>100cm) in comparison to smaller girth-class (25-50 cm); however, bark regeneration completed within 9-12 months after second harvest (Figure 1a-f). Interestingly, the bark biomass was found to be maximum in regenerated bark as compared to original bark in each girth-class. Furthermore, during microtomy, the regenerated bark sections were found to be harder to cut than original bark sections. Studies on changes in anatomical properties of original and regenerated bark in forest tree species are scanty. The current study aimed to explore the cause of higher biomass and rigidity in the regenerated bark of *Terminalia arjuna* by comparing the changes in anatomical properties of original and regenerated bark.

MATERIAL AND METHODS

The experiment was conducted among arjuna trees of different girth classes (25-50 cm to 100-150 cm) to study the sustainable bark harvesting from block and road side plantations established at Navsari Agricultural University, Navsari, Gujarat (20.95°N latitude, 72.90°E longitude), India. For anatomical investigations, three trees were randomly selected from the middle girth-class (50-75cm) and used for the study. A longitudinal bark strip of 10 cm (length) and 5cm (width) was removed in month of March from each selected tree at the breast height of 1.37m from the ground level (Fig. 1a-b). The renewed bark was harvested twice after completing its regeneration at the interval of nine months and brought to the laboratory in order to compare the anatomy of original bark with regenerated bark from same trees.

Anatomical measurements: In the laboratory, both original and regenerated bark (after first and second harvest) were converted into rectangular blocks and then transverse and tangential sections were cut with a sliding microtome, and anatomical observations were made at 4x, 10x and 40x objectives under a Leica trinocular microscope. Ray parameters (Ray width, ray height and ray frequency) were measured from the slides of tangential sections at 10x objective. However, tissue proportions (Phloem fibre, ray and sieve tube proportions) were determined by point sampling method under an eyepiece scale (11-point micrometer scale) attached with a Leica stereo-zoom microscope (Rao et al 1997). The slides of transverse section were moved randomly at 10 places using a 10x objective to identify and record the different tissue proportions. For the measurement of fibre dimensions such as length, width, lumen width and cell-wall thickness, the maceration of bark samples was carried out by Schult'z method (Jane 1956). Minimum 25 observations were taken for the measurement of fibre dimensions and tissue proportion as per IAWA guidelines (Wheeler et al 1989).

Statistics: The anatomical features of original and regenerated barks were compared using t-test to confirm the significant differences between treatments using the online statistical software package (Sheoran et al 1998).

RESULTS AND DISCUSSION

Anatomical variation between original and regenerated bark: The results of anatomical properties of regenerated bark after first and second years of harvesting was compared with original bark in *Terminalia arjuna* trees of 50-75 cm girth-class (Table 1). Results showed that there was significantly higher proportion of phloem fibres (about 52%), ray cells (about 32%) and lower proportion of sieve tubes in regenerated bark (about 17%) as compared to original bark (about 40%). Among the fibre dimensions, lumen width (about 15 µm) was significantly higher in regenerated bark than original bark; while, fibre width (26.25 µm) was higher in regenerated bark of second harvest. In fact, fibre wall thickness (6.94 µm) was found to be higher in original bark. The similar trend was also observed for the ray parameters, where ray height and ray frequency were significantly higher in original bark than regenerated bark. Interestingly, aggregate rays were observed along with uniseriate rays in the original bark (Fig. 2c); however, aggregate rays were absent in the regenerated bark (Fig. 2d).

The present comparative anatomical studies of original and regenerated bark showed that the higher proportion of

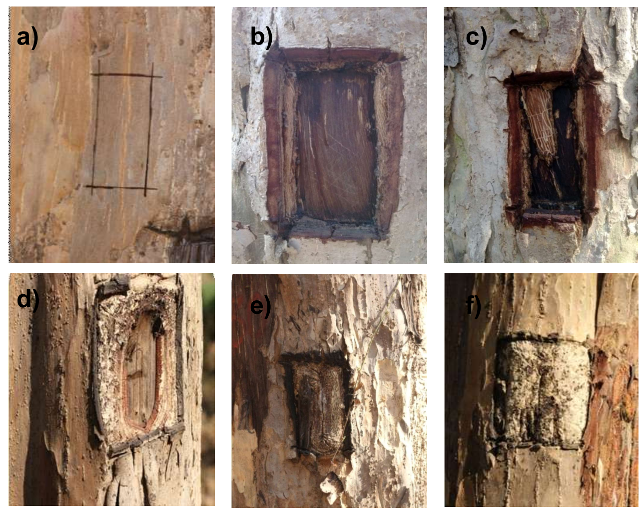

Fig. 1a-f. Regeneration process of *Terminalia arjuna* bark after harvesting

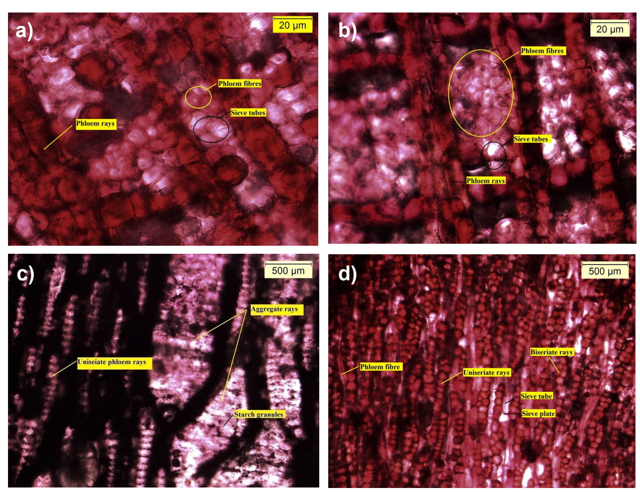

Fig. 2. Bark anatomy of *Terminalia arjuna* in Transverse Section (TS) at 40x and Tangential Longitudinal Section (TLS) at 10x objective (a) TS of original bark showing lower proportion of phloem fibres (b) TS of regenerated bark showing higher proportion of phloem fibres (c) TLS of original bark showing uniseriate and aggregate rays (d) TLS of regenerated bark showing uniseriate rays only

Table 1. Comparison of anatomical properties of original bark and regenerated bark of *Terminalia arjuna* in girth class of 50-75 cm after first and second year of harvesting

Anatomical properties	Original bark (O)		Regenerated bark at first harvest (R_1)		Regenerated bark at second harvest (R_2)		't' value		
	Range	Mean	Range	Mean	Range	Mean	(OxR_1)	(OxR_2)	(R_1xR_2)
Fibre length (mm)	0.78-1.89	1.18±0.27	0.79-1.36	1.10±0.14	0.86-1.47	1.19±0.15	1.545 ns	-0.179 ns	-2.587 *
Fibre width (µm)	16.59-27.01	22.18±3.72	18.97-28.62	22.88±2.53	20.66-37.42	26.25±4.42	-0.665 ns	-2.440 *	2.749 **
Fibre lumen width (µm)	5.40-13.03	8.29±3.21	12.92-18.33	15.77±1.72	9.97-20.27	13.34±3.39	-7.819 **	-3.720 **	-2.645 *
Fibre wall thickness (µm)	5.56-8.96	6.94±1.12	2.64-5.15	3.56±0.73	4.77-9.39	6.46±1.35	9.172 **	0.837 ns	7.818 **
Ray width (mm)	0.03-0.06	0.05±0.01	0.03-0.04	0.04±0.01	0.02-0.07	0.05±0.01	1.456 ns	-0.267 ns	-2.350 *
Ray height (mm)	0.21-0.78	0.44±0.19	0.24-0.44	0.32±0.06	0.24-0.58	0.35±0.09	2.216 *	1.927 ns	-0.756 ns
Ray frequency (Nos./mm)	6-10	9±1.17	5-9	7±1.42	5-10	8±0.77	2.984 **	0.636 ns	-3.138 **
Fibre (%)	27.27-54.54	36.36±8.57	36.36-72.73	53.64±10.01	18.18-72.72	50.00±16.18	-4.146 **	-2.356 *	0.604 ns
Ray (%)	9.09-36.36	23.64±9.77	18.18-36.36	30.91±7.48	18.18-45.45	33.64±8.62	-1.635 ns	-2.426 *	-1.007 ns
Sieve tube (%)	27.27-54.54	39.99±9.78	9.09-27.27	17.3±8.35	9.09-36.36	16.14±11.17	5.813 **	5.035 **	0.002 ns

*,** Significant at 5 and 1% level

phloem fibres and lower proportion of sieve tubes in regenerated bark may have occurred for quick healing of wounded bark and protection from the surroundings (Fig. 2b). It seems that tree gives first preference to the protection of the wounded bark than food conduction, since proportion of sieve tube is already higher in the remaining uncut bark. Hence, the protection of the wounded bark of tree from surroundings becomes the first priority to save itself from injury. Similar type of result was also reported in regenerated bark of *Hevea brasiliensis*, where, a large number of sclereids was observed in the regenerated bark (Thomas *et al.* 1995). The higher proportion of ray cells in regenerated bark was observed and it may be due to the reason that rays play a significant role in the process of wound healing by formation of wound phellogen at the site of injury (Fig. 2d). As a result of bark injury, there is an increased ethylene production in the parenchyma cells (either ray or axial parenchyma) below the cut surface that increases the growth either by cell enlargement and/or by cell division (Lev-Yadun and Aloni 1992). The increase in total width and lumen width of fibre of regenerated bark may have occurred due to dilatation of growth of cells during compartmentalization process. However, the thicker cell-wall of fibre and increase in ray height and frequency in original bark may be caused by the normal growth of the original bark.

Anatomical variation between regenerated bark of first and second harvest: Considering the regenerated bark of first and second harvests, the fibre dimensions such as fibre length, fibre width, lumen width and cell-wall thickness and ray parameters such as ray width and ray frequency varied significantly between the barks of two harvests. It was found that most of the fibre and ray parameters were higher in the regenerated bark of second harvest. This anatomical variation between regenerated barks of two harvests may be caused due to drastic change in the physiological and biochemical activities of wounded plant after repeated bark harvesting. The regrowth of injured bark is usually influenced by both vascular cambium and the polar patterns of periderm formation which is regulated by the intensity of ethylene and auxin production in wounded tree at physiological levels (Lev-Yadun and Aloni 1990, Thomas et al 1995). The comparative anatomical studies showed that sustainable harvesting in terms of strips of recommended size is feasible in Arjuna bark, since the change in the anatomical properties of regenerated bark has given priority for its protection from the surroundings by quick healing.

CONCLUSION

The wounded tree of *Terminalia arjuna* produces higher proportion of phloem fibres/ray cells and lower proportion of sieve tubes in regenerated bark as compared to original bark for fast wound healing/protection from the surroundings. The wounded tree gives first priority to the protection of the injured bark rather than food conduction through sieve tubes. Information provided in the study supports the sustainable harvesting of arjun tree bark.

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Economic Analysis of *Melia dubia* Cav. Drupe Pulp as New Alternate Feed for Small Ruminants

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Abstract: An experiment was conducted to evaluate the effect of replacing basal diet of goat kids with 20% and 40% of *Melia dubia* Cav. drupe dry pulp to ascertain its effect on body weight, dry matter intake (g day^{-1}), and growth rate, feed conversion ratio and economics of feeding. Twenty four goat kids (average 121 days old and 6.49 kg live weight) were assigned randomly to 0%, 20%, or 40% *M. dubia* dry pulp diets (8 kids diet^{-1}). The study lasted for 90 days. Total mixed rations (TMRs) replaced by *M. dubia* drupe pulp (BF; Basal feed, 20% and 40% *M. dubia* drupe pulp) did not have any significant effect on body weight, dry matter intake, growth rate and feed conversion ratio by the kids of all groups. Inclusion of *M. dubia* drupe pulp in different TMRs of kids reduced the cost of feeding. Replacement up to 40% of normal ration with *M. dubia* drupe pulp was most economical. The investigation divulged that feeding is economically beneficial without any difference in growth performance and hence *M. dubia* drupe dry pulp could be a good alternative feed source.

Keywords: *Melia dubia***,** Pulp, Feed, Goat kids, Alternate feed, Small ruminants

Agro-industrial by-products and/or alternate feeds may be economically advantageous in reducing feeding costs and can play an important role in feeding of sheep and goats. These include industrial by-products, agro-by-products, horticulture and vegetable wastes, local grasses, tree leaves, tree pods and tree fruit pulps, weeds and other non-conventional feed resources (Andrade-Montemayor et al 2011, Anon. 2012, Obeidat and Shdaifat 2013, Sirohi et al 2017). The interest in search for alternative/additional food and feed ingredients is of paramount importance mainly because of the global demand for grains which has exceeded the production and stiff competition between man and the livestock industry for existing food and feed material (McCalla 2009). Numerous tree species have been evaluated for their leaf fodder or pod feed quality and their effect on livestock and are advocated to reduce cost of feed by replacing the concentrates (Gunasekaran et al 2014, Gebeyew et al 2015, Navale et al 2017, Sirohi et al 2017). Apart from tree leaves and twigs, pods and fruits also being looked as alternate energy rich feed sources for small ruminants and cattle. However, a meager research has been done on fruit pulp of trees for nutritive value and their potential to be utilized as top feeds. Moreover, the use of alternative feed resources which are adaptive to long dry seasons is important for livestock production in arid areas globally (Gusha et al 2015).

There are a number of lesser-known and under-utilized plants that adapted to local, harsh conditions and have tremendous potential as livestock feed. *Melia dubia* Cav. is one such species, drupes of which could be utilized as top feed. It originates from the Meliaceae family. The species is indigenous to Western Ghats region in India, it is found in Bangladesh, Myanmar, Thailand, Mexico, Sri Lanka, Malaysia, Java, China, America, Philippines and Australia (Thakur et al 2018). It is valued for its high-quality termite and fungus resistant timber, used for furniture, agricultural implements and house construction, as alternative pulp wood species, fuel wood and leaf used as a fodder (Parthiban et al 2009). *M. dubia* is being planted under industrial agroforestry models and is reported to be a amenable agroforestry ideotype (Thakur et al 2018, Bhusara et al 2018) without any allelopathic effect on under-storey crops (Kumar et al 2017, Parmar et al 2018). It's fruit pulp possess many beneficial biological activities (Susheela *et al.* 2008, Sukumaram and Raj 2010). Studies suggest that the apart from possible top feed source the drupe pulp could be a good supplement for various ailments in small ruminants and livestock. While collecting the fruits for seed extraction for commercial seedling production, we observed that deer, goats and cattle browse fallen drupe of *M. dubia* from naturally growing trees in the northern Western Ghats parts in Gujarat, India. After having insight in to the literature no scientific report was encountered regarding feeding studies (either on small ruminants or livestock) of dupe pulp of this species. Hence, we took this study to evaluate the effect of feeding drupe pulp on growing kids of goat to find out possibilities of it as economic alternative feed resource during lean period..

MATERIAL AND METHODS

The present investigation was carried out in Livestock Research Station, Vanbandhu College of Veterinary Science and Animal Husbandry, Navsari Agricultural University (NAU), Navsari, in 2018. Twenty four goat kids of average 121 days old and 6.49 kg live weight were selected. These kids were distributed for three treatments (representing male and female in each treatment). The kids allotted to each treatment were statistically tested as per CRD design and were found statistically at par in age and body weight within three groups.

Three treatments were arranged in a Complete Randomized Design (CRD) with 8 repetitions. The feeding treatments were according to Indian Council of Agricultural Research, New Delhi, India (ICAR, 1998) feeding standard. Treatments were Control (Basal feed; FB), MDDP20-replacement of basal feed (Sumul dan- pelleted compound cattle feed manufactured in cattle feed factory of Sumul Co-operative Dairy at Chalthan, Surat Gujarat, India by *M. dubia* drupe pulp @ 20%) and MDDP40-replacement of basal feed with *M. dubia* drupe pulp @ 40%. Other fodders fed to experimental kids are given in Table 1 and 2. The feeding period was of 105 days. The first 15 days of the experiment were considered as preliminary period to provide adaptation time to kids for new ration. Mature fresh *M. dubia* drupes were collected from naturally growing trees in Southern Gujarat region, falling in northern Western Ghats of India. Drupes were de-pulped manually and shade dried up to constant weight. Course grounded dry pulp was stored properly. For daily feeding pulp was weighed according to feeding schedule and individually offered to kids of each treatment/group (described later) and after feeding left over was weighed. At the time of feeding of experimental feed kids were shifted in cages individually.

Dry matter intake (DMI g day^{-1}): The feeds and fodders as per the feeding schedule were weighed before feeding and offered separately to the experimental kids. Daily refused dry fodder of each kid was collected. The DMI Kg/100Kg body weight (BW) was calculated by considering body weight of animals during respective observation. The pooled observations pertaining to DMI were worked out by averaging all fortnight observations.

Body weight (BW) and growth rate: The animals were weighed at fortnight intervals, in the morning before feeding on Weigh Bridge. Fortnightly average daily gain (ADG) was calculated for all experimental kids by working out the difference of particular fortnight observation with previous observation of body weight divided by number of days between these two observations. Likewise the pooled ADG was calculated by working out the differences in body weight from first and last observation divided by number of days between first and last observation. The raw data of ADG (fortnightly and pooled) were subjected to statistical analysis.

Feed conversion ratio (FCR): FCR was calculated at the end of the experiment as per procedure described by Mamta and Sharma (2008) using the formula, FCR=Feed consumed (kg)/Gain in live weight.

Economics of feeding: All the day to day records regarding fodders, feeds and supplements supplied to experimental kids were maintained. However, the total quantity of feed ingredients for all individual experimental kids was worked out by considering feed intake/day multiplied by duration of experiment (90 days). The price of farm grown green and dry fodder fixed by Directorate of Research, Navsari Agricultural University, Navsari, Gujarat, India, was used to work out the feed cost. The actual purchase price for Sumul dan from the source was used to calculate the feed cost. The cost of feed ingredients consumed during experimental period was worked out by multiplying it with unit price of particular ingredients (Table 4). Thus, the total cost of ration for whole experimental period was calculated for every kid.

Statistical analysis: All respective observations pertaining feeding experiment were analyzed as per standard statistical procedure using Complete Randomized Design (CRD) as experimental design described by Snedecor and Cochran

Table 1. Proximate composition and mineral matter of tree fodder fed *ad libitum* to experiment kids during study period

Tree Species	CP	EE	CF	NFE	TA	P	Ca
Azadirachta indica	17.04	2.74	29.41	46.27	8.44	0.22	1.90
Leucaena leucophala	23.33	1.92	12.83	55.77	6.15	0.30	1.90
Ziziphus mauritiana	13.10	3.90	40.27	59.81	6.7 0	0.21	1.20
Hardwickia binata	10.80	3.80	27.5	47.3	10.50	0.16	2.86
Pithecellobium dulce	20.20	7.20	24.2	38.10	10.30	0.35	0.96
Samanea saman	24.70	5.90	29.2	35.00	5.20	0.26	1.28

Source: Gaikwad et al (2017); https://www.feedipedia.org/content/feeds?category=13594, accessed on 02/07/2018
CP=Crude protein; EE=Ether extract; CF=Crude fibre; NFE=Nitrogen free extract TA=Total ash; P=Phosphorous; Ca=Calcium

(1980). The means in different treatments were tested for statistical significance using Duncan's multiple range tests with significance difference of P≤0.001.

RESULTS AND DISCUSSION

Effect of feeding of *M. dubia* drupe pulp on goat kids: The findings of investigation evinced that, body weight (BW kg kid^{-1}), dry matter intake (DMI g day^{-1}), growth rate (GR g day^{-1}) and feed conversion ratio (FCR) of Surati goat kids and dry matter intake did not vary significantly (P≤0.001) among groups either fed entirely on basal feed (BF group) or 20% (MDDP20 group) or 40% (MDDP40 group) replacement with *M. dubia* drupe pulp throughout the feeding period (Table 3) after 15 (initial) and 90 days (final) of feeding.

Sirohi et al (2017) replaced standard concentrate mixture with *Prosopis juliflora* pods and found that average daily dry matter intake (DMI)/100 kg body weight did not differ among the groups. They also reported that, goats were not adversely affected in terms of growth performance. Similarly, Obeidat et al (2008) reported that final body weight, average daily weight gain (ADG) and FCR in Awassi male lambs were not affected when *P. juliflora* pods (PJP) were included at rates of 0, 10 and 20% (replacing barely grains) in lamb diets. Similarly, PJP diets offered *ad libitum* to replace the barley grain, fed to nursing Awassi ewes and their lambs, did not showed differences (*P* > 0.05) in dry matter (DM), organic matter (OM), crude protein (CP), and metabolizable energy (ME) intake among groups (Obeidatand Shdaifat 2013). Kushwaha and Rai (2011) fed babul pods *(Acacia nilotica)* to crossbred (Alpine x Beetal) lactating goats, and concluded that feeding of babul pods to the extent of 16.5% in TMR equivalent to 3% tannin in diet could be safely incorporated in the diet of lactating goats without affecting their performance. In present study also there was no effect of feeding *M. dubia* drupe pulp on growth rate of Surati goat kids due to inclusion of dried pulp up to 40%. Ratan and Sawal (2005) found that grounded siris (*Albizia lebbeck*) pod incorporated in feeding diet of rams can be moderate source of protein and energy without adversely affecting live weights and wool production of sheep.

Similar to present finding, Kaur et al (2016) supplemented wheat straw with either conventional concentrate mixture (control) or 40% KMW (kinnow mandarin (*Citrus nobilis* Lour x *Citrus deliciosa* Tenora*)* waste (KMW)) containing concentrate mixture (Treatment) in diet of local goats (age= 8-10 months; BW= 23.00 kg). The mean body weights of the animals were similar throughout the feeding trial irrespective of the diet or period indicating that nutrient supply from KMW was sufficient for maintaining the body weight of the animals. They concluded that KMW could be incorporated up to 40% level in the concentrate mixture without any effect on intake, nutrient digestibility and

Table 2. Composition (%) of concentrate, green fodder, dry fodder and drupe pulp of *M. dubia* offered to experimental kids

Attributes	Concentrate*	Green fodder**	Dry fodder*	*M. dubia* drupe pulp**
Dry matter	90.05	25.00	90.00	29.95
Organic matter	93.20	98.20	89.5	93.66
Crude protein	19.60	2.20	6.00	7.63
Crude fibre	11.20	8.00	39.00	8.31
Ether extract	2.80	0.80	1.00	5.11
Total ash	6.80	1.80	10.5	6.34
NFE	59.60	12.20	43.50	72.60

*Specifications given on Sumul Dan packaging, Sukhadiya (2018), **Sukhadiya et al (2021)

Table 3. Initial and final (After 90 days) body weight (BW), dry matter intake (DMI), growth rate (GR) and feed conversion ratio (FCR) of Surati goat kids fed on different total mixed rations (TMRs) replaced (basal feed Sumul Dan) with *M. dubia* drupe dry pulp

Feeding treatments	Body weight (BW kg/kid)		Dry matter intake (DMI g/day)		Growth rate (GR g/day)		Feed conversion ratio (FCR)	
	Initial*	Final**	Initial*	Final**	Initial*	Final**	Initial*	Final**
BF	7.01[a]	10.13[a]	333.098[a]	375.63[a]	35.83[a]	65.00[a]	20.01[a]	8.23[a]
MDDP20	7.27[a]	10.67[a]	334.205[a]	377.47[a]	47.50[a]	57.25[a]	9.49[a]	8.13[a]
MDDP40	7.20[a]	10.58[a]	334.161[a]	376.29[a]	39.17[a]	83.83[a]	10.33[a]	6.24[a]
SE(m)	0.47	0.78	2.46	2.01	8.93	16.41	4.29	1.32

BF- Basal feed; MDDP20=20% basal feed replaced by *M. dubia* drupe pulp; MDDP40=40% basal feed replaced by *M. dubia* drupe pulp; Same superscript letter in vertical columns denotes non-significant difference according to Duncan's multiple range test (P ≤ 0.001); *After 15 and **90 days of feeding nitrogen balance. In present study, *M. dubia* pulp up to 40% did not showed any negative effect on growth performance of Kids. Vijay et al (2016) fed male crossbred (Black Bengal x Beetal) kids wheat bran of control ration replaced with tamarind seed meal and found that daily DM intake of kids, body weight and average daily body weight gain between groups did not varied significantly. The results indicated that there was no adverse effect of replacement of wheat bran with tamarind seed meal in the ration of kids.

Economics of total mixed rations (TMRs): The study evinced that the cost (Table 4) of feeding was reduced due to inclusion of *M. dubia* drupe pulp in different TMRs of goat kids. 20% replacement of basal feed with *M. dubia* drupe pulp reduced total cost of TMR to Rs. 492.56 and 40% replacement reduced the feed cost to Rs. 1012.33/group (8 kids). Hence, the investigation suggests that feeding small ruminants could be economically beneficial without any difference in growth performance.

The economics of feeding small ruminants with industrial by-products, agro-by-products, horticulture and vegetable wastes, tree pods and tree fruit pulps, weeds and other non-conventional feed resources have been found economically beneficial when included in feed replacing the costlier concentrates without any effect on growth performance, production (meat, milk, wool etc.) in small ruminants and cattle. Studies on inclusion of mixed grass hay, milled and whole *Acacia tortilis* pods of pastoral goats in the arid rangelands (Lengarite et al 2014); feeding fattening Awassi lambs with diets containing PJP 200 g kg^{-1} of diet (Obeidat et al 2008) and PJP as a feed ingredient for nursing awassi ewes (Obeidat and Shdaifat 2013) have been reported to potentially reduce the cost of feed without compromising with growth and milk production.

Fifty per cent replacement of concentrate mixture similar to that of the standard concentrate mixture of PJP0 (no *Prosopis juliflora* pods) with crushed and entire PJP have been found to make diets economical by Rs. 471.50 and 521.50/quintal basis in PJPG and PJPE, respectively (Sirohi et al 2017). Vijay et al (2016) also reported that among three diets *i.e.* T_1 (concentrate feed without tamarind seed meal), T_2 and T_3 (wheat bran in concentrate feed replaced with a tamarind seed meal at the rates of 1/3rd and 2/3rd (w/w) the cost of concentrate mixture per quintal for T_1 (Rs.1540.00) was maximum followed by T_2 (Rs. 1529.00) and T_3 (Rs. 1515.00) and the cost of feed per kg live weight gain remained non-significant among three groups. They concluded that replacement of wheat bran with tamarind seed meal reduced the cost of concentrate feed. *Albizia lebbeck* pods have been found as a cheaper feed in the arid tropics and can be incorporated as moderate source of

Table 4. Cost and economics of feeding (up to 90 days) Surati goat kids fed on basal feed, and 20 and 40 per cent basal feed replaced with *M. dubia* drupe pulp

Cost of feed ingredients

Item	Cost (Rs. kg^{-1})	Source
Concentrate (Sumul Dan)	16.00	Sumul Co-operative Dairy at Chalthan, Surat Gujarat, India
Green fodder	3.00	As fixed annually by Directorate of Research, NAU, Navsari, Gujarat India
Dry fodder	4.00	
M. dubia pulp	3.00	Considered equal to legume straw, As fixed annually by Directorate of Research, NAU, Navsari, Gujarat, India

Quantity (per group, n=8) of total mixed rations (TMRs) fed to experimental kids during entire feeding experiment

Treatments (kid group)	Concentrate (kg)*	Green fodder (kg)	Dry fodder (kg)	*M. dubia* pulp (kg)	Total (kg)
BF	93.15	169.63	133.89	0.00	396.67
MDDP20	63.18	125.53	101.27	83.25	373.23
MDDP40	34.10	58.71	82.23	157.30	332.34
Total	190.43	353.96	317.39	240.55	1102.33

Cost (INR) of feeding different TMRs fed to experimental Surati goat kids during study period

Treatments (kid group)	Concentrate (Sumul dan)	Green fodder (Tree leaves)	Dry fodder (Gotar)	*M. dubia* drupe pulp	Total	Cost reduction over basal feed
BF	1490.42	508.89	535.55	00.00	2534.86	-
MDDP20	1010.90	376.59	405.07	249.74	2042.30	492.56
MDDP40	545.57	176.13	328.92	471.91	1522.53	1012.33
Total	3046.90	1061.61	1269.55	721.65	6099.70	-

BF - Basal feed; MDDP20=20% basal feed replaced by *M. dubia* drupe pulp; MDDP40=40% basal feed replaced by *M. dubia* drupe pulp protein and energy, substituting up to 40 % in the concentrate supplements without adversely affecting live weights and wool production of sheep (Ratan and Sawal 2005). Mlambo et al (2002) suggested that *Dichrostachys cinerea* pods can be used by smallholder farmers in place of expensive commercial products, with only inputs required are milling of the pods and storage. These investigations indicate that there are alternative unexplored feed sources which could as good as costlier concentrates. Similarly, *M. dubia* pulp could be a good energy rich cheap alternative feed supplement for goats in semiarid regions rangelands considering its acceptable nutritional characteristics. It can alleviate nutritional constraints in the dry season.

CONCLUSION

The results showed that *M. dubia* drupe dry pulp has a good nutrient content indicating the possibility of using it at up to 40% in goat kids diets to replace basal feed without any negative effect on growth performance. Further, inclusion of *M. dubia* drupe pulp in different TMRs of Surati goat kids reduced the cost of feeding. The *M. dubia* drupe is a good alternative/agro-industry by-product (pulp extracted from drupes to raise seedlings) as a feed source for small ruminants.

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Assessment of Major Threats for Conservation of *Anthropoides virgo* in The Thar Desert of Rajasthan (India)

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Abstract: The Demoiselle crane (*Anthropoides virgo,* Linnaeus 1758) is one of the winter migratory bird in Thar desert of India. The study aims to critically analyze the major threats and post-rehabilitation scenarios faced by the crane. The scan and focal sampling methods were used for the study of crane behavior and their threats. Powerlines are considered to be havoc when contacted take a toll on almost 50% of the crane. A total of 138 birds were injured and post-rescue treatment shows only 32% healthy Individuals and 14 % of crane mortality was observed due to dog attacks. Insecticide poisoning due to Monocrotophos is a major threat. Furthermore, change in land-use pattern remains another threat with an increase of IGNP network for agricultural expansion. This species also shows lesser improvement in rehabilitation. Post rescue rehabilitation observes the death of 49% of species and only 16% of the bird can be successfully released back into the wild. With a globally-declining trend of the majestic bird due to facing several pressures, in pertinence to their habitat, population, and above-mentioned threats. Thus, there is an urgent need for the hour to conserve this species.

Keywords: Thar desert, Demoiselle crane, Conservation, Threats

The Thar desert on the eastern range longitudinally joins the Great Sahara Desert of the western range thus, completing the Iranian Arabian desert extension. The Thar is about 640 km long and 160 km wide and shifts continuously from the southwest due to high wind velocity (Kotia 2008). It is one of the bio-geographic regions of India and is very rich in avian diversity, particularly migratory birds (Gehlot et al 2021a). Birds are ideal bio-indicators and useful models for studying a variety of environmental problems. The Rajasthan state of India harbours about 510 species of birds (Grimmett and Inskipp 2018). The Demoiselle Cranes breed on wetlands across Eurasia ranging from Eastern Europe to north-eastern China, and they migrate to the Indian subcontinent during winter. The Demoiselle Crane is one of the 15 known species of cranes in the world and is the most abundant winter visitor birds of India. It is confined to the Thar desert of Rajasthan at various artificial wetlands in Jodhpur, Pali, Barmer, Nagaur, and Jaiselmer districts. The famous winter ground of Demoiselle Crane is Khichan, where a large congregation of the visitor Crane forms every winter (Jain et al 2013). The Thar desert has a very significant Avian diversity (Gehlot et al 2021a) but, due to alarming increase of anthropogenic pressure, such as uncontrolled development and increase of urbanization, and climate change the population and diversity of bird species are on a decline (Chen et al 2011, Şekercioğlu et al 2012). Increased anthropogenic activities is resulting in habitat destruction, fragmentation and altering of the birds' habitat, thus increasing threats not only for birds but also several resident faunal species as reported by Datta (2011) and Gautam and Kafle (2007). Similarly, birds present near the lakes are affected by pollution, perturbance by anthropogenic activities, and unmaintained water bodies (Rathore and Sharma 2000). Therefore, we studied Demoiselle crane every year from September to March in the Thar Desert of Rajasthan, whose major threats have thus far remained undocumented. The objective of the present study is to assess the major threats to Demoiselle crane in the Thar desert of Rajasthan, India.

MATERIAL AND METHODS

Study was carried out in the Thar desert landscape which is situated in the extreme west of the India, which predominantly shares its border with Pakistan. Thar landscape comprises 12 districts of Rajasthan extending from 24° N and 35°5' N and 70°7' N and 76°2' E. Study area were surveyed from 2015 to 2020 each year during September to March. Sites such as wetland, riverbank, village pond, Scrubland (Oran), agricultural fields were selected. Survey site selection was done on the basis of earlier experience and from the secondary data gathered from the Forest department of Rajasthan about the presence of Demoiselle crane in the region. Demoiselle cranes were observed using 8×42 mm Bushnell H_2O binoculars. Garmin

Oregon 650 GPS was used to gather spatial information. The scan and focal sampling method were adopted to gather threats to Demoiselle Crane (Gehlot et al 2021b). The focal sampling procedure is particularly adopted for injured, sick, or bird with distinctive behaviour. Identification of the bird species was carried out using a field manual and identification guide as prescribed by (Kazmierczak 2000). A questioner survey was also executed for identification and gathering of information about threats of cranes species in the study area. Two peoples were randomly chosen from each village to be interviewee of the questioner survey irrespective of their sex, age, and occupation.

RESULTS AND DISCUSSION

During the study period the following major threats were assessed in Thar desert of Rajasthan (Table 1).

Anthropogenic pressure: Several anthropogenic pressures affect the distribution and density of migratory birds in village ponds and their other habitat in the desert region. Villagers use water from the village ponds for their domestic purposes, for cattle bathing. Excessive grazing by livestock, encroachment of habitats like oran and gauchar by residents for cultivation and developmental activities and solid waste dumped in the area adjoining the village pond all leads to major encroachment on the habitat of the cranes imposing serious threat. During the study period, changes in the migration period of cranes at different locations in the desert region. Commonly, the cranes left migrating ground in March before the onset of the summer season but during study they left Cherai village on 28 December 2017, Guda Bishnoi on 10 December 2017 and korna village on 15 December 2017, Jajiwal on 30 December 2018 and Guda Bishnoi on 25 December 2018. All locations are good wintering grounds for crane but due to anthropogenic pressure; they left before their usual time. Migration of crane is depended upon the protection by local people and the current situation of the habitat. Destruction of desert grassland and habitat fragmentation due to various anthropogenic activities like grazing by livestock, fodder collection, encroachment on orans and gauchar. The traditional water bodies of Thar desert like nadi, village pond or *talab* are going to disappear due to these above-mentioned anthropogenic activities which are making the acute effect on crane population during winter. The global avian diversity is declining constantly due to climate change and human disturbances (Chen et al 2011). Consequently, Bird Life International, (2020) has documented 1486 bird species as threatened globally and India reported 94 threatened bird species, thus ranking the seventh position. Perveen and Khan (2010) has revealed the decrementing trend in populations of Eurasian and Demoiselle Cranes due to poaching, mismanagement of natural habitats and human activities. The minimum anthropogenic interference in the ecosystem in terms of developmental activity near wetlands are the other major features that provide conducive conditions to the migratory birds (Nalawade et al 2008).

High voltage power lines: High voltage power lines are a threat for all key avian species of the Thar Desert. Power lines passing through their habitat make an extremely high collision risk for the Crane population in the Thar Desert. Seventeen cranes were injured and 11 had died due to electrocution by power lines in the Thar Desert. Recently, the High Court of the state of Rajasthan has ordered the state government to shift high voltage power lines from the feeding place of migratory birds at Khichan. Similarly, death of five Great Indian Bastard (GIB) was due to Powerline in the Jaisalmer district of Thar Desert during 2017-18. Many times, High voltage power lines are responsible for the death of bird species (Parasharya et al 2000, Sundar and Choudhury 2005). Suthar et al (2017) also observed that the power lines and windmills which are in close proximity to important bird areas and water bodies make the barrier for flying and sometimes leads to electrocution and collision causing injuries or even death to the birds. Gruiformes, particularly cranes, are on the verge of extinction due to electrical wires in America and Europe (Bevanger 1998), and at least three of the 15 existing species experience increased mortalities rates that are of major concern to endangered species and local populations in South Africa and North America (McCann and van Rooyen 2002, Wassenich 2003).

Increase of feral dog population: The population of natural predators like wolves, fox, and the desert cat is on a decline while the feral dog population has increased remarkably in the desert landscape (Chishty et al 2021, Rajpurohit et al 2011). The feral dogs are attacking more rampantly on migratory cranes and which at times become hazardous for this migratory species at different water bodies in the Thar Desert of Rajasthan. The porous area boundaries of the resting ground of cranes make it easy for stray dogs to enter from various adjoining villages and cause heavy toll on this majestic migratory bird. During the study, 29 cranes were injured and 5 were dead owing to attack of feral dogs. The 18

Table 1. Mortality and Injury of Demoiselle crane owing to different causes at the Thar desert

Total rescued	Feral dogs	Electric wire	Accident	Disease	Poison	Tangled in thread
238	34	28	20	6	138	12

episodes of a dog attack on the migratory bird (Demoiselle Crane, pelican, painted stork, and water birds) were recorded and many incidents of a dog attack on common birds like peafowl, sandgroves, dove, and vulture were also noticed. Furthermore, Dogs also attack small mammals like the hare, desert cat, gerbil as well as prey upon desert antelope viz. Chinkara, Blackbuck, and fawn of bluebull in the Thar Desert. Our findings were similar to Gehlot (2006). Gehlot and Jakher (2015) stated that the major death of Blackbuck (45%) and Chinkara (35 %) is owing to the rising feral dog population in their habitat during fawning hours. Apart from migratory birds, sometimes the feral dog attacks on Great Indian Bustard in the Thar desert (Dutta et al 2013) and in remote protected areas and former "closed areas" (Collar et al 2015). The dogs make an adverse effect on many threatened wild species which was (Doherty et al 2016, Hughes and Macdonald 2013). The alarming increase of dog population in natural habitat could have diverse and complex ecological effects, potentially influencing community dynamics. Sometimes dogs compete with predator and prey upon wild fauna (Ritchie et al 2014).

Poisoning: A total of 138 birds were fell sick due to insecticide poisoning, out of which 32% of birds rescued and later released back into its habitat. Two major incidents of insecticide poisoning were recorded during the study period after eating pesticide laden seeds. Approximately 39 Demoiselle cranes were found dead due to insecticide poisoning at Khichan on 07 November 2019, and 15 cranes were injured at Vijay Sagar pond, 16 carcasses were reported at Ratri nadi village pond and 6 birds near Lordia road, 2 cranes at the agricultural field of Khichan area and added to it 11 birds were injured and 04 were killed at Luni river basin area. Another case of crane mortality was reported where 5 were found dead and 40 other fell sick on 01 January, 2020 at Khichan village of Jodhpur. The National Centre for Avian Ecotoxicology attributed the mortality to a toxic insecticide Monocrotophos. Similarly, 15 Sarus Cranes (*Grus antigone*) were found dead due to food poisoning in Keoladeo National Park of Rajasthan (Pain et al 2004). Muralidharan et al (2017) has reported 40 Cranes dead in the Amreli districtof Gujarat during December 2012 attributed to Phorate poisoning, and a few Demoiselle Crane deaths were noted at Sakria lake due to rodenticide.

It was estimated that about 672 million birds are exposed to pesticides and 10% of these die in the USA every year (Mitra et al 2011). More than 4000 Swainson's Hawk (*Buteo swainsoni)* died in Argentina during 1995-96 (Pimentel and Burgess 2014) pertaining to the use of pesticide. Austin (2018), has reported that insecticide poisoning is one of the greatest threats to Blue Crane (*Grus paradisea)* in South Africa during 1980's and 90's as well as the cause of mass mortality for 145 Demoiselle Crane (*Grus virgo) in Mangolia.*

Land use changes: The Indira Gandhi Nahar Project (IGNP) is one of the largest canal projects in India which was constructed to convert Desert wasteland into an agricultural field. Majority of the IGNP canal lies in the north-western part of Jaisalmer District. The Major canal has a length of 257.57 Km along with the secondary canal network of 3811.82 Km which was digitized using ArcMap (Fig. 1). Canal irrigation has led to an increase in land degradation and has also up surged the weed population in the desert region. The canal lines now extended with the subsidiary branches and had reached till Desert National Park and it was observed that many exotic and local plants are also growing alongside the IGNP likewise: *Tecomella undulata*, *Eucalyptus camaldulensis*, *Acacia tortillaria, Acacia nilotica, Zizipus mauritiana, etc.* In the vicinity of IGNP canal along with adjoining protected regions of Desert National Park and the crane migrating regions 150 villages had been surveyed, and discussed for behavioural changes in cranes as perceived by locals. The demoiselle crane getting bad reputation for raiding croplands and 210 interviewees perceived it as a crop destroyer. Direct sightings of the Crane from field had concluded that 90% of the times they are either raiding on Moong (*Vigna radiata*), or Moth bean (*Vigna aconitifolia)* fields and rest on the Gram (*Vigna mungo* (L.) *Hepper*) field and rarely seen in the field of cash crops.The availability of canal water in the desert area has helped extremely in the growth of irrigated areas and has led to a substantial change in agricultural land productivity. On the contrary, the irrigation has resulted in rapid changes in the desert ecosystem. The vast extension in the cultivated area has been mostly at the expense of desert grasslands. Furthermore, it also has been noticed that, agricultural area is on the bloom near IGNP canal along with the increase in cash crop like Cotton (*Gossypium arboreum*), horticultural crops like Pomegranate (*Punica granatum*) and Date palm (*Phoenix dactylifera*), rabi crops like Mustard (*Brassica juncea*), Wheat (*Triticum aestivum*), and cumin (*Cuminum cyminum*) and medicinal plant like *Isabgol* or Desert Indian wheat (*Plantago ovata*) than that of traditional crops like Bajra (*Pennisetum glaucum*), Jau or Barley (*Hordeum vulgare*), Guar or Cluster Bean (*Cyamopsis tetragonoloba*), Gram (*Vigna mungo* (L.) Hepper), Moong (*Vigna radiata*), Moth bean (*Vigna aconitifolia),* Maize (*Zea mays*), ground nut (*Arachis hypogaea*), sesame (*Sesamum indicum*) etc. Few typical desert faunas are now seen rarely like Great Indian Bustard, desert cat, and caracal. Another effect of the increase of irrigation in the desert region is the alarming increase in the human density i.e. 165 people per square kilometre (Gehlot et al 2021a) as well as livestock populations including sheep, goats, cows, and camel which are present in the desert region along with hundreds of shepherds moving with their herds. Thus, there is insufficient habitat left for the survival of crane and desert wild fauna owing to the newly irrigated area and its occupants (Sharma 2001). It has been also mentioned that land use pattern significantly effects habitat and displacement of a bird from its native ranges (Wani et al 2021). About 27% of the total irrigated area is fed by canals, while 70% by wells and tubewells (NITI Ayog 2016) but due to irrigation, there has been an increase of the exotic *Prosopis juliflora* in the Thar Desert, leading to the decline in total productivity of grass (Gehlot and Jakher 2015). Lakshmi (2006) concluded that the arid region of Rajasthan fulfills basic food, safety, and shelter for migratory birds, although the agricultural expansion and increasing use of pesticides, fertilizers has been destroying habitat and amplifying disturbance for wildlife, (Collar 2017). Thus, owing to the growth of the IGNP, tremendous ecological changes are taking place in the Great Thar Desert of Rajasthan.

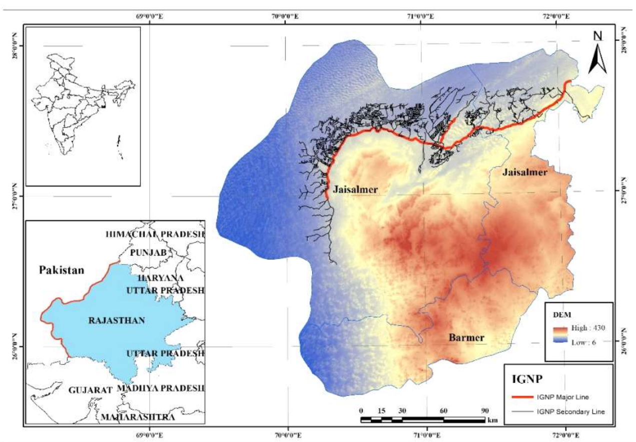

Fig. 1. IGNP canal network in Jaisalmer, Rajasthan

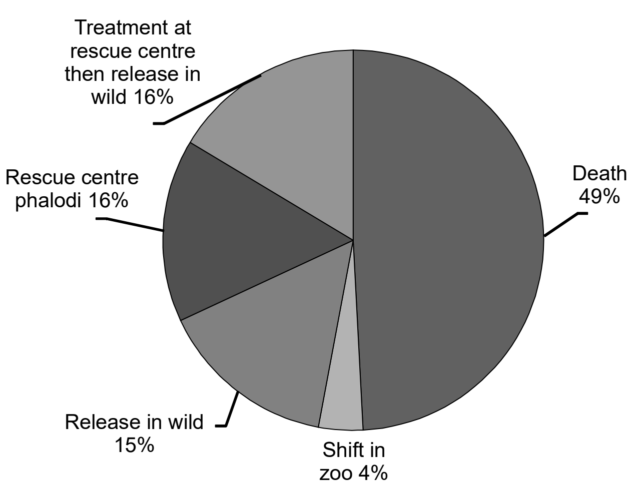

Fig. 2. Rehabilitation of rescued Demoiselle Crane

Plate 1. Anthropogenic pressure (A), Feral dog attack (B), Power line (C), and Food poisoning (D)

Poaching: Poaching is another major threat to the avian fauna.The poaching of the crane was not recorded during the study period, although author had observed that the injured cranes were captured by local tribes for their meat for consumption at Sardarsamand area in Pali district. As per the rescue centre data of Jodhpur zoo, Rajasthan. Many of the injured or dead Demoiselle Crane subjected to different causes were rescued (Fig. 2). Availability of food, location of nest sites, and nest materials and the occurrence of predators are the major factors influencing the bird population and their diversity.

CONCLUSION

Pertaining to the anthropogenic pressure, Demoiselle cranes are leaving before their usual hours. Generally, Cranes are roosting and feeding in the village common property resources leading to interspecies resource competition and sometimes conflict. Developing network of high voltage powerlines are making increased mortalities. Alarming increase of feral dog population and attacks making this species more vulnerable and need attention in present hours. Insecticide poisoning has caused large mortalities in the recent years. Abrupt landuse change is another huge attribute making impact on the feeding behaviour of the species as well as few poaching activities are reported in the different corners of this huge Thar landscape are remain unaddressed. This piece of work will facilitate to fulfil the great need of framing the diverse conservatory strategies for the reduction of various forms of anthropogenic influence over the water birds and their habitat.

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Increasing Interference of Stray and Wild Animals in Farming: Reflections from Western Himalayan Foothills

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Abstract: The problem of animal menace is a burning issue and has direct bearing on the socio-economic conditions of the people in general and farming community in particular. Therefore, the present study was conducted to examine the various aspects of animal menace such as animal species responsible, frequency of crop raiding, extent and degree of menace and crop damages. The study is based on the primary data collected from 60 farm households selected through three stage random sampling technique in Kangra district of Himachal Pradesh.The results revealed that cattle, monkey, wild boar, *sambar* and *nilgai* were the major animal species associated with crop damages. Among these, the problem of cattle was reported to be of relatively recent origin (2-5 years) compared to wild animals' menace (5-10 years). During 2009-2015, there had been a significant increase in animal population from 1.68 to 8.53 in case of stray cattle and 5.66 to 29.48 for wild animals with monkey as dominant species. As far as degree of menace was concerned, the problem of wild animals was more serious compared to the stray cattle. Further, among the wild animals the degree of monkey menace was the major concern round the year.

Keywords: Animal menace, Crop damage, Crop raiding, Stray cattle, Wild animals

Agriculture is the major source of livelihood for the majority of rural population in mountainous regions of India where the farming community generally practices mixed farming to meet their multifarious demands. With the advancement of agricultural technology and extension services, the production and income generating potential of traditional farming systems have improved through the diversification and intensification. Despite of farmers' efforts and public safety nets, farming still remains a risky venture. Since the inhabited villages and farming lands are surrounded by forests, rivulets and gorges which are natural hideouts for wild animals (monkey, *sambar*, wild boar, *nilgai,* etc.) and the fragmentation of forest lands has led to the constant increase in the human- animal conflict (Saraswathi et al 2021).Due to changes in techno-socio-economic conditions in these regions, abandoning unproductive cattle (mainly bullocks) has become a common practice. The increasing population of these animals has assumed the form of menace for the farming.

Animal menace has become one of the major threats for growth and sustainability of agriculture and its extent varies from region to region depending upon the prevalence of animal species and their population status. Among these animals, the problems of menace associated with monkeys (Chauhan and Pirta 2010, Saraswat et al 2015, Reddy and Chander 2016, Rathi and Bhatt 2020) and stray cattle (Arya et al 2019, Lal et al 2019) are more widespread and serious compared to others. In Himachal Pradesh there are 3243 panchayats out of which about 71 per cent are suffering from monkey menace and the population of stray cattle is around 32160.The conservative estimates of wildlife wing of Himachal Pradesh indicated an annual loss of worth Rs 300-450 crore in the horticulture and agriculture sectors on account of animal menace which may go upto Rs 1,500 crore if expenditure on watch and ward of crops is also accounted for. The crop loss, livestock loss and human injury or even deaths have also been reported (Karanth et al 2013). The farmers are abandoning cultivation due to stray and wild animal menace. Thus, the problem of animal menace is a burning issue and has direct bearing on the socio-economic conditions of the people in general and farming community in particular. Dev et al (2019) also reported that the problem of animal menace in Himachal Pradesh was limiting the farmers from effective use of advanced technologies. The problem needs to be tackled in a planned and systematic manner after examining and identifying the causes and key factors responsible for the ever increasing animal menace at local or regional levels. Thus, a diagnostic analysis on animal menace especially with respect to its origin, animals associated, degree of menace and extent of crop losses was conducted to provide insights for effective planning and management of animal menace at farmer and government level.

MATERIAL AND METHODS

The present investigation had been conducted in foothills of Western Himalayan region. The Kangra district of Himachal Pradesh was purposively selected for the study as it represents the average situation of the region with respect to agro-climatic conditions and has the highest number of holdings & stray cattle population among different districts of Himachal Pradesh. The study is based on the primary data collected from farming households selected through three stage random sampling design (blocks, villages and farmers). Finally, a sample of 60 farming households was drawn from the ten villages by adopting equal allocation method. Detailed information about the origin of the animals menace, major animals responsible for crop damages, trend of the wild/stray animal population, extent of crop damages, etc. were collected from the respondents. The data were collected through personal survey method on specifically designed and pre-tested survey schedules. The data were analysed by using simple tabular method, percentages, averages and total weighted score for the interpretation of results.

RESULTS AND DISCUSSION

Origin of animal menace: The responses indicated that the problem of stray cattle was of recent origin as compared to wild animals (Table 1). The majority of respondents (62 %) revealed that the problem of stray cattle had become more serious between last 2-5 years. It may be attributed to the fact that the farmers no longer wanted to rear bullocks (being replaced by tractors and power tillers) and cattles with low productivities and abandoned them. The problem of wild animals was not serious about over 10 years back. About 67 per cent of the respondents reported that these had become more prominent during last 5- 10 years. This could be attributed to the shrinkage of fodder and other food species in forests forcing the wild animals to raid the cultivated lands (Anonymous 2012).

Animals involved in menace: The prevalence of wild animals responsible for crop losses varied from area to area. The monkey, wild boar, *sambar and nilgai* were reported to be the major wild animals responsible for crop damages (Chhangani et al 2008). About 48, 37 and 28 per cent of the respondents reported problems due to monkey, wild boar and *sambar*, respectively, while 25 per cent of the respondents encountered the problem from other wild animals such as *nilgai* (Table 2). The problem of stray cattle was reported by about 42 per cent of the sample households. The figures given in the table are with respect to major animal species responsible for menace; however, in some areas more than one species might have also caused losses.

Population pattern of stray and wild animals: The crop damages and extent of losses depends on the population of animals (wild & stray cattle) prevalent in the locality. Their population might increase or decrease in a particular area. According to the sample respondents, over the period of 2009 to 2015, there had been an increase in population of wild and stray animal raiding the crops (Table 3). The total population of wild animals prevalent in the study area (2015) was estimated at 29.48 in which the proportion of monkeys was found to be highest (55.51%) followed by wild boar and *sambar.* The population of monkeys was comparatively more as compared to the other wild animals mainly because they are not hunted/killed by the locals on account of religious reasons. Saraswat et al (2015) also observed the Human-rhesus macaque monkey conflict as a major problem affecting northern India, particularly the states of Himachal Pradesh and Uttarakhand. Similarly the population of stray cattle increased from 1.68 during 2009 to 8.53 in 2015. The population of wild animals, especially monkeys and stray cattle, is increasing continuously and may have adverse impact on farming in the years to come.

Herd size of animals: Larger the size of herd, higher will be the extent of crop damages. It was reported by the majority of respondents that total population of herd prevalent in an area was not important for crop losses but the extent of damage is usually directly related with the number of animals actually raiding the crops (Table 4). It was found that among the

Table 1. Response of farmers regarding origin of animal menace

Particulars	Number	
	Wild animals	Stray animals
2yr back	-	-
2-5 yr back	16 (26.67)	37 (61.67)
5-10 yr back	40 (66.67)	23 (38.33)
>10 yrs	4 (6.67)	-
Total	60 (100.00)	60 (100.00)

Figures in parentheses indicate percentages to total in each category

Table 2. Distribution of respondents with respect to animals responsible for menace

Particulars	Number	Per cent
Wild animals		
Monkey	29	48.33
Sambar	17	28.33
Wild boar	22	36.67
Any other (*Nilgai*)	15	25.00
Stray animals		
Cattle	25	41.67

different animals, the herd size raiding the fields was found to be highest in case of monkeys (7.50) ranging from 5-12 in number followed by cattle (3.78) and wild boar (3.28) ranging from 3-6 and 2-6, respectively. However, the crop raiding by other animals like *Sambar* and *Nilgai* was comparatively lower. Though the animal population in the locality was more yet they attacked in smaller numbers. The smaller groups might allow them to easily escape from the fields after causing the damage to the crop fields.

Resting and entry points for wild/stray animals: Majority of respondents mentioned that animals enter the village and (or) farmers' fields through some common entry points. As the number of entry points leading to the crop fields increases the entry of crop raiding animals becomes easy and safe, while watch & ward of crop fields become difficult. It was also observed that the fragments nearer to the entry points were more prone to damage as compared to the fragments situated far away from the entry points. Monney et al (2010) recommended growing of plants that are undesirable to the animals close to the boundary to act as buffer. It was found that on an average there were about 3.6 and 2.4 entry points for wild and stray animals, respectively in the sample villages. It was reported by majority of respondents that these animals usually rest at some preferred places in the villages in case of stray cattle and nearby hideouts in case of wild animals. The total number of resting or hiding places was found to be about three in case of stray cattle whereas there was no common resting/hiding spot near fields/ villages in case of wild animals.

Frequency and time of visit of wild and stray animal: The study revealed that the animals visited the fields at different crop stages as per their preferences. Stray cattle, *sambar* and *nilgai* visited the fields in any of the crop growth stages as they feed on the vegetative growth but wild boar and monkeys feed on tubers, maize cobs, etc. and usually raided and damaged the crops at reproductive stages. In case of wild animals, monkey damaged the fields during the day time while other wild animals such as wild boar, *sambar* and *nilgai* raided the fields during the night time, whereas both the day and night hours were preferred by the stray cattle for raiding the crop fields (Table 5). Wild/stray animals visited the crop

Table 4. Average size of herd raiding crop fields on sample farms

Particulars	Number	Range (Number)
Wild animal		
Monkey	7.50	5-12
Wild boar	3.28	2-6
Sambar	1.42	2-5
Other (*Nilgai*)	0.75	1-4
Stray animal		
Cattle	3.78	3-6

Table 5. Farmers' response regarding frequency of crop raiding by wild and stray animals

(Weekly)

Crop raiding	Day		Night	
Wild animals	No.	Percentage	No.	Percentage
Once	32	53.33	37	61.67
Twice	24	40.00	20	33.33
>Twice	4	(6.67	3	5.00
Total	60	100.00	60	100.00
Stray animals				
Once	33	55.00	34	56.67
Twice	25	41.67	24	40.00
>Twice	2	3.33	2	3.33
Total	60	100.00	60	100.00

Table 3. Pattern of population of stray and wild animals in study area

Year	Monkey	Wild Boar	*Sambar*	Other	Sub-total	Stray animal	Total
2009	3.75 (51.09)	1.27 (17.30)	0.52 (7.08)	0.12 (1.63)	5.66 (77.11)	1.68 (22.89)	7.34 (100.00)
2010	6.50 (54.90)	1.47 (12.42)	0.77 (6.50)	0.32 (2.70)	9.06 (76.52)	2.78 (23.48)	11.84 (100.00)
2011	10.08 (59.12)	2.20 (12.90)	0.83 (4.87)	0.32 (1.88)	13.43 (78.77)	3.62 (21.23)	17.05 (100.00)
2012	15.83 (61.21)	2.83 (10.94)	1.08 (4.18)	0.67 (2.59)	20.41 (78.92)	5.45 (21.08)	25.86 (100.00)
2013	18.57 (60.87)	3.18 (10.42)	1.58 (5.18)	0.9 (2.95)	24.23 (79.42)	6.28 (20.58)	30.51 (100.00)
2014	19.08 (56.72)	4.50 (13.38)	1.78 (5.29)	1.08 (3.21)	26.44 (78.60)	7.20 (21.40)	33.64 (100.00)
2015	21.10 (55.51)	4.82 (12.68)	2.13 (5.60)	1.43 (3.76)	29.48 (77.56)	8.53 (22.44)	38.01 (100.00)

Figures in parentheses indicate percentages to total in each category

fields once in a week during the day and night time. About 40 and 33 per cent of the respondents reported that wild animals' raided the field twice a week during day and night time, respectively. It was observed that the stray cattle raided the fields once a week and preferably during the night hours. Only 3.33 per cent of the respondents informed that stray cattle raided the fields more than twice. Thus, it can be concluded that crop fields were raided usually once a week by stray and wild animals during the night hours, as it was easier to raid the crops during the night hours.

Degree of menace by different animals: The degree of animal menace in the study area was not uniform; it varied with type of animals prevalent in a particular area (Table 6). It was observed that 30 and 33 per cent of the sample respondents were facing the problem of stray cattle and wild animals, respectively, while about 37 per cent of the sample respondents were having the problem of stray and wild animals both. The problem of wild animals was rated as of high degree by about 50 per cent of the farmers. Majority of farmers having the problem of stray cattle and wild animal menace rated it asof moderate (50%) and high degree (38.89 %). About 55 and 27 per cent of the sample farmers facing problems with both categories of animals reported the problem as of medium and high degree, respectively. The highest total weighted score *i.e.* 47 was observed in case of wild animals followed by both wild/ stray animal problem (46). This indicated that the problem of wild animals was more serious in areas compared to stray animals.

Seasonal pattern and degree of crop damage by animals: The pattern of crop raiding by stray and wild animals was not uniform throughout the year. It was reported to be influenced by the availability of fodder in common land, forests as well as crop stand in the agricultural fields. The fodder availability in the forests/common lands in summer and winter months was usually less and there were more chances of wild and stray animals raiding the field crops. The respondents were enquired about the degree of animal menace in different seasons of the years and the responses have been depicted in Table 7. Depending on the degree of problem, the crop raiding animals were ranked on the basis of total weighted score. The total weighted score was computed by assigning weight; 1, 2 and 3 for low, medium and high degree of problem, respectively. The analysis revealed that in summer and winter season the total weighted score was highest in case of monkey, thus the damage by monkey was more serious in these seasons followed by stray cattle, whereas the total weighted score was highest for wild boar during the rainy season, thus it caused maximum problem during this season. Rao et al (2015) have also reported enormous damage by wild boar in Southern India. In general the problem of animal menace in case of *sambar*, stray cattle, *nilgai* was found to be low in rainy season, mainly because ample fodder was available for these animals in areas other than crop fields. Similar analysis of seasonal crop raiding was also done by Prashanth et al (2013)and Warren et al (2007).

Degree of crop damage at different crop stages: The frequency of crop raids by a particular animal depends upon the preferred crops and preferred crop stages (vegetative, reproductive & maturity) of a particular crop. Among the different categories of crops *viz.* cereals, pulses, oilseeds, fodder and vegetable crops; cereals were more preferred crops by the wide range of wild and stray animals as compared to others because these crops provided fodder as well as grains of their preference. Thus, these were raided by *sambar*, *nilgai* and stray cattle throughout the entire growth period; while monkey preferred these crops especially maize at reproductive and maturity stages. Sahoo and Mohnot (2004)also specified that the major agricultural crops targeted by monkeys in Himachal Pradesh were maize, potato, wheat, vegetables and pulses and horticultural crops like apple, pear, cherries, plum, almond, walnut and apricot (Table 8, 9). Khatun et al (2013) also observed the extensive

Table 6. Degree of animal menace on sample farms

Particulars	L	M	H	Total	TWS	Rank
Wild animal	3	7	10	20	47	I
	(15.00)	(35.00)	(50.00)	(33.33)	-	-
Stray cattle	2	9	7	18	41	III
	(11.11)	(50.00)	(38.89)	(30.00)	-	-
Both	4	12	6	22	46	II
	(18.18)	(54.55)	(27.27)	(36.67)	-	-
Total	9	28	23	60	-	-
	(15.00)	(46.67)	(38.33)	(100.00)	-	-
	(100.00)	(100.00)	(100.00)	(100.00)	-	-

L= Low, M= Moderate, H= High, TWS= Total weighted score
Figures in parentheses indicate percentages to total in each category

Table 7. Degree of menace by important animals during different seasons on sample farms

Season/Animal	Low		Medium		High		Total		TWS	Rank
	No.	%	No.	%	No.	%	No.	%		
Summer										
Monkey	3	10.34	7	24.14	19	65.52	29	100.00	74	I
Sambar	5	29.41	4	23.53	8	47.06	17	100.00	37	IV
Wild boar	5	22.73	7	31.82	10	45.45	22	100.00	49	III
Cattle	2	8.00	5	20.00	18	72.00	25	100.00	66	II
Other	2	13.33	5	33.33	8	53.33	15	100.00	36	V
Winter										
Monkey	2	6.90	12	41.38	15	51.72	29	100.00	71	I
Sambar	2	11.76	5	29.41	10	58.82	17	100.00	42	IV
Wild boar	2	9.09	9	40.91	11	50.00	22	100.00	53	III
Cattle	1	4.00	10	40.00	14	56.00	25	100.00	63	II
Other	1	6.67	4	26.67	10	66.67	15	100.00	39	V
Rainy										
Monkey	20	68.97	7	24.14	2	6.90	29	100.00	40	I
Sambar	11	64.71	3	17.65	3	17.65	17	100.00	26	IV
Wild boar	11	50.00	5	22.73	6	27.27	22	100.00	39	II
Cattle	20	80.00	5	20.00	-	-	25	100.00	30	III
Other	9	60.00	6	40.00	-	-	15	100.00	21	V

TWS=Total Weighted Score

Table 8. Extent of crop damage by different animals at vegetative stage on sample farms

Particulars	Damage						
	N	L	M	H	Total	TWS	Rank
Cereals							
Monkey	55	5	-	-	60	5	V
	(91.67)	(8.33)	-	-	(100.00)		
Wild Boar	38	20	2	-	60	24	III
	(63.33)	(33.33)	(3.33)	-	(100.00)		
Sambar	43	5	12	-	60	29	II
	(71.67)	(8.33)	(20.00)	-	(100.00)		
Cattle	35	5	20	-	60	45	I
	(58.33)	(8.33)	(33.33)	-	(100.00)		
Other	45	9	6	-	60	21	IV
	(75.00)	(15.00)	(10.00)	-	(100.00)		
Vegetables							
Monkey	31	22	7	-	60	36	II
	(51.67)	(36.70)	(11.70)	-	(100.00)		
Wild Boar	38	16	6	-	60	28	III
	(63.30)	(26.70)	(10.00)	-	(100.00)		
Sambar	43	12	5	-	60	22	IV
	(71.70)	(20.00)	(8.33)	-	(100.00)		
Cattle	35	10	15	-	60	40	I
	(58.30)	(16.70)	(25.00)	-	(100.00)		
Other	45	10	5	-	60	20	V
	(75.00)	(16.70)	(8.33)	-	(100.00)		

N= Nil, L= Low, M= Moderate, H= High, TWS= Total weighted score
Figures in parentheses indicate percentages to total in each category

Table 9. Extent of crop damage by different animals at reproductive and maturity stage

Particulars	Damage						
	N	L	M	H	Total	TWS	Rank
Cereals							
Monkey	31	-	2	27	60	85	I
	(51.70)	-	(3.33)	(45.00)	(100.00)		
Wild Boar	38	-	4	18	60	62	III
	(63.30)	-	(6.67)	(30.00)	(100.00)		
Sambar	43	-	3	14	60	48	IV
	(71.70)	-	(5.00)	(23.30)	(100.00)		
Cattle	35	-	3	22	60	72	II
	(58.30)	-	(5.00)	(36.70)	(100.00)		
Other	45	-	4	11	60	41	V
	(75.00)	-	(6.67)	(18.30)	(100.00)		
Vegetables							
Monkey	31	-	7	22	60	80	I
	(51.70)	-	(11.70)	(36.70)	(100.00)		
Wild Boar	38	-	6	16	60	60	III
	(63.30)	-	(10.00)	(26.70)	(100.00)		
Sambar	43	-	5	12	60	46	IV
	(71.70)	-	(8.33)	(20.00)	(100.00)		
Cattle	35	-	10	15	60	65	II
	(58.30)	-	(16.70)	(25.00)	(100.00)		
Other	45	-	3	12	60	42	V
	(75.00)	-	(5.00)	(20.00)	(100.00)		

N= Nil, L= Low, M= Moderate, H= High, TWS= Total weighted score
Figures in parentheses indicate percentages to total in each category

damage of fruit crops by monkeys in Bangladesh.

Vegetative growth stages: The vegetative stage suffered damage on account of trampling by monkeys and eating of leaves by wild boar, *sambar*, *nilgai* and stray cattle. In this stage, low level of damage in cereals by monkeys was reported by about eight per cent of respondents while it was of medium level in case of wild boar, *sambar* and stray cattle as indicated by about 3, 20 and 33 per cent of the respondents, respectively. In case of vegetables, about 37, 27, 20, 17 and 17 per cent of the respondents reported low degree damage by monkey, wild boar, *sambar*, stray cattle and others, respectively. The magnitude of TWS for different animals indicated that during vegetative crop stage stray cattle was at rank-I as far as losses to the crops were concerned. On the other hand, monkey was the least damaging at this crop stage.

Reproductive and maturity stage: In case of cereals and vegetables, damage to crops was both by trampling and consumption of vegetative parts of cereals and vegetables by animals. Among all the stages of cereals, reproductive and the maturity stages were the most vulnerable to damage by animals. About 45, 30, 23, 37 and 18 per cent of the respondents reported high damage during the maturity and reproductive stage in cereals by monkey, wild boar, *sambar*, cattle and others animals, respectively. In case of vegetables about 37, 27, 20, 25 and 20 per cent of the respondents reported high damage by monkey, wild boar, *sambar*, stray cattle and others animals, respectively. The crop damages by monkeys were reported to be highest for both the cereals and vegetables during the reproductive and maturity stages followed by cattle, wild boar, *sambar* and other animals.

CONCLUSION

In the recent years the animal menace has emerged as a major threat for the sustainability and progress of farming in hilly regions. The study revealed that monkey, wild boar, sambar, *nilgai* and stray cattle were major animals responsible for crop losses. The problem of stray cattle was relatively of recent origin compared to wild animals. Although the animal population was high yet the size of herd raiding fields and damaging crops was relatively small. The frequency of crop raiding by wild and stray animals was once a week. As far as the degree of menace was concerned, half of the respondents felt that the menace of wild animals was of high degree while it was of medium category for stray cattle, which indicated that menace of wild animals was the major issue in the study area. The season wise analysis of the degree of menace indicated that among the major animals, monkey was reported to be the highly crop damaging animal in all the seasons (summer, winter and rainy). Next to monkey, stray cattle in summer and winter seasons and wild boar in rainy season were reported as major animals responsible for menace. Stray cattle, *sambar* and *nilgai* were damaging the crops during all stages while monkey and wild boars damaged the crops during reproductive/maturity crop stage. In vegetative growth stage of cereals and vegetables, cattle caused highest loss to crops while during reproductive and maturity stages of the cereals and vegetables, monkey were responsible for highest extent of losses. Thus, these findings can be used in tackling the growing problem of animal menace to keep alive the avocation of farming in hills.

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Assessment of Floristic Diversity and its Structural Composition in South Gujarat

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Abstract: The study deals with the status of floristic diversity and its structural composition in South Gujarat, Tehsil-Mandvi. District-Surat, Stratified random sampling method was used for vegetation assessment. Total 77 plant species were recorded from the study site out of that total of 47tree species, 20 shrub species, 3herbs, 2 climbers, 2 grass and 1 weed species belonging to 18 families. Vegetation analysis revealed that plant communities were dominated by the family Lamiaceae, Rhamnaceae and Asteraceae which indicatea huge difference in site conditions. The higher level of diversity and the high basal area of woody plant species representthe good condition of the forest. However, the effect of anthropogenic activities and stresses areobserved so that proper management for maintaining or enhancing the present species diversity is needful. *Butea monosperma, Tectona grandis, Terminalia arjuna*and*Terminalia crenulata* were the most dominant species documented from the study site which containsthe highest biomass and carbon. Nearly all the specific plant species show the contagious distribution pattern. The value of the Shannon index shows the extremely high diversity of all the plant habits except shrub species.

Keywords: Floristic diversity, Structural composition, Species diversity, Biomass, Carbon sequestration

Biodiversity is critical for the survival of humans, economic wellbeing and the functioning or stability of the ecosystem (Singh, 2002). The diversity of trees provides resources and habitat for nearly all other life forms of forest. The tree species diversity varies significantly with the variation in biogeography and habitat disturbance (Ali et al 2018). Diversity at all structural levels, changing from the genetic diversity of the ecosystem in a landscape, contributes ultimately to global biodiversity. In particular, species diversity has functional importance, because the number and types of species existing at any place determine the organismic characteristics which influence the ecosystem process (Chapin Iii et al 2000). Floristic diversity within a specific area is referred to as the variety of plant species scattered in a particular area, which is based on climate conditions, the appearance of vegetation and biotic influences (Gaston and Spicer 2013). A complete report of plant species existing in any geographic region is very essential for the identification of characteristic features of different types of land use classes. Floristic diversity is a reflection of environmental conditions, physiognomy and biotic influences (Ali et al 2018)· Besides, floristic diversity is a vital foundation for most of our terrestrial ecosystems. Human beings and faunas are completely relying on plant species, by the means of energy source over their capability for converting the sun's energy by the process of photosynthesis. However, due to anthropogenic activities, urbanization, climate change and over-exploitation of natural resources, people are becoming gradually dissociated from nature.

To assess the plant biodiversity of an area vegetation/phytosociological analysis is the crucial activity as a state of vegetation. This data not only describes the health of the commons but also determines the range of resources available that its provisions and the composition of users. The structural analysis encompasses the study of vegetation and its internal "social" relationships and also provides information on classifications of plant communities' composition and successional relations.

Forests regulate local and regional rainfall and also play a major role in slow down global warming by storing or sequestering carbon (Eliasch 2008). Consequently, they impact global atmospheric carbon levels and, in turn, are influenced by atmospheric carbon levels and related climate change (Kellogg 2019). Mandvi forest can play in the mitigation of climate change via carbon sequestration and help in the proper management of the forest with positive implications for forest conservation. Understanding the economic value of carbon sequestered in forests is important in addressing the risk of global climate change that has presented a profound challenge to the international community. The forest needs to be saved from the pressure of human activities such as illegal cutting, cultivation, overgrazing, encroachment, poaching and increased human-wildlife conflicts. Currently, Forest was protected by local, government, and forest departments for the resources and economic benefits of the forest. The forest area which is being protected by the community too but the proper management of this forest area is crucial for the survival of people who directly depend on the forest for their livelihood. Therefore, to protect the forest ecosystem, research on biodiversity with a participatory approach for the conservation and management of forest resources is essential. The present study will highlight the current status of vegetation and its structure in the forest.

MATERIAL AND METHODS

Site selection and data collection: The study site was selected using ground inventories and present study has been carried out in selected villages of Mandvi (Tehsil), Surat (District), South Gujarat region (Fig. 1). Mandvi is situated at an altitude of 50 meters and 113 km (Arial distance) from the sea coast. Villages named Regama, Raghipura, Khodamba, Kalibel, Titoi and Parva of Mandvi were selected for data collection. These villages are in a tribal area with average annual rain is 1701.8 mm. The area has a dry deciduous type of forest. Commercial land use is broadly mixed type. However, in another part of the town slum area, agricultural land, wasteland, and hilly area are also present.

Field survey and vegetation sampling: Floristic diversity and assessment survey has been carried out in the forest region of Mandvi. A total of 50 plots were taken for vegetation data collection by using stratified random sampling. The vegetation study was carried out on the selected sites during December 2018 to January 2019. The collected unidentified plants are dried and pressed properly. The moisture on the plants was absorbed by a clean paper. After that, the plant herbarium sheets were made for further identification. The inventory of plants was identified using the digital flora of Gujarat website (www.gujaratflora.com) and GEER Foundation, Gandhinagar.

Measurement of diameter at breast height (DBH): All the vegetation such as trees, shrubs, herbs and grasses were considered for the structural composition analysis. The sample plot size was set to 314 sq. meters (10×10 meters) quadrate for trees having a girth above 10 cm at breast height (DBH). A subplot of 28 sq. meters quadrate (3×3 meters) was nestled within the sample plot to get the information of shrubs, saplings/regeneration (<10 cm DBH) (Stohlgren et al 1995).

Structural composition: Various measures of the physiognomy of the area such as basal area, density, abundance, frequency, dominance, diversity indices, and importance value index (IVI), density per hectare and abundance to frequency ratio were examined. In specific, IVI is considered as one of the most significant ecological attributes for understanding the community (Ratter et al 2003). IVI is based on the total sum of relative frequency, relative dominance and relative density. IVI of the particular species in the ecosystem exhibits their dominance in trapping the available resources. The higher value of IVI shows the higher dominance of particular species that reflecting the maximum utilization of available resources. Species diversity was determined by Shannon index (H), Simpson's index of diversity (1-D) (Shannon and Weaver 1949), (Kerkhoff 2010). Regenertion status of the forest was examined according to Dhaulkhandi et al (2008) and Tiwari et al (2018) by comparing seedlings and saplings with the matured woody tree species that means the regeneration status is good), if seedlings > saplings > mature (fair regeneration), if seedlings > or ≤ saplings ≤ mature species (poor regeneration), if the species survives only in sapling stage (saplings may be ≤ or ≥ mature); and if a species is present only in an mature woody plants form it is reflected as not regenerating status.

Shannon and Simpson index: The Shannon index (H') was calculated by the following equation.

$$H' = -\sum_{i=1}^{s} p_i \ln p_i \qquad (1)$$

The Simpson index (D) was calculated by the following equation.

$$D = \frac{1}{\sum_{i=1}^{s} p_i^2} \qquad (2)$$

Where p_i = ni/N; ni is the number of individual trees present for species i, N is the total number of individuals, and S is the total number of species (Shirima et al 2015).

Biomass: Sample plots with diameters of 10-meters were taken from the forest to estimate the above-ground tree biomass by using non-destructive methods. DBH and height (in meter) of all the tree species within the plot were noted and extrapolated for the entire study area. The equation developed by(Brown, 1997)was used for calculating the biomass for the tree species.

Tree Biomass (kg) = $Exp^{[-2.134+(2.530\times \ln D)]}$(3)

Where following assumptions were used for the calculation of biomass of dominant species.

Volume (meter^3) = (3.14×DBH×DBH×height)/4 (4)

Conversion of green weight to volume of wood is 1 meter^3 and weight 2118 kg. The dry weight of wood was taken 46% of the green weight.

Estimation of forest carbon: The carbon sequestration value was calculated. The carbon content equals to 45-47% of dry biomass (Aalde et al 2006) (IPCC 2006, Tewari and Karki 2007).

CO_2 Stock = Biomass (ton/ha)×45/100 (5)

RESULTS AND DISCUSSION

The local inhabitants depend on the forest for grazing and forest product (firewood, fodder and other products are Timaru leave for making bidis and fruits of Mahuda for making alcohol, Kadaya tree mainly for Gum). The fuelwood is collected by communities together twice a year, first before the rainy season and second after the harvesting season. Forest has no entry restriction and grazing restriction to the forest area but the community also conserved the forest and protects the forest resources for their better livelihood.

Plant species: The 77 plant species were recorded from the study site, tree species, 20 shrub species, 3 herbs, 2 climbers, 2 grass and 1 weed species belonging to 18 families were recorded from the study area (Table 1). The structural composition of the plant species includes a total 61% of tree species, 26% shrub, 4% herbs, 5% climbers, 4% of grass were distributed at the study site (Fig. 2). The area was covered by the highest percent of mature woody trees followed by shrub, herbs. Climbers and grasses. The percentage of grasses, herbs, and climbers is less may be due to overgrazing and the autumn season. So there is an urgent need to focus on the newly planted species.

Structural Characteristics

Tree: The 49 species of mature trees were recorded and the importance value index (IVI) showing that *Butea monosperma* (17.85%) was dominant and this species exploited maximum resources across all the sites, (Table 2) followed by *Tectona grandis*, *Terminalia arjuna* (total), *Terminalia crenulata*, *Miliusa tomentosa*, Azadirachta indica. All the three attributes relative density, relative frequency, and relative dominance are high for *Butea monosperma, Tectona grandis, Terminalia arjuna,*and *Terminalia crenulata showing* that these species are well distributed in the area. Higher value of relative frequency as compared to relative dominance and relative density of *Terminalia crenulata* & *Milius tomentosa* shows that small trees of this species frequently occurred at the study site. Less value of all three attributes of including IVI of rest of the species indicate that only a few numbers of rest of the species were present at the study area. The distribution pattern of species was determined by the ratio of abundance to frequency if the ratio is below 0.025 then it indicates regular distribution, between 0.025-0.050 indicates the random distribution, and when exceeds 0.050 indicates contagious distribution (Curtis 1956).

Regeneration status: About 25 species of saplings were present at the study site (Table 3). Importance value index (IVI) showing that *Butea monosperma* (31% of total) is dominant like tree habit and *Tectona grandis*, *Canavalia ensiformis*, *Dyospyros melanoxylon*, *Terminalia arjuna*, *Acacia catechu* are co-dominant species. All the three attributes relative density, relative frequency, and relative dominance are high for *Butea monosperma, Tectona grandis, Canavalia ensiformis* and *Dyospyros melanoxylon* showing that these species are well distributed in the area. Higher value of relative frequency as compared to relative dominance and relative density of *Terminalia arjuna* & *Acacia catechu* shows that saplings, these species frequently occurred at the study site. Less value of all three attributes of including IVI of rest of the species shows that only a few numbers of rest of the species are present at the study area. In the present study area the regeneration status is also poor regenerating status because the seedlings ≥sapling≤ mature woody trees.

Shrubs: Nine species of the shrub were recorded from the study area (Table 4). Importance value index (IVI) showing

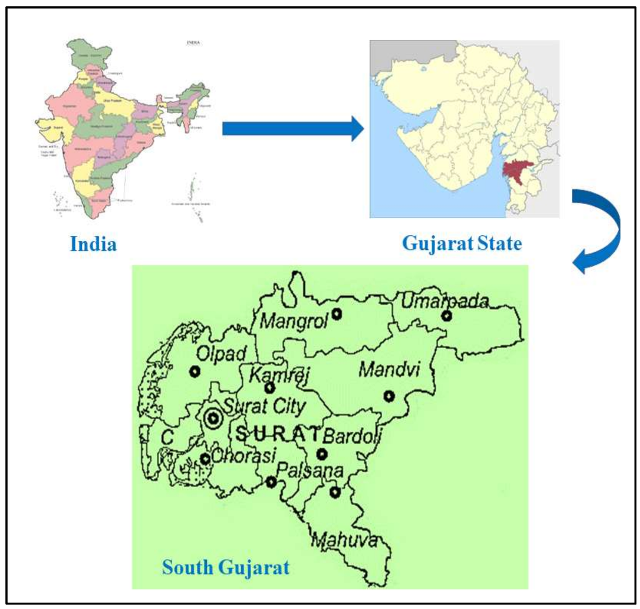

Fig. 1. Map of the study site

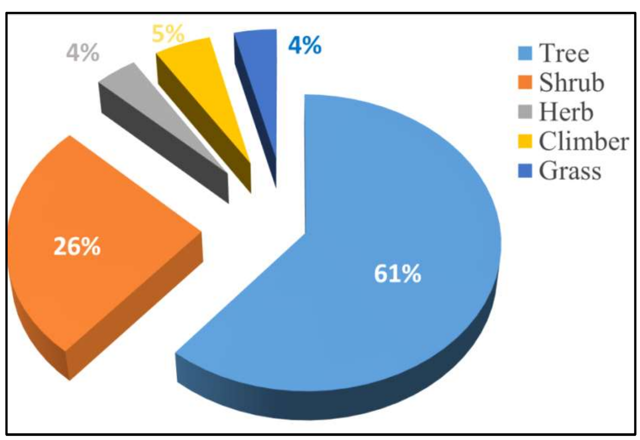

Fig. 2. Percent wise distribution of plant species

Table 1. Plant species recorded from the study site

English name	Botanical name	Family	Habit
Dwarf Heliotrope	*Heliotropium supinum*	Boraginaceae	Herb
Malkangani	*Celastrus paniculatus*	Celastraceae	Climber
Famado	*Canavalia ensiformis*	Fabaceae	Climber
Bhoybala	*Sida cordata*	Malvaceae	Herb
Mollugo	*Mollugo verticillata*	Mollunginaceae	Weed
Bamboo	*Bambusa vulgaris*	Poaceae	Long grass
Asi, Asvel	*Ventilago denticulata*	Rhamnaceae	Climber
Devahehaldo	*Curcuma arometica*	*Zingiberaceae*	Herb
Gado	*Tinospora cordifolia*	Menispermacea	Climber
Congress grass	*Parthenium hysterophorus*	Asteraceae	Grass
Ghans	*Cynodon dactylon*	Poaceae	Grass
Karavu	*Erenthemum pulchellum*	Acanthaceae	Shrub
Ankdo	*Calotropis gigantean*	Apocynaceae	Shrub
Karamda	*Carissa Carandas*	*Apocynaceae*	Shrub
Dudhilu	*Wrightia tinctoria R.Br*	*Apocynaceae*	Shrub
Kudi	*Holorrhena antidysenterica*	*Apocynaceae*	Shrub
Kachku	*Ceasalpinia bonduc*	*Caesalpiniaceae*	Shrub
Nashedi	*Ipomea fistula*	*Convolvulaceae*	Shrub
Kamboi	*Phyllanthus reticulatus*	Euphorbiaceae	Shrub
Jungali arenda	*Ricinus communis*	*Euphorbiaceae*	Shrub
Chanothi	*Abrus pricatorious Linn.*	Fabaceae	Shrub
Kuvach	*Mucuna pruriens*	*Fabaceae*	Shrub
Babool	*Vachellia nilotica*	Fabaceae	Shrub
Nirgundi	*Vitex nirgunda*	Lamiaceae	Shrub
Pembadiyu	*Cassia tora*	*Leguminosae*	Shrub
Bor	*Zizyphus mauritiana*	Rhamnaceae	Shrub
Chanibor	*Zizyphus nummulatria*	Rhamnaceae	Shrub
Ghatbor	*Ziziphus xyiopyra*	*Rhamnaceae*	Shrub
Motabor	*Ziziphus jujuba*	*Rhamnaceae*	Shrub
Chamatoda	*Ziziphus oenoplia*	*Rhamnaceae*	Shrub
Gongadu	*Lantana camara*	*Verbenaceae*	Shrub
Kaju	*Anacardium occidentale, L*	Anacardiaceae	Tree
Mahudo	*Madhuca longifolia*	Sapotaceae	Tree
Madhlo	*Lannea coromandelica*	Anacardiaceae	Tree
Sitafal	*Annona squamosal*	Annonaceae	Tree
Umbha	*Miliusa tomentosa*	Annonaceae	Tree
Med singu	*Dolicandrone falcate*	Bignoniaceae	Tree
Gundo	*Cordia dichotoma*	Boraginaceae	Tree
Kakdo	*Garuga pinnata Roxb*	Burseraceae	Tree

Cont...

Table 1. Plant species recorded from the study site

English name	Botanical name	Family	Habit
Kojalo	*Bauhinia purpurea*	Caesalpiniaceae	Tree
Ashitro	*Bauhinia racemosa Lam*	Ceasalpiniaceae	Tree
Dhamdo	*Anogeissus latifolia*	Combretaceae	Tree
Baheda	*Terminalia bellirica*	Combretaceae	Tree
Arjun Sadad	*Terminalia arjuna*	Combretaceae	Tree
Safed Sadad	*Terminalia crenulata*	Combretaceae	Tree
Ankol/Akinu	*Alangium salviifolium*	Coranaceae	Tree
Timaru	*Diospyros melanoxylon*	Ebenaceae	Tree
Khakhro	*Butea monosperma*	Fabaceae	Tree
Garmado	*Cassia fistula*	Fabaceae	Tree
Sheesham	*Dalbergia sissoo*	Fabaceae	Tree
Karanj	*Pongamia pinnata*	Fabaceae	Tree
Gor baval	*Prosopis juliflora*	Fabaceae	Tree
Amli	*Tamarindus indica*	Fabaceae	Tree
Saag	*Tectona grandis*	Lamiaceae	Tree
Kher	*Acacia catechu*	Leguminosae	Tree
Samar	*Bombax ceabae*	Malvaceae	Tree
Neem	*Azadirachta indica*	Meliaceae	Tree
Kalohero	*Albizia labbeck*	Mimosaceae	Tree
Vad	*Ficus benghalensis*	Moraceae	Tree
Karveto	*Ficus hispida*	Moraceae	Tree
Umar	*Ficus racemosa L.*	Moraceae	Tree
Peepal	*Ficus religiosa*	Moraceae	Tree
Atayu	*Ficus amplissima*	Moraceae	Tree
Peepali	*Ficus virens*	Moraceae	Tree
Nilgiri	*Eucalyptus hybrid*	Myrtaceae	Tree
Hakano	*Bridelia retusa*	Phyllanthaceae	Tree
Amla	*Phyllanthus emblica*	Phyllanthaceae	Tree
Thumro	*Securinega leucopyrus*	Phyllanthaceae	Tree
Bor	*Zizyphus mauritiana*	Rhamnaceae	Tree
Kanabo/ Kalam	*Mitragyna parvifolia*	Rubiaceae	Tree
Anudo	*Morinda pubescens*	Rubiaceae	Tree
Kadamb	*Neolamarckia cadamba*	Rubiaceae	Tree
Bili	*Aegle marmelos*	Rutaceae	Tree
Rayan	*Manilkara Hexandra*	Sapotaceae	Tree
Arduso	*Ailanthus excels*	Simaroubaceae	Tree
Kadayu	*Sterculia urens*	Sterculiaceae	Tree
Kanajo /Kukranj	*Holoptelea integrifolia*	Ulmaceae	Tree

Table 2. Vegetation parameters of tree species

Name of species	Relative density	Relative frequency	Relative dominance	Important value Index	Abundance/Frequency ratio
Butea monosperma	21.31	14.18	18.05	53.55	0.10
Tectona grandis	18.79	10.76	13.55	43.10	0.15
Terminalia arjuna	9.71	7.82	8.69	26.22	0.15
Terminalia crenulata	5.80	5.87	4.77	16.44	0.16
Miliusa tomentosa	6.56	3.42	3.41	13.39	0.53
Azadirachta indica	4.04	4.89	3.32	12.25	0.16
Acacia catechu	4.16	5.38	2.05	11.59	0.14
Madhuca longifolia	0.76	2.93	7.71	11.40	0.08
Tamarindus indica	0.88	2.20	6.49	9.58	0.16
Eucalyptus hybrid	1.77	2.93	4.25	8.95	0.19
Ficus religiosa	0.25	0.98	7.64	8.87	0.25
Ficus benghalensis	2.27	0.98	4.29	7.53	2.25
Diospyros melanoxylon	3.15	2.93	1.23	7.32	0.35
Holoptelea integrifolia	1.77	2.44	0.88	5.09	0.28
Aegle marmelos	1.64	1.47	0.62	3.73	0.72
Bauhinia racemosa	1.39	1.47	0.75	3.60	0.61
Sterculia urens	0.63	1.47	1.27	3.37	0.28
Canavalia ensiformis	1.26	1.47	0.55	3.27	0.56
Dalbergia sissoo	1.01	0.98	1.16	3.14	1.00
Vachellia nilotica	1.01	1.47	0.65	3.13	0.44
Morinda pubescens	0.76	1.96	0.23	2.94	0.19
Ricinus communis	1.13	1.47	0.24	2.84	0.50
Andrographis paniculata	0.76	0.98	0.80	2.53	0.75
Dolicandrone falcate	0.25	0.49	1.77	2.51	1.00
Zizyphus xyiopyra	1.13	0.98	0.34	2.45	1.13
Bridelia retusa	0.63	1.47	0.33	2.43	0.28
Garuga pinnata Roxb	0.63	0.98	0.81	2.42	0.63
Mitragyna parvifolia	0.38	0.98	0.84	2.19	0.38
Lannea coromandelica	0.63	0.98	0.52	2.13	0.63
Ficus racemose	0.88	0.98	0.25	2.11	0.88
Terminalia bellirica	0.38	1.47	0.18	2.02	0.17
Prosopis juliflora	0.38	0.98	0.48	1.84	0.38
Anogeissus latifolia	0.38	0.98	0.19	1.55	0.38
Anacardium occidentale,	0.76	0.49	0.30	1.54	3.00
Annona squamosal	0.25	0.98	0.21	1.44	0.25
Pongamia pinnata	0.25	0.98	0.12	1.35	0.25
Carissa Carandas	0.25	0.98	0.03	1.26	0.25
Ficus virens	0.38	0.49	0.26	1.13	1.50
Mitragyna parviflora	0.25	0.49	0.11	0.85	1.00
Cassia fistula	0.25	0.49	0.11	0.85	1.00
Albizia labbeck	0.13	0.49	0.18	0.80	0.50
Cordia dichotoma	0.13	0.49	0.11	0.73	0.50
Alangium salviifolium	0.13	0.49	0.09	0.71	0.50
Phyllanthus emblica	0.13	0.49	0.08	0.70	0.50
Bombax ceabae	0.13	0.49	0.04	0.65	0.50
Manilkara Hexandra	0.13	0.49	0.03	0.65	0.50
Securinega leucopyrus	0.13	0.49	0.03	0.64	0.50
Ailanthus excelsa Roxb	0.13	0.49	0.00	0.62	0.50
Acacia leaucophlea	0.13	0.49	0.00	0.62	0.50

that *Holorrhena antidysenterica*, 70.23% of total) is dominant and which is spread all over the study site. *Holarrhena antidysenterica* is good indicator species of healthy teak forest (Majumdar et al 2012). It is primarily used for the treatment of dysentery but has several other therapeutic usages but locally it is used for fodder and fuelwood purposes. The other three species have the lowest IVI value with less Relative density, Frequency, and Dominance showing that few numbers of these species were present in the area. *Wrightia tinctoria R.Br*, *Ceasalpinia bonduc*,

Table 3. Vegetation parameters of saplings

Name of species	Relative density	Relative frequency	Relative dominance	Important value index	Abundance/ Frequency ratio
Butea monosperma	30.06	22.92	40.04	93.02	0.1
Tectona grandis	21.17	17.71	15.8	54.68	0.12
Canavalia ensiformis	8.59	7.29	9.34	25.22	0.29
Diospyros melanoxylon	6.44	7.29	3.94	17.67	0.21
Terminalia arjuna	2.76	3.13	3.27	9.15	0.5
Acacia catechu	4.29	3.13	1.43	8.85	0.78
Aegle marmelos	3.99	3.13	1.68	8.8	0.72
Morinda pubescens	2.76	5.21	0.37	8.34	0.18
Ficus racemose	0.92	1.04	6.2	8.16	1.5
Terminalia crenulata	3.07	3.13	1.75	7.94	0.56
Prosopis juliflora	1.23	2.08	3.28	6.59	0.5
Azadirachta indica	1.23	2.08	3.13	6.44	0.5
Dolicandrone falcate	2.15	1.04	2.84	6.03	3.5
Miliusa tomentosa	2.15	3.13	0.46	5.73	0.39
Cassia fistula	0.92	2.08	2.51	5.51	0.38
Holoptelea integrifolia	1.53	3.13	0.4	5.06	0.28
Cordia dichotoma	1.23	3.13	0.62	4.98	0.22
Carissa carandas	1.53	1.04	0.92	3.5	2.5
Anogeissus pendula	1.23	2.08	0.12	3.43	0.5
Mitragyna parvifolia	0.92	1.04	0.75	2.72	1.5
Manilkara Hexandra	0.31	1.04	0.94	2.29	0.5
Zizyphus mauritiana	0.61	1.04	0.04	1.7	1
Acacia leucophlea	0.31	1.04	0.07	1.42	0.5
Eucalyptus hybrid	0.31	1.04	0.05	1.39	0.5
Anogeissus latifolia	0.31	1.04	0.03	1.37	0.5

Table 4. Vegetation parameters for shrub species

Name of species	Relative density	Relative frequency	Relative dominance	Important value index	Abundance/freque ncy ratio
Holorrhena antidysenterica	76.63	53.23	80.86	210.72	0.09
Wrightia tinctoria R.Br	8.43	11.29	12.16	31.88	0.22
Ceasalpinia bonduc	4.98	11.29	3.53	19.80	0.13
Lantana camara	3.07	6.45	1.32	10.84	0.25
Calotropis gigantean	2.68	6.45	1.41	10.55	0.22
Carissa Carandas	1.15	4.84	0.00	5.99	0.17
Ipomea fistula	1.92	3.23	0.71	5.85	0.63
Vitex nirgunda	0.77	1.61	0.00	2.38	1.00
Ricinus communis	0.38	1.61	0.00	2.00	0.50

*Lantana camara*are co-dominant species followed by *Calotropis gigantean, Carissa carandus, Ipomea fistula, Vitex nirgunda and Ricinus communis* In the study area there is less number of invasive species were recorded i.e. *Prosopis juliflora* and *Lantana camara*. This is also a good indicator of a healthy forest as it secrets the chemical which suppresses the growth of other species.

Climbers/Grasses/herbs: Eleven Species of Climbers/Herbs/ Grasses /weed were recorded from the study area (Table 5). Importance value index (IVI) showing that *Bambusa vulgaris* (108.3% of total) is dominant which is distributed in patches all over the study area. *Canavalia ensiformis*, *Cynodon dactylon*, *Parthenium hysterophorus*, *Mollugo verticillata* IVI are co-dominant species followed by *Heliotropium supinum, Sida cordata, Ventilago denticulata Willd. Celastrus paniculatus, Curcuma arometica* has the lowest IVI value with less relative density, frequency, and dominance and it is showing that less in a number of these species were present in the area.

Dominant species: The total Density of all the individual tree species is higher as compared to saplings in the study area. This may be possible for these species may disappear soon in near future. The highest density/ha was recorded by *Butea monosperma* (108 plants/ha) of tree species and followed by *Tectona grandis* & *Terminalia arjuna*. But the number of saplings and regeneration were less than tree species this

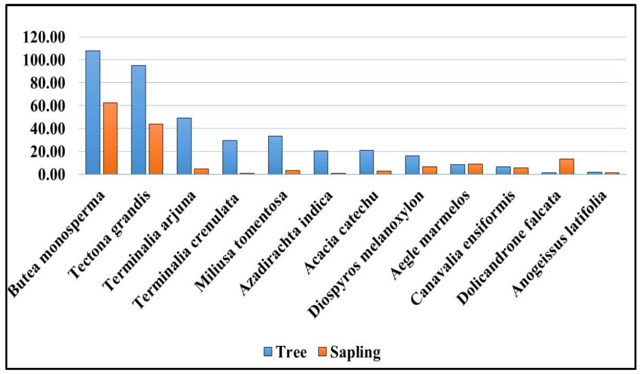

Fig. 3. Density per hectare of dominant species

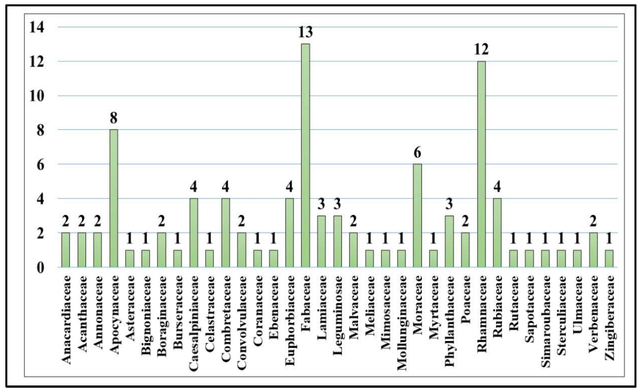

Fig. 4. Family wise number of species at the study site

Table 5. Vegetation parameters of Climbers/Grasses/Herbs

Botanical name	R.D	R.F	R.A	IVI	A/F
Bambusa vulgaris (Long grass)	17.93	4.9505	28.44	51.32	0.66
Canavalia ensiformis (Climbers)	15.76	21.78	5.68	43.22	0.03
Cynodon dactylon (Grass)	14.67	20.79	5.54	41	0.03
Parthenium hysterophorus (Grass)	13.59	18.81	5.67	38.06	0.03
Mollugo verticillata (Herb)	13.04	6.93	14.77	34.74	0.24
Heliotropium supinum (Weed)	10.33	7.92	10.23	28.48	0.15
Sida cordata (Grass)	4.891	4.95	7.75	17.59	0.18
Ventilago denticulata Willd.(Climber)	3.804	3.96	7.54	15.30	0.22
Celastrus paniculatus (Climber)	2.174	2.97	5.74	10.89	0.22
Tinospora cordifoilia (Gado) (Climber)	2.174	3.96	4.31	10.44	0.13
Curcuma arometica (Herb)	1.63	2.97	4.31	8.90	0.17

Table 6. Species diversity indices

Diversity indices	Shannon index	Simpson index**	No. of species	Diversity
Trees	2.83	0.10	49	Extremely high
Sapling	2.39	0.15	25	Extremely high
Shrub	0.81	0.65	20	Moderate
Herbs/Grass/Climber	2.16	0.12	11	Extremely high

** Lower the value higher the diversity

indicating that the forest is being utilized by the local people. *Terminalia arjuna* regeneration status was lower than tree species may be due to exploitation of the species and it is endangered species of Gujarat so it is important to the conservation of these plant species (Fig. 3). Teak has many economic benefits as it is considered to be one of the world's most important woody species due to its valuable timber (Pandey and Brown, 2000).At the study site, the member of the panchayat sell teak wood for their economic benefits.

Family wise number of species: The Lamiaceae family is mainly essential to human beings for herb species useful for medicinal properties, flavor, fragrance, valuable in food, cosmetics, pesticide, and pharmaceutical industries. Total 13 individual species were recorded higher from family Lamiaceae which by Asteraceae Moraceae, Coranaceae and Phyllanthaceae (Fig. 4) is followed by the Rhamnaceae family 12 individual plant species, followed

Diversity indices of tree/saplings/herb/shrub: It takes into account the number of species present, as well as the abundance of each species. The total of 49 trees, 25 saplings, 20 Shrub and 11 herb/climber/grass were collected (Table 6) with a diversity of Shannon index (H') 2.83, 2.39, 0.81, and 2.16 in the study area where the lower value of Simpson index also indicating that the diversity of species is higher at the study site.

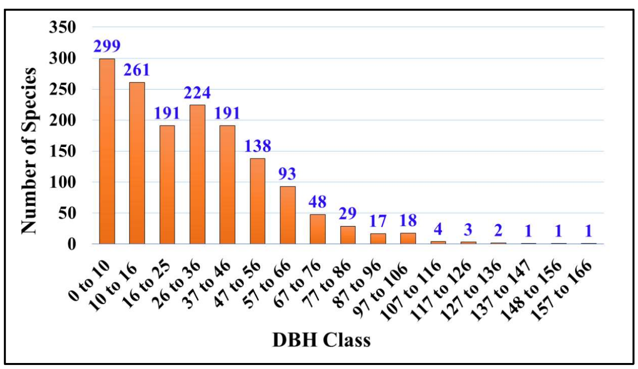

Fig. 5. DBH class of plant species

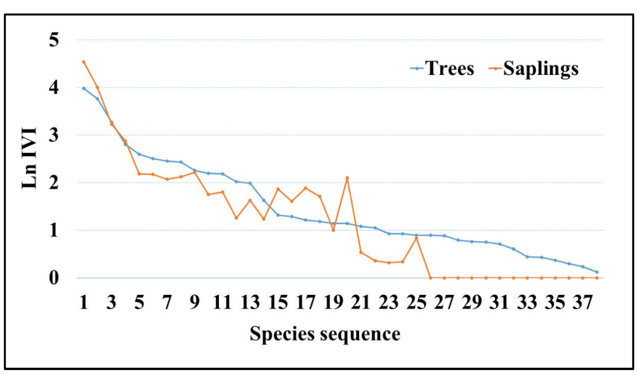

Fig. 6. Dominance-diversity curve

DBH class of plant species: DBH class of plant species in the area it indicates that the higher number of species found in the study site was between 0 to 10 cm DBH (Fig. 5). This indicates that the forest is newly planted or newly regenerated. These immature trees have the potential to absorb more carbon making higher carbon stock. However, the forest has a higher potential to grow and sequestrates more carbon. The maximum number of individual plant species was Shannon index (H') above 36cm DBH mature woody trees in the selected area that indicates the community is protecting the mature trees.

Dominance-diversity curve of tree species: The interrelationship among the species of the area with respect to the resources is tried to be understood after drawing the dominance diversity curve for the study area (Fig. 6) The diversity-dominance curve showing where species ranked from most to least abundant and the majority of the species had lower abundance and population, while few species showed higher values. *Butea monosperma* and *Tectona grandis* appeared to be the most abundant in the forest. the curve is more towards geometric series distribution exhibited log-normal condition and represents high diversity condition. This type of distribution is foundin a community where species richness is very good and all the environmental parameter is good enough for the survival of species. Besides serious past logging experience for timber, several other anthropogenic disturbances were still ongoing but to some limited extent. Grazing and fuelwood collection was more intense at the site.

Role of community participation in conserving the forest resources: Interviews were taken for the information about the village people's participation and field observation in conserving the forest resources and their utilization sustainably. All these selected villages are associated with the forest region (community reserved forest). The plantation was done by Surat Van Vibhag Samiti in a degraded forest for afforestation. The community people are very much aware of Biodiversity conservation & its act. They conserve the forest

Fig. 7. Conservation through traditional belief

Table 7. Biomass andcarbon sequestration of dominant species

Biomass & carbon stock of tree/saplings	Tree		Sapling	
Name of species	Biomass (T ha^{-1})	CO_2 (T ha^{-1})	Biomass (T ha^{-1})	CO_2 (T ha^{-1})
Butea monosperma	356	160	14	10
Tectona grandis	257	116	8	5
Terminalia arjuna	164	74	1	0
Terminalia crenulata	90	41	1	1
Miliusa tomentosa	57	26	1	1
Azadirachta indica	66	30	1	1
Acacia catechu	67	30	1	1
Madhuca longifolia	347	156	-	-
Tamarindus indica	251	113	-	-
Eucalyptus hybrid	110	49	0	0
Ficus religiosa	404	182	-	-
Ficus benghalensis	142	64	-	-
Diospyros melanoxylon	19	9	2	1
Aegle marmelos	10	5	1	1
Bauhinia racemosa	13	6	-	-
Total	2352	1058	29	21

through their traditional beliefs, customs, or religious rules (Fig. 7). The nursery was established for forest vegetation management by the Surat Municipal Corporation, maintenance of that nursery and plantation is done by local people only. It is evident from the survey, that the local people can play a significant role in conserving the forest and its resources.

Biomass and carbon sequestration of dominant species: *Tectona grandis* has the highest value of Biomass tonnes per hectares among all the species as it has the higher value of basal area and volume of a species (Table 7). The basal area is a good indicator for biomass and carbon meanwhile it combines the effect of the size and number of trees. The basal area and biomass of the species-area related to tree diameter, so, the correlation between these two variables can be expected. Among the species found in the forest area, the carbon stock was highest in species *Butea monosperma* (160 ton/ha), *Tectona grandis* (116 ton/ha). Mature woody plants capture three times more CO2. Mature trees store more carbon and are very important for biodiversity by providing shelter to many creatures to survive. They keep store carbon but no longer remove much carbon from the atmosphere as new growth is offset by some decayingof deadwood. The growing plant species capture more carbon from the atmosphere for their growth but are too small to be a significant store of carbon. So, it could be good if every year plantation should be done at the site as it is evident from the study that the saplings are less as compared to mature plants.

CONCLUSION

Floristic diversity and it structural composition of any particular forest is very much important for ecosystem stability. *Butea monosperma, Tectona grandis* and *Terminalia Arjuna* were the dominant species and less number of exotic species present at the study site. The area was covered by the highest percent of mature woody tree species is more as compared to saplingsfollowed by shrub, herbs. climbers and grasses.The overall density of saplings was less than tree species which we can understand the forest will become less dense in the near future so there is an urgent need to focus on regereration status of the forest area. The area comprises endangered species (*Terminalia arjuna, Celastrus paniculatus, Tinospora cordifolia,* with higher medicinal importance and traditional use. The conservation of these species in the natural habitat will help the local people for their primary treatment as well as an economic benefit. This study will deliver the baseline for further study in this area and the development of conservation as well as proper management strategies for important plant species.

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Genetic Diversity in *Toona ciliata* M. Roem., progenies using D^2 Analysis

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Abstract: Genetic diversity studies were carried out for morphometric attributes in sixteen progenies of *Toona ciliata*. Among the genetic resources of *Toona ciliata* a multivariate analysis was carried out using D^2 clustering technique and classified sixteen progenies into five clusters. Cluster II revealed the maximum intra-cluster distance. The maximum inter cluster distance was found between clusters III and IV which exhibits a higher genetic distance between *Toona ciliata* progenies. Volume index (81.66 percent) contributed the highest genetic divergence among the growth characters, followed by basal diameter and plant height.

Keywords: Toona, Growth attributes, Genetic divergence, D^2 clustering

Toona ciliata comes under the family is called Meliaceae, which is native to India, Australia, Indo-china peninsula, Pacific Islands and southern china. It is commonly known as Australian red cedar or Chinese mahogany (Yang et al 2020). It is a shade bearer and tree attains 30m height with well spreading crown. The wood of *Toona* is more valued because of its colour, durability and timber quality (Zhan et al 2019). The current forest and tree cover of the country is 21.67 per cent (71.22 million ha) and 2.89 per cent (9.51 million ha), respectively. The annual harvest of the timber from the forest declined from 10 million m^3 in the 1970's to 4 million m^3 in 1990 and currently it is 3 million m^3. The annual timber production of TOF is 85 million m^3 in 2020. The total wood demand of India is 153 million m^3 in 2020 and the productivity of wood is only 60 million m^3 (Shrivastava and Saxena 2017). To meet the demand of large sized wood, the policy of importing wood has been liberalized since the 1990s. Total import of round wood and sawn wood logs was 6 million cubic meters from 2014-15 to 2019-20. India imports all type of wood except pulp, paper and news prints (Rai and Chakrabarti 2001). The importing of wood increases day by day so to meet out the wood demand we need to identify and screen alternate fast growing multipurpose trees. *Toona ciliata* is the one among the best fast growing and alternative species which could be used as raw material for wood based industries.

The study of genetic diversity becomes more valuable in tree improvement programme because it increases the chances of recovering superior genotypes (Zobel and Talbert 1984). To assess the genetic divergence among the genotypes D^2 statistics has been considered as one of the most powerful technique. D^2 analysis, the superior group or individual may legitimately be used to raise profitable plantations to meet industrial wood demand. None of the studies have indicated about genetic diversity in *Toona ciliata* against this backdrop the current investigation have been carried out.

MATERIAL AND METHODS

Progenies evaluation trail was established at Forest College and Research Institute, Mettupalayam with 16 which were collected from elected Candidate Plus trees (CPTs) from 3 different states viz., Tamil Nadu, Karnataka and Punjab. *Toona ciliata* progenies collected form CPTs were planted in a Randomized Block Design (RBD) with three replications at an espacement of 4m x 4m. The details of the actual locations of the sixteen chosen candidate plus trees were presented in the Table 1.

Plant height: The plant height was measured in centimeters with the help of measuring tape from ground level to the tip of the stem.

Basal diameter: The Basal diameter was measured in centimeters with the help of digital caliper at the base of the stem (near the ground level).

Volume index: After estimating the plant height and basal diameter, the volume index was calculated using the formula below.

$$\text{V.I.} = (\text{Basal diameter})^2 \times \text{Height (cm)}$$ (Hatchell 1985, Manavalan 1990)

Estimation of genetic diversity: The data were resolved 2 months interval after planting in *Toona ciliata* progenies for evaluation of genetic diversity.

Determination of genetic divergence: Genetic divergence was calculated using D^2 statistics design. The progenies were clustered using D^2 statistical results. The parameters used in the D^2 statistics were plant height, collar diameter and volume. The mean squares and mean products between groups and within components at the progeny level were estimated using one way analysis of variance, covariance and level of significance. A variance – covariance was calculated and essential condensation was performed to obtain the linear function for transforming character mean values (x) to set of independent variables (uncorrected mean) value (y).

To calculate the D^2 square values the variation between any two mean values for any pair of progenies was squared and added. Collective D^2 square values in all possible combinations of progeny were determined for each character.

$$y_1 = x_1$$

$$y_2 = x_2 - a_2 x_1$$

$$y_3 = x_3 - a_{32}\, y_2 - a_{31}\, y_1$$

$$yp = yp - a_{pp\text{-}1}\, y_{p\text{-}1}\ldots\ldots ap_1\, y_1$$

Where,

X1 = Normalized variables

$$a_{ij} = b_{ij}/v(yj)\ S < -1$$

$$v(y_j) = \lambda\ \Sigma\ a_{(ij)}\, b_{ij} - b_{ij} = \lambda_{ij} - 1/atbt$$

$$\lambda_{ij} = \text{Covariance of i and } j_t - j_i$$

All probable n(n-1)/2 D^2 values were calculated by adding the sum of the differences between two corresponding 'y' values for two progenies at a time.

Estimation of clusters or grouping: The genotypes were classified into different clusters using the “GENERES” statistical packages based on the root of D^2 values, by using Tocher's method as recommended by Rao (1952).

Tocher's method: Tocher's method used to cluster all values. Rao (1952)

n (n-1)

……... D^2

2

Estimation of Average intra and inter cluster distance: Once clustering was achieved, the intra and inter cluster associations were arranged, and the communal associations among clusters and their distances were represented. The following formula was used to calculate the average intra cluster distances.

$$D = D^2/n$$

The average inter cluster divergences were calculated by taking into account all possible D^2 values between the records of the two clusters, where D^2 was the sum of distances between all possible combinations of progeny included in a cluster. Following that, the genetic distance 'D' between the clusters was calculated by taking the square root of the average D^2 values.

Statistical analysis: GENERES statistical package new version was used to determine the genetic diversity analysis Kanna et al (2019).

Table 1. Details of *Toona ciliata* progenies and their location

Sources	District	State	Name of sources	Latitude	Longitude
Katteri, Nilgiri hills	Nilgiri	Tamil Nadu	FCRI TC 1	11°33'31"N	076°79'7"E
Aravenu, Kotagiri stretch	Nilgiri	Tamil Nadu	FCRI TC 2	11°32'43"N	076°95'58"E
Nadugani, Gudulur division TC1	Nilgiri	Tamil Nadu	FCRI TC 3	11°47'21"N	076°41'31"E
Nadugani, Gudulur division TC2	Nilgiri	Tamil Nadu	FCRI TC 4	11°44'59"N	076°41'27"E
Pandalur, Gudulur division	Nilgiri	Tamil Nadu	FCRI TC 5	11°33'71"N	076°93'66"E
Devala, Gudular division	Nilgiri	Tamil Nadu	FCRI TC 6	11°33'52"N	076°92'50"E
Choondi, Gudulur division	Nilgiri	Tamil Nadu	FCRI TC 7	11°32'40"N	076°92'60"E
Thadiyankudisai TC4	Dindigul	Tamil Nadu	FCRI TC 8	10°29'44"N	077°70'50"E
Thadiyankudisai TC3	Dindigul	Tamil Nadu	FCRI TC 9	10°29'27"N	077°70'19"E
Pongalarmedu, Thadiyankudisai beat	Dindigul	Tamil Nadu	FCRI TC 10	10°31'98"N	077°65'40"E
Sampallioothu, Thadiyankudisai beat	Dindigul	Tamil Nadu	FCRI TC 11	10°31'03"N	077°65'29"E
Kodagu	Kodagu	Karnataka	FCRI TC 12	12°14'43"N	075°93'95"E
Ponampet	Kodagu	Karnataka	FCRI TC 13	12°14'47"N	075°94'51"E
Ludhiana TC5	Ludhiana	Punjab	FCRI TC 14	30°90'10"N	075°80'71"E
Ludhiana TC6	Ludhiana	Punjab	FCRI TC 15	30°90'10"N	075°80'71"E
TC 02	Ludhiana	Punjab	FCRI TC 16	30°90'10"N	075°80'71"E

RESULTS AND DISCUSSION

The biometric parameters viz., plant height, collar diameter, and volume index were recorded at four different growth phases viz., Initial, 60 DAP (Days after Planting), 120 DAP and 180 DAP in sixteen progenies of *Toona ciliata*. The data were examined for genetic diversity, and the results are shown below.

Genetic divergence: For all positive pairs, D^2 values were computed. The biometric characteristics of plant height, collar diameter and volume index were used to examine divergence and clustering. The sixteen *Toona ciliata* progenies were divided into 5 genetically divergent clusters.

Intra and inter cluster average distance: Table 2 depicts the average intra and inters cluster values for each of the five clusters. Cluster II revealed the highest average intra cluster value (1.546), while Cluster IV and V had the lowest (0.00). Cluster IV and III showed the highest inter-cluster value (2.941). The lowest inter-cluster value was found between clusters I and II (1.693).

According to Tewari and Singhania, (1994), the plant diversity refers to the variety and variability within an environment. To improve all kind of tree species, breeders are constantly engaged in the effective selection of desirable parents with high genetic variability so that the individuals with desirable character combinations can be selected achieved. The majority of plant species especially forestry species have very long rotation period, out crossing mechanism and huge heterozygosity which evolved a amount of natural mechanisms to keep up heterozygosity and intra specific variations. Such genetic mechanisms, combined with natural environment variations, appear to have contributed to forest species particularly in trees being among the most genetically variable organisms studied to date (Libby WJ, 1987). Traditionally the genetic diversity in trees has been done through provenance testing, enzyme electrophoresis and molecular techniques using DNA (Kertadikara and Prat 1995, Mandal and Gupta 1996, Williams et al 1990).

Cluster components: D^2 analysis classified sixteen progenies into five clusters. Table 3 exhibits the cluster members and the number of progenies in each cluster. In the five clusters, the cluster II showed highest number of progenies which is resolved with nine progenies, namely FCRI TC 3, FCRI TC 4, FCRI TC 5, FCRI TC 7, FCRI TC 8, FCRI TC 9, FCRI TC 10, FCRI TC 11, and FCRI TC 12. Cluster I had three progenies, namely FCRI TC 1, FCRI TC 2, and FCRI TC 6, Whereas Cluster III had only two progenies, namely FCRI TC 14, and FCRI TC 16. Clusters IV and V each had only one progeny, FCRI TC 13 and FCRI TC 15, respectively.

Cluster mean for each morphometric character was calculated and it is shown in table 4. Cluster IV had the highest cluster mean for plant height (556.667cm), while cluster II had the lowest cluster mean for plant height (145.620 cm). Cluster V performed best in terms of collar diameter (4.898 cm), followed by cluster I (4.794 cm), and cluster II exhibited the worst performance (3.822 cm). In terms of volume index, cluster I had the highest cluster mean value (4876.568 cm^3) and cluster II had the lowest (2410.375 cm^3). The main goal of the clustering method is to divide the pool of observations into many subgroups in order to achieve homogeneity within and between the subgroups. Genetic divergence is an important tool in the field of plant breeding for achieving desirable qualities in trees and plants. The genetic diversity estimates the degree of diversity that existed between the genotypes that were chosen.

The D^2 clustering method was used in *Toona ciliata* to segregate the sixteen progenies into five clusters; cluster II

Table 2. Intra and Inter cluster values of *Toona ciliata* progenies based on biometric attributes

Cluster	1	2	3	4	5
I	1.693	2.092	2.005	2.563	1.278
II		1.546	1.704	2.941	1.777
III			0.679	2.546	1.050
IV				0.000	2.271
V					0.000

Table 3. *Toona ciliata* cluster pattern details based biometric attributes

Cluster No	No of progenies	Members
I	3	FCRI TC 1, FCRI TC 2, FCRI TC 6
II	9	FCRI TC 3, FCRI TC 4, FCRI TC 5, FCRI TC 7, FCRI TC 8, FCRI TC9, FCRI TC 10, FCRI TC 11, FCRI TC 12
III	2	FCRI TC 14, FCRI TC 16
IV	1	FCRI TC 13
V	1	FCRI TC 15

Table 4. *Toona ciliata* cluster mean values based on biometric characters

Cluster	Plant height (cm)	Basal diameter (cm)	Volume index (cm^3)
I	197.056	4.754	4876.568
II	145.620	3.822	2410.375
III	154.917	4.585	3388.913
IV	556.667	4.657	4085.778
V	181.417	4.898	4626.987

exhibited the most progenies (nine). The results stand similar with the findings of Kanna et al (2019) classified thirty *Ailanthus excelsa* progenies into nine clusters. Cluster IV had most progenies (10 progenies) of the nine clusters. In *Neolamarckia cadamba* 20 progenies were divided into five clusters. Cluster II had demonstrated the greatest intra-cluster distance. The greatest inter-cluster distance was measured between clusters III and V (Parthiban et al 2019). According to Singhdoha et al. (2017), sixty CPTs of *Acacia nilotica* were distributed among seven different clusters, with cluster I had the most (14 CPTs), followed by cluster V. The average intra-cluster distance was found to be greatest in cluster I, followed by cluster IV and cluster II, while the inter-cluster distance ranged from 2.681 to 5.734, with cluster I and VII having the greatest distance. The genetic diversity studies classified twenty *Neolamarckia cadamba* progenies into five clusters, with cluster III having the greatest intra –cluster distance. Clusters I and IV had the greatest inter-cluster distance (Shree et al 2018). In groundnut (*Arachis hypogaea*) 93 genotypes were divided into eight clusters. Cluster VI has the most members (18), followed by cluster VII and I. cluster V had the highest intra cluster values, followed by cluster IV Dhakar et al (2017). In sorghum (*Sorghum bicolor* L.) 20 genotypes were classified into four distinct clusters. The maximum (6) and lowest (4) number of genotypes were found in clusters I and IV respectively. Clusters II and IV (150.99) and cluster III and IV (150.99) had the greatest and smallest inter cluster distances respectively Navya et al (2021).

In the present study, it was observed that progenies from various locations were grouped together to form a single major cluster, as seen in cluster II, and thus the degree of divergence was not dependent on geographic location. The above-mentioned findings also confirmed an earlier report of Kanna et al (2019), Parthiban et al (2019*),* Shree et al (2018), Singhdoha et al (2017*),* Sangram and Keerthika (2013). The presence of divergent provenances in the same cluster in nature may be attributed to factors other than geographic distribution being responsible for their genetic relationship. The intra and inter cluster recorded values indicated that IV and V had no intra cluster because they only had one progeny.

Contribution of Characters towards Genetic Divergence

Table 5 explained the percentage and number of times each character ranked first, along with their genetic divergence. The volume index contributed the most to divergence (81.667%), followed by the collar diameter (15.833%). Contribution of plant height was found to have the lowest to the genetic divergence (2.500%). The findings are in corroboration with the findings of Singhdoha et al (2017*) in* *Acacia nilotica*, Parthiban et al. (2019) in *Neolamarckia cadamba*; Kanna et al (2019) in *Ailanthus excelsa*. Volume index, along with other biometric characteristics, contributed to genetic divergence between the progenies tested, which could be due to the existence of broad genetic base (Kanna et al. 2019). Based on previous research and current findings, the Volume index for genetic divergence could be used as an index for the *Toona ciliata* tree improvement programme.

Table 5. Percentage wise contribution of each character towards genetic divergence in *Toona ciliata* progenies based on biometric attributes

Character	No. of first rank	Contribution (%)
Plant height	3	2.5000
Basal diameter	19	15.8333
Volume index	98	81.6667
Total	120	100

CONCLUSION

The D^2 analysis classified sixteen *Toona ciliata* genetic resources into five clusters. Cluster II had the most progenies among the five clusters. Cluster II determined the greatest intra-cluster distance. Cluster IV had the greatest inter-cluster distance, indicating a greater genetic distance between *Toona ciliata* progenies. Among the growth characters, volume index contributed the greatest percentage to genetic divergence, followed by collar diameter and plant height played the smallest role in the divergence.

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Impact of Livestock Grazing Pressure and Above-Ground Vegetational Changes on Yield of Caterpillar Mushroom (*Ophiocordyceps sinensis*)

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Abstract: The perceptible decline in the yield of caterpillar mushroom or Yartsa Gunbu [*Ophiocordyceps sinensis* (Berk.) Sung, Sung, Hywel-Jones & Spatafora], has taken place, primarily because of over-exploitation, and resultant habitat degradation. Does livestock grazing worsen the problem? This aspect vis-a-vis salient changes in the above-ground vegetation profile with increasing magnitude of grazing pressure remains the prime objective of the present study. Three sites- Janthri, Balmiya top, and Rukhiyan, were selected based on increasing order of magnitude of livestock grazing pressure, with the site- Janthri being treated as 'Control site', since it exhibited no grazing pressure. Care was taken, that all other parameters- slope aspects, altitudinal range, anthropogenic pressure, duration of grazing, etc, were relatively similar across the selected sites, with the only variable being the livestock grazing pressure. With 13 out of 21 palatable species and 3 out of 15 unpalatable species recorded as host plant species of the obligate host of Yartsa Gunbu, i.e., *Thitarodes balmiya* The perceptible changes in palatable plant species being replaced by non-palatable species with grazing intensity, is a cause of concern for the future viability of the host *Thitarodes balmiya*larva; as is so succinctly observed by the declining number of *Thitarodes* larval population size with grazing intensity, in the present study.

Keywords: Livestock grazing pressure, Non-palatable, Palatable species, *Thitarodes balmiya,* Yartsa Gunbu

Ophiocordyceps sinensis (Berk.) is known to infect around 60 species of lepidopteran larva, distributed across the Himalaya, and the adjoining Tibet Autonomous Region (Sung et al 2007, Wang and Yao 2011), primarily *Thitarodes* (order Lepidoptera, family Hepialidae). Yartsa Gunbu represents a mummified larva, filled and coated with mycelia of *Ophiocordyceps sinensis*, with slender, brown, club-shaped stroma, usually emerging out just above the eyes of the larva (Plate 1), and reaching a length of 8-15 cm (Negi et al 2015). *O.ps sinensis* contains a broad range of bioactive compounds, considered both nutritional as well as with proven pharmacological benefits (Holliday et al 2004). The exorbitant increase in the international price between US$ 13,000 and US$ 20,000 per kilogram depending upon the quality of the harvested lot of Yartsa Gunbu has resulted in its over-exploitation, and the resultant falling yield. Among the principal causal factors- over-exploitation (Negi et al 2016), habitat degradation (Cannon et al 2009, Negi et al 2016) and climate change (Yan et al 2017, Hopping et al 2018) are highlighted for this decline in yield. The livestock grazing pressure result in changes in the above-ground plant community characteristics or diversity (Tarhouni et al 2015, Álvarez-Martínez et al 2016). The impact of grazing pressure on vegetation phenology is defined by herbivore density (Austrheim et al 2008), productivity of the grassland (Eskelinen et al 2012) evolutionary history of grazing phenomenon (Milchunas et al 1988) and the time aspect (Olofsson 2006, Maurset 2015). The present is being carried out in *in situ* conditions, with each of the three study sites known for exploitation of Yartsa Gunbu differing in the magnitude of grazing pressure.

MATERIAL AND METHODS

Study area and grazing pressure: The present study was undertaken in three alpine meadow sites situated in the Munsiari Tehsil, District Pithoragarh, Uttarakhand, Western Himalaya, and are known habitat sites of Yartsa Gunbu or caterpillar mushroom. The altitudinal range, on average, of the three selected sites, lies approximately between 3800 and 3900m amsl, and are situated between N=30°088′46″ and E= 80°17.935′ (Fig. 1). All three sites differ in the magnitude of grazing pressure, with Janthri, experiencing no grazing pressure (on account of the presence of the poisonous species of *Aconitum lethale*) and thus were treated as the 'control site'. Balmiya top, experiencing relatively lesser grazing pressure than the Rukhiyan study site, principally on account of the relative area- larger than that of the latter (Table 1). All the study sites are separated apart, on an average of 2.5 km. The study was carried out from June till August end. The ambient temperature recorded was between 7-8°C, while the average humidity was around 50 percent that varied between a minimum of 26 percent increasing to 83 percent.

A preliminary survey of the three sites reflected a similar vegetation profile, with the average height of each site, not varying much- Balmiya Top (3822m), Rukhiyan (3792m), and Janthri (3899m), and similar slope aspect, with minor variation in Janthri. Due care was taken that the study within each broad study site is confined to sites with similar slope aspects. The livestock population size, their duration of stay, was procured from the local shepherds, frequenting the two sites- Balmiya top and Rukhiyan, over the last 10 years. Since the same number of livestock move from one site to the other, the grazing intensity could be calculated based on the duration of stay of the livestock population in each site, and the relative size of the alpine meadows. Lastly, the anthropogenic pressure, i.e., the number of harvesters, too was ascertained, which in all three sites, were more or less the same. Thus, **g**razing pressure was calculated as the number of livestock (AU- animal unit) divided by the area of the study site (Sharma et al 2021). The animal unit (AU) equivalent was calculated disjointedly for the sheep/goat (predominantly) and horse and then multiplied by their numbers (Table 1).

Phytosociology-palatable versus non-palatable species: Within each sub-quadrate (1m x 1m), phytosociology was carried out as per Misra (1968). Growth forms of plant species were studied as per Raunkiaer (1934). Palatability and non-palatability of the plant species were ascertained, through close observation (presence of the bite marks of the livestock), and through information gathered from the *Anwals* (local shepherds). All plant species were photographed and cross-referenced with the standard texts for identification (Polunin and Stainton 1984, Stainton 1988). The nomenclature of Uniyal et al (2007) was followed, which again was cross-checked with www.plantlist.org for accepted nomenclature and author citation.

Host insect-*Thitarodes balmiya* larval population size: Within each sub-quadrate measuring 1m x 1m, 3 pits measuring 1 x 1 x 1 foot (0.028 m^3) were dug and the larvae were hand sorted, across each soil profile- 0-10, 10-20, and

Plate 1. Yartsa Gunbu (caterpillar mushroom)

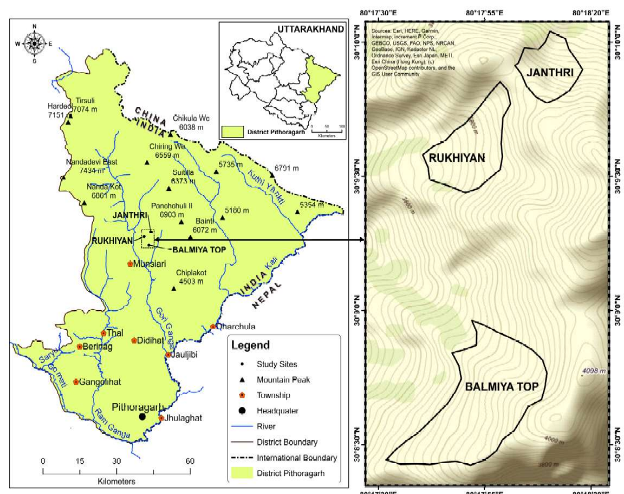

Fig. 1. Study sites- Janthri, designated as control site with no grazing pressure; Balmiya and Rukhiyan, both experiencing grazing pressure, with relatively more in case of Rukhiyan, primarily on account of the relatively smaller area than in case of Balmiya top

Table 1. Grazing pressure in the two study sites

Study site	Class of animal	Number (A)	AUE* value (B)	Total AU (A x B)	Grazing pressure (AU/Area)
Balmiya top	Sheep	2010	0.3	603	12.53
	Horse	20	1.25	25	0.52
Total					13.05
Rukhiyan	Sheep	1680	0.3	504	26.52

* AUE- Animal Unit Equivalent. The site Janthri experiencing no grazing pressure, hence not included in the table

20-30 cm depth. *T. balmiya* larva were selectively collected based on the diagnostic features, principally, the subdorsal SD1 and SD2 setae possessing a mat of microtrichia around the base of the setae (Grehan and Gargiulo 2021).

Statistical analysis: All data are represented as an average value, with statistical analyses being carried out using IBM SPSS software (version 23).

RESULTS AND DISCUSSION

Grazing pressure: The Rukhiyan study site exhibits a relatively higher grazing pressure than the adjoining Balmiya top, simply on account of its relatively lesser area, even when the livestock population size in Balmiya top exceeds that of Rukhiyan (Table 1).

Phytosociology-palatable versus non-palatable species: Altogether 36 species (33 genera, 19 families) were encountered during the study (Table 2). This number is significantly more than Devkota (2009) and Sigdel et al (2017), reporting 15 species and 10 families, and 33 species and 16 families, respectively, being associated with the caterpillar fungus. Apart from Hypericaceae, Balsaminaceae, Boraginaceae, and Liliaceae, the rest of the associated families encountered in the present study relates to those reported by several authors (Wu 1997, Zang and Kinjo 1998, Chen et al 2000, Devkota 2009, Lei et al 2011, He et al 2017, Sigdel et al 2017, Zhong et al 2014, Wang et al 2020) (Table 2). The families- Balsaminaceae and Boraginaceae, are represented by non-palatable species. Out of the 36 species, 21 species were recorded as palatable and 15 as unpalatable (Figure 2, Table 2). The number of unpalatable species shows an increase with the increase in grazing pressure (Table 2).

The dominance (calculated in terms of the abundance, density, and frequency) of the palatable species decreases with grazing pressure. In Janthri, the first 9 species in terms of relative IVI (sum of relative frequency, relative density, and relative basal cover), are all palatable. This number, declines to 8 in Balmiya site, while Rukhiyan site, the most intensely grazed site is marked out by *Megacarpaea polyandra* Benth, a non-palatable species, occupying the top second spot in IVI (Table 2). Change in vegetation profile with increase in grazing pressure becomes more conspicuous when one compares the cumulative IVI of the palatable species versus unpalatable species in each of the study sites. The cumulative IVI of palatable species exhibit a decline with an increase in grazing pressure, being 2.459, 2.311, and 2.108 for Janthri, Balmiya top, and Rukhiyan, respectively. The values for the non-palatable species exhibit an increase, to 0.488, 0.681, and 0.878 across the gradient of increased grazing pressure (Fig. 3, Table 2). Further, when one compares the two sites experiencing the grazing pressure, the average figure for abundance for all the palatable species combined, exhibit a perceptible decline- Balmiya top (22.84 m^2) and Rukhiyan (16.14 m^2), while non-palatable species exhibit a marked increase in abundance with increased grazing pressure, with values 5.5, 5.92, and 8.26 m^2 for Janthri, Balmiya Top, and Rukhiyan, respectively (Table 2).

The overall number of palatable species remains more or less constant throughout the three sites- 19-21 in Janthri, Balmiya top, and Rukhiyan, respectively, while the number of unpalatable species shows a marked increase with the increasing grazing pressure (Table 2). The increase in species richness 29, 33, and 36 in Janthri, Balmiya Top, and Rukhiyan, respectively, is primarily due to the increase in the number of non-palatable species, i.e., *Aquilegia pubiflora* Wallich ex Royle, *Megacarpaea polyandra* Benth., *Rumex nepalensis* Spreng., *Impatiens glandulifera* Royle, and *Hackelia uncinata* (Royle ex Benth.) Fisch., all non-palatable species (Table 2). In contrast to palatable species, the non-palatable species are predominated by short or tall forbs (93 percent, Fig. 4, Table 2).

Host insect-*Thitarodes balmiya* larval population size: A greater number of larvae were collected in the upper two soil profiles (0-10 and 10-20 cms). Larva population size exhibits

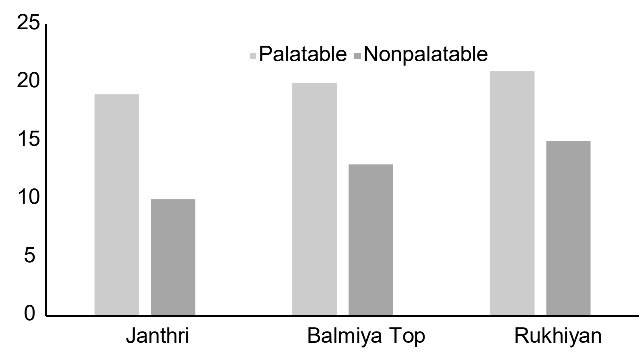

Fig. 2. Extent of the palatable versus non-palatable

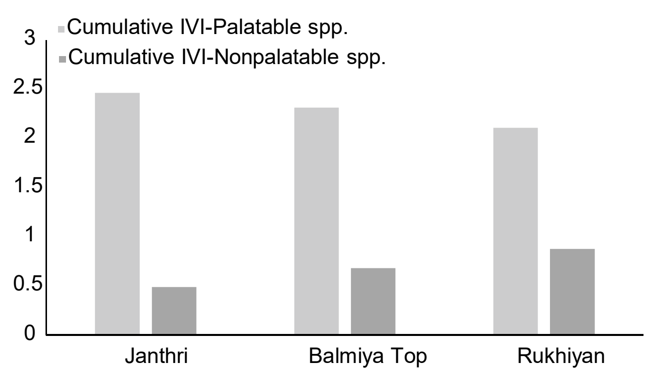

Fig. 3. Cumulative IVI of palatable species versus non-palatable species

Table 2. Comparative statement of the diversity, palatability, life and growth forms, abundance, and IVI of the species encountered in the study sites differing in the magnitude of grazing pressure

Name of species	Family	Palatability	Study sites			Life form	Growth form	Abundance (m^{2-})			IVI		
			1	2	3			1	2	3	1	2	3
Cortia depressa (D. Don) C. Norman	Apiaceae	PA	+	+	+	Th	SF	48.11	42.03	31.87	0.321	0.193	0.145
Selinum candollei Edgew.	Apiaceae	PA	+	+	+	Th	TF	2.9	2.83	2.41	0.066	0.040	0.048
Carex setosa Boott	Cyperaceae	PA	+	+	+	He	Gr	18.73	9.65	13.19	0.075	0.070	0.061
Polystichum stimulans (Kunze ex Mett.) Bedds	Dryopteridaceae	PA	+	+	+	Ge	TF	4.28	3.22	3.14	0.366	0.286	0.142
Euphorbia stracheyi Boiss.	Euphorbiaceae	PA	+	+	+	He	CF	5.8	17.5	2.8	0.020	0.057	0.020
Hypericum monanthemum Hook.f. & Thomson ex Dyer	Hypericaceae	PA	+	+	+	Ch	SF	7.02	6.0	14.27	0.078	0.043	0.054
Lloydia longiscapa Hook.	Liliaceae	PA	+	+	+	Th	G	9.69	10.75	9.58	0.038	0.027	0.048
Corydalis cashmeriana Royle	Papaveraceae	PA	+	+	+	He	SF	1.9	3.27	3.52	0.015	0.033	0.037
Poa annua L.	Poaceae	PA	+	+	+	He	G	14.96	192.75	15.39	0.173	0.176	0.154
Polygala sp.	Polygalaceae	PA	-	-	+	He	SF	-	-	52.16	-	-	0.038
Persicaria wallichii Greuter and Burdet.	Polygonaceae	PA	+	+	+	Th	TF	3.51	3.77	6.72	0.063	0.059	0.177
Primula denticulata Sm.	Primulaceae	PA	+	+	+	Th	SF	3.0	2.5	1.66	0.179	0.141	0.088
Anemone obtusiloba D. Don	Ranunculaceae	PA	+	+	+	Th	SF	5.02	7.7	5.43	0.136	0.132	0.082
Anemone tetrasepala Royle	Ranunculaceae	PA	+	+	+	Th	SF	3.43	3.56	3.94	0.106	0.094	0.093
Caltha palustris L.	Ranunculaceae	PA	+	+	+	Ge	TF	7.05	4.64	9.05	0.158	0.156	0.126
Oxygraphis polypetala (Raf.) Hook.f. & Thomson	Ranunculaceae	PA	+	+	+	He	SF	57.07	97.52	102.42	0.367	0.441	0.496
Ranunculus hirtellus Royle	Ranunculaceae	PA	-	+	+	Ch	SF	-	5.76	13.4	-	0.044	0.067
Aruncus diocus (Walter) Fernald	Rosaceae	PA	+	+	+	Ch	SF	3.7	4.9	3.66	0.024	0.029	0.011
Geum elatum Wallich ex Hook.f	Rosaceae	PA	+	+	+	Ge	SF	7.63	7.93	9.13	0.152	0.147	0.106
Potentilla atrosanguinea G. Lodd. ex D. Don	Rosaceae	PA	+	+	+	He	SF	11.7	14.88	3.37	0.073	0.059	0.020
Potentilla lineata Trevir	Rosaceae	PA	+	+	+	Ge	CF	28.16	15.72	31.76	0.049	0.084	0.095
Average value of all palatable combined								12.82	22.84	16.14	0.13	0.11	0.10
Seseli roylei (Lindl.) Pimenov & Kljuykov	Apiaceae	NP	+	+	+	Th	SF	1.94	2.16	4.31	0.079	0.091	0.072
Anaphalis triplinervis (Sims) Sims ex C.B. Clarke	Asteraceae	NP	+	+	+	He	SF	6.2	4.37	3.12	0.010	0.022	0.015
Ligularia amplexicaulis DC.	Asteraceae	NP	+	+	+	He	CF	5.16	3.94	4.94	0.077	0.106	0.051
Impatiens glandulifera Royle	Balsaminaceae	NP	-	+	+	Th	TF	-	6.0	19.11	-	0.069	0.119
Hackelia uncinata (Benth.) C.E.C. Fisch.	Boraginaceae	NP	-	+	+	He	SF	-	7.4	6.66	-	0.028	0.036

Cont...

Table 2. Comparative statement of the diversity, palatability, life and growth forms, abundance, and IVI of the species encountered in the study sites differing in the magnitude of grazing pressure

Name of species	Family	Palatability	Study sites			Life form	Growth form	Abundance (m^{-2})			IVI		
			1	2	3			1	2	3	1	2	3
Megacarpaea polyandra Benth. ex Madden	Brassicaceae	NP	-	-	+	Ge	TF	-	-	6.55	-	-	0.345
Nardostachys grandiflora DC.	Caprifoliaceae	NP	+	+	+	Ge	SF	16.94	2.16	9.42	0.062	0.013	0.023
Clintonia udensis Trautv. & C.A. Mey	Liliaceae	NP	+	+	+	He	SF	3.04	4.18	5.83	0.047	0.068	0.020
Nomocharis sp.	Liliaceae	NP	+	+	+	Ge	SF	10.6	24.4	17.6	0.041	0.066	0.019
Epilobium sp.	Onagraceae	NP	+	+	+	He	SF	2.16	4.54	7.13	0.009	0.024	0.051
Bistorta affinis (D. Don) Greene	Polygonaceae	NP	+	+	+	He	SF	3.73	7.48	9.83	0.028	0.075	0.016
Rumex nepalensis Spreng.	Polygonaceae	NP	-	+	+	He	TF	-	6.1	21.88	-	0.044	0.044
Aconitum balfourii Stapf	Ranunculaceae	NP	+	+	+	Ge	TF	2.96	2.2	3.0	0.083	0.026	0.016
Aquilegia nivalis (Baker) Falc. ex B.D. Jacks	Ranunculaceae	NP	-	-	+	Ch	SF	-	-	1.83	-	-	0.014
Aquilegia pubiflora Wall. ex Royle	Ranunculaceae	NP	+	+	+	Ge	SF	2.57	2.0	2.75	0.052	0.049	0.037
Average value of all non-palatable combined								5.5	5.92	8.26	0.048	0.052	0.058

Study sites: 1- Janthri, 2-Balmiya Top, 3- Rukhiyan
*NP- Nonpalatable, PA- palatable (the palatable and nonpalatable species were differentiated based on personal observations (e.g., signs of herbivory- bite marks, as well as physical observation) and ascertaining the observed facts with the local shepherds, the *anwals,* and the harvesters). Those species, e.g., *Rumex nepalensis* Spreng., which is grazed upon by the livestock, when all other palatable species are unavailable, has been categorized as unpalatable.
Plant species were separated into different life forms following Raunkiaer (1934) classification. Ph =Phanerophytes; Ch = Chamaephytes; He = Hemicryptophytes; Ge = Geophytes, Th = Therophytes; G= grass; CF= Cushion forb; SF= short forb; TF= tall forb; Gr= graminoid. + =present; - = absent

a marked decline when both Balmiya Top and Rukhiyan sites (experiencing grazing pressure) are compared with Janthri (experiencing no grazing pressure) (Fig. 5). Also, the data shows significant differences in all sites and across the soil depth except in between Balmiya Top and Rukhiyan.

Future viability of Yartsa Gunbu: The dominance of shrubs with poor forage quality, in general, is considered indicative of the degraded pasture (Roques et al 2001), as is also depicted in the present study, where the number of the forbs- both short and tall forbs, greatly outnumber the number of the graminoids as also their relative dominance being

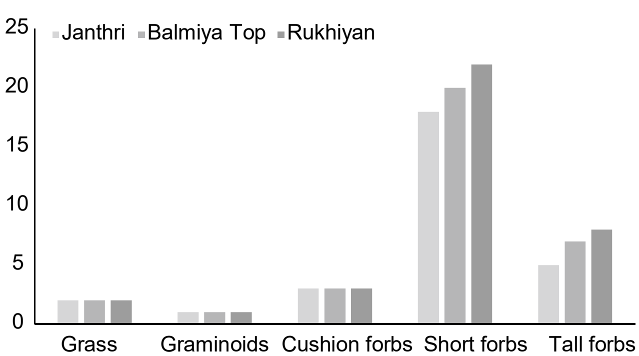

Fig. 4. Growth form types encountered in the three study sites (differing in grazing pressure), represented mostly by forbs- short forbs (< 30 cm) and tall forbs (> 30 cm)

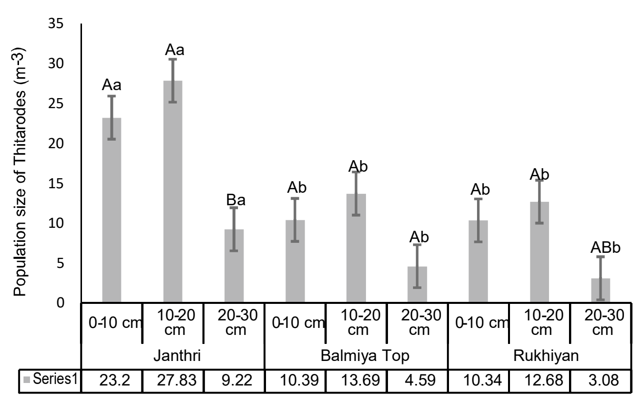

Fig. 5. Comparison of *Thitarodes balmiya* larva population size with standard deviation in three study sites across the soil depth- 0-10, 10-20, and 20-30 cm. The Upper-case letters indicate significant differences in *T. balmiya* larval population among three different soil layers within the same study site; whereas lower case letters indicate significant differences in soil layers across the three different study sites, differing in the order of increasing grazing pressure

proportional to the increasing grazing pressure (Fig. 4). It's obvious that the change in the vegetation characteristic- tall or even short forbs replacing the graminoids or grasses, will impinge upon the spore dispersal and thus the infective pathway, and thus the abundance of Yartsa Gunbu. This fact has been aptly emphasized by Cannon et al (2009). The host insect (*T. balmiya*) in turn depends on the host plant species, upon whose roots it feeds upon during its larval stages, any increase in the abundance of the non-host plant species vis-à-vis increase in richness of non-palatable species, majority of which are non-host species, will effectually result in a decline in the population size of the obligate host-*T. balmiya*. The perceptible decline in the population size of the host *T. balmiya* larva was, with the increase in grazing pressure (Fig. 5).

CONCLUSIONS

The grazing pressure impinges upon the habitat ecology, principally in terms of the resultant changes in the above-ground vegetation profile vis-à-vis palatable species being replaced by non-palatable. Since most of the palatable species are also the hosts of *T. balmiya* larva (13 spp. as against just 3 non-palatable species), it would not be impertinent to predict that the yield of Yartsa Gunbu is only going to decline further. However, studies of similar nature need to be undertaken in multiple different sites experiencing the different intensity of grazing pressure, to derive conclusively the impact of livestock grazing upon the yield of Yartsa Gunbu. There is a need to not just monitor the anthropogenic pressure, but also the livestock population size, and their duration of stay in one habitat site. This does not imply that the meadows or the habitat sites be altogether excluded from grazing, since grazing exclusion will impinge upon the very livelihood of local practitioners, but may result in an irreversible change in vegetation profile. Monitoring of livestock primarily means restricting the duration of stay in the site for long.

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Effect of Pre-sowing Treatment and Sowing Time on Germination and Early Performance of *Melia composita*

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Abstract: The pre-sowing treatments (soaking drupes in gibberellic acid 50 ppm for 24 hours, soaking drupes in gibberellic acid 100 ppm for 24 hours, soaking drupes in concentrated H_2S0_4 for 10 minutes, soaking drupes in concentrated H_2S0_4 for 15 minutes, mechanical scarification-cracking of drupes, soaking drupes in cow dung slurry for 30 days and control-no treatment) were tested to enhance the germination of *Melia composita* at two sowing time (20th April and 04th May). Germination and most of the growth parameters were recorded highest in mechanical scarification. The sowing of 20th April had significantly higher collar diameter, number of leaves, fresh shoot weight, dry shoot weight, length of primary root, number of secondary roots, fresh root weight, dry root weight, total seedling fresh weight, total seedling dry weight and seedling quality index than the sowing date of 04th May. The interaction of mechanical scarification x sowing-20th April also had significantly higher values for the most studied growth parameters than the remaining interactions. The study implies that mechanical scarification of drupes of *Melia composita* and sowing in the month of April is appropriate for obtaining good quality planting stock.

Keywords: Seed, Germination, Seedling, Growth, *Melia composita*

Forests and trees play an important role in people's livelihoods and provide products such as food, fodder, fuel, timber and many other non-timber products in addition to indirect services in the form of contribution to maintenance of ecological balance and nutrient cycling. Forests have now gained importance for their role in storing and recycling the earth's carbon through photosynthesis (Schroeder 1994). Forests also play an important role in conservation of biodiversity (FAO 2020) and they have a key role in alleviating poverty and improving food security (FAO 2003). Forests and trees also make an indirect contribution to food security by helping to maintain the environmental conditions suitable for agricultural production (FAO 2020). There are about 1.6 billion people in the world who rely heavily on the forest resource use for their livelihoods. For the world's poor, trees and forests are a vital part of everyday survival and provide 2.4 billion people with fuel to cook (FAO 2020). Deforestation and forest degradation is continuing at a very faster rate, which have adverse affects on the direct and indirect benefits being derived from the forests.

A plantation of trees is one of the solutions to increase the tree cover. At present, forest plantations and agroforestry farms in many countries are dominated by few species like Eucalyptus, Poplar and *Casuarina* spp. as major sources of raw materials for pulp and paper. However, these species are now being constrained by poor productivity, pests and diseases and are causing ecological degradation. So, there is an urgent need to diversify forest plantations, which is now dominated by few exotics. To address these concerns, there is a need to explore new potential of tree species, which are fast growing and adapted to wide agro-climatic conditions as alternate sources of tree products and raw materials for pulp and paper. *Melia composita* is one of such species. The species has been reported to have null allelopathic effect on under storey crops (Kumar et al. 2017, Parmar et al 2018), hence could be a promising species for on-farm and off-farm plantations. Wood of *Melia composita* is an excellent and highly suitable raw material for wood based industries like paper and plywood industries owing to its natural anti-termite property, high pulp recovery and exceptional fibre strength as compared to traditional raw material (Sarvannan et al. 2013). The species performs exceedingly well attaining the harvestable size within 6-8 years and has a ready and assured market due to its multipurpose utilities. Poor germination is a hurdle in afforestation of this species. Therefore, there is a need to enhance its germination capacity and growth by suitably treating its seed (drupes) to obtain quality planting stock for afforestation programmes. Hence, study was conducted to record the performance of pre-sowing treatment and sowing time on germination and early growth of *Melia composita*.

MATERIAL AND METHODS

The present study was conducted at the experimental farm of the Division of Agroforestry, Sher-e-Kashmir University of Agricultural Sciences and Technology of Jammu (SKUAST-Jammu), India during the period from April 2019 to November 2019. The experimental site is situated in subtropical, Jammu region of Union Territory of Jammu and Kashmir which is located at an altitude 332m above mean sea level with 32° 40′ N latitude and 74° 58′ E longitude. Jammu being a subtropical region experiences hot dry summers, humid rainy season and cold winter months. The summer season usually starts from April and lasts up to June. The maximum temperature rises upto 45°C during May to June and minimum falls to 1°C during winter. The average annual rainfall ranges from 1000-1200 mm with 75-80% of which is received during July to September and rest 20-25% during winter months of December to February.

Seed collection and experimental design: Drupes for carrying out the experiment were collected from the four year old plantation in February, 2019. The drupes were dried in shade for about a month and different pre-treatment were given to the drupes. The sowing of pre-treated drupes was done on 20th April and 04th May (2019). Light irrigation was applied immediately after each sowing followed by weeding and watering as per requirement till the end of the experiment. The experiment was laid out in Factorial CRD (Complete Randomization Design) having two factors i.e. seven pre-sowing treatments (soaking drupes in gibberellic acid 50 ppm for 24 hours, soaking drupes in gibberellic acid 100 ppm for 24 hours, soaking drupes in concentrated H_2S0_4 for 10 minutes, soaking drupes in concentrated H_2S0_4 for 15 minutes, mechanical scarification-cracking of drupes, soaking drupes in cow dung slurry for 30 days and control-no treatment) and two above mentioned dates. There were 10 polybags (size 16 cm x 24 cm filled with sieved soil, sand and FYM in ratio of 1:1:1) per replication per treatment. For recording data, two plants per treatment per replication were chosen using simple random sampling with replacement method. In this way a total of forty two plants were chosen for data recording. The observations on germination, collar diameter (mm), seedling height (cm), number of leaves, length of primary root (cm), number of secondary roots, fresh shoot weight (g), dry shoot weight (g), fresh root weight (g), dry root weight (g), total seedling fresh weight (g), total seedling dry weight (g), root: shoot ratio (dry weight basis), seedling quality index and sturdiness quotient were recorded in the month of November 30, 2019. The final seed germination was recorded 72 days after sowing when no further germination took place. The shoots and roots of sampled plants were dried in hot air oven at 65°C for 48 hours to obtain respective dry weights. After drying, the shoot and root weights of each sampled seedling were recorded using digital electronic balance. Sturdiness quotient was calculated by using the formula given by Rollar (1977) and Seedling quality index was estimated by using the formula given by (Dickson et al 1960). The data was analyzed using the technique of analysis of variance (ANOVA) in accordance with procedure outlined by Gomez and Gomez (1984). The effect of different treatments was tested at 0.05 level of significance.

RESULTS AND DISCUSSION

Germination: The pre-sowing treatments significantly affected drupe germination (Table 1). The maximum germination (46.68%) per cent was observed in mechanical scarification, which was statistically at par with treatments of soaking drupes in GA_3 100 ppm for 24 hours and soaking drupes in GA_3 50 ppm for 24 hours but significantly higher than the remaining treatments. The minimum germination (20%) was observed in the cowdung treatment and control (Table 1). The effect of date of sowing on germination was also significant (Table 1). The germination obtained in sowing of 04th May (50.48%) was significantly higher than that of 20th April (14.76%). The interaction of treatment x sowing date exhibited non-significant influence on seed germination (Table 1).

Aboveground parameters: All the aboveground parameters (seedling height, collar diameter, number of leaves, fresh and dry weight) of the seedlings were significantly influenced by the pre-sowing treatment of the drupes (Table 2). The maximum seedling height (163.18 cm), collar diameter (12.96 mm), number of leaves (24.72), fresh shoot weight (229.66 g) and dry shoot weight (75.80 g) was observed in mechanical scarification, which were statistically superior to the respective values in the remaining treatments (Table 2) but collar diameter in mechanical scarification was statistically at par with soaking drupes in concentrated H_2SO_4 for 15 minutes but significantly superior to the remaining treatments (Table 2). The number of leaves in mechanical scarification was statistically at par with soaking drupes in GA_3 50 ppm for 24 hours, soaking drupes in concentrated H_2SO_4 for 15 minutes and soaking of drupes in H_2SO_4 for 10 minutes (Table 2).

The interaction effect of pre-sowing treatment x sowing date was also significant with to respect to all the studied aboveground parameters (Table 2). The interaction mechanical scarification x 20th April resulted in maximum seedling height (239.43 cm), collar diameter (20.90 mm), fresh shoot weight (345.00 g) and dry shoot weight (113.86 g) which were statistically superior to all the remaining interactions. The interaction mechanical scarification x 20th April also resulted in maximum number of leaves (35.37) but this was statistically at par with interaction soaking drupes in H_2SO_4 for 15 minutes x 20th April but superior to the remaining interactions.

Belowground parameters: The maximum length of primary root (26.17 cm), number of secondary roots (20.80), fresh root weight (80.37 g) and dry root weight (22.70 g) were recorded in mechanical scarification, which was statistically higher than respective values in the remaining treatments (Table 3). The lowest root length (7.35 cm), number of secondary roots (8.67), fresh root weight (38.77 g) and dry root weight (10.41g) was recorded in control. The length of primary root (19.60 cm), number of secondary roots (13.71), fresh root weight of (74.86 g) and dry root weight (17.50 g) was significantly higher in sowing of 20th April than respective values of 04th May (Table 3).

The interaction of pre-sowing treatment x sowing date also significantly affected all the above ground parameters of the seedlings (Table 3). The interaction mechanical scarification x 20th April had the maximum number of secondary roots (26.00), fresh root weight (131.50 g) and root weight (35.20g) which were statistically superior to the remaining interactions. The interaction mechanical scarification x 20th April also resulted in longest primary root (30.23 cm) but was statistically at par with mechanical scarification x 20th April but superior to remaining interations (Table 3).

The pre-sowing treatment response on seedling parameters was also the same. All the parameters (except root: shoot ratio and sturdiness quotient) were highest in treatment mechanical scarification. Most of these parameters (seedling height, fresh shoot weight, dry shoot weight, length of primary root, number of secondary roots, fresh root weight, dry root weight, total seedling fresh weight and total seedling dry weight) were statistically superior in mechanical scarification in comparison to remaining all the pre-sowing treatments. The germination per cent in mechanical scarification was highest but it was statistically at par with soaking of drupes in GA_3 100 ppm for 24 hours and soaking of drupes in GA_3 50 ppm for 24 hours. Highest collar diameter was observed in mechanical scarification but it was at par with that of soaking drupes in H_2SO_4 for 15 minutes. In treatment mechanical scarification, the number of leaves was highest but at par with soaking of drupes in GA_3 50 ppm for 24 hours, soaking drupes in H_2SO_4 for 15 minutes and soaking drupes in H_2SO_4 for 15 minutes. Similarly seedling quality index in mechanical scarification was observed to be highest but at par with cowdung. Luna et al. (2014) also described mechanical scarification as one of the effective pre-sowing treatments to break physical dormancy caused by hard seed coat.

Mechanical scarification was found to be most effective

Table 1. Effect of pre-sowing treatment and sowing date on germination percentage*

Treatment	Sowing date		Mean
	20th April	4th May	
Soaking drupes in GA_3 50 ppm for 24 hrs	10.00 (18.43)	63.33 (53.13)	36.67 (35.78)
Soaking of drupes in GA_3 100 ppm for 24 hrs	26.66 (30.98)	66.67 (55.05)	46.67 (43.02)
Soaking of drupes in conc. H_2SO_4 for 10 minutes	10.00 (18.43)	40.00 (38.83)	25.00 (28.63)
Soaking drupes in conc. H_2SO_4 for 15 minutes	16.67 (23.35)	43.00 (41.05)	30.00 (32.20)
Mechanical scarification	20.00 (26.06)	73.33 (58.98)	46.68 (43.52)
Cowdung	10.00 (18.43)	30.00 (33.19)	20.00 (25.81)
Control- no treatment	10.00 (18.43)	36.67 (37.13)	23.33 (27.77)
Mean	14.76 (22.02)	50.48 (45.34)	
Effect		CD (p=0.05)	±SE(m)
Treatment		12.77 (7.99)	4.41 (2.76)
Sowing date		6.83 (4.27)	2.36 (1.47)
Treatment x Sowing date		N.S -	6.24 (3.90)

*Figures in parenthesis are transformed (angular) values

Table 2. Effect of pre-sowing treatment and sowing date on aboveground parameters

Treatment	Parameter	Sowing date		Mean
		20th April	4th May	
Soaking drupes in GA_3 50 ppm for 24 hrs	SH	43.33	138.17	90.75
	CD	8.02	7.37	7.69
	NL	28.33	20.83	24.58
	FSW	128.43	150.77	139.60
	DSW	37.50	39.20	38.35
Soaking of drupes in GA_3 100 ppm for 24 hrs	SH	85.57	121.27	103.42
	CD	8.63	6.90	7.77
	NL	20.20	19.93	20.07
	FSW	144.13	151.38	147.75
	DSW	34.16	37.85	36.00
Soaking of drupes in conc. H_2SO_4 for 10 minutes	SH	128.00	122.40	125.20
	CD	8.47	6.38	7.42
	NL	24.33	20.50	22.42
	FSW	135.89	145.53	140.71
	DSW	44.80	40.75	42.76
Soaking drupes in conc. H_2SO_4 for 15 minutes	SH	164.53	100.40	132.47
	CD	16.33	6.36	11.34
	NL	33.10	15.80	24.45
	FSW	250.01	145.07	197.54
	DSW	58.50	33.37	45.94
Mechanical scarification	SH	239.43	86.93	163.18
	CD	20.90	5.01	12.96
	NL	35.37	14.07	24.72
	FSW	345.00	114.33	229.66
	DSW	113.86	37.73	75.80
Cowdung	SH	23.17	54.67	38.92
	CD	9.83	4.60	7.22
	NL	27.67	13.07	20.37
	FSW	168.17	110.92	139.55
	DSW	42.20	26.64	34.42
Control- no treatment	SH	24.33	85.57	54.95
	CD	7.17	3.79	5.47
	NL	17.67	13.10	15.38
	FSW	167.26	88.45	127.85
	DSW	43.49	20.35	31.92
Mean	SH	101.21	101.34	
	CD	11.24	5.87	
	NL	26.67	16.76	
	FSW	191.27	129.49	
	DSW	53.50	33.70	

Effect	Parameter	CD (p=0.05)	±SE(m)
Treatments	SH	4.50	15.55
	CD	2.42	0.84
	NL	3.08	1.06
	FSW	16.69	5.76
	DSW	1.27	0.23
Sowing date	SH	N.S	8.31
	CD	1.30	0.44
	NL	1.64	0.57
	FSW	8.92	3.07
	DSW	0.67	0.43
Treatments x Sowing date	SH	63.75	22.00
	CD	3.42	1.18
	NL	4.36	1.50
	FSW	23.60	8.14
	DSW	1.79	0.62

SH-Seedling height (cm), CD-Collar diameter (mm), NL- Number of leaves, FSW-Fresh shoot weight (g), DSW-Dry shoot weight (g)

Table 3. Effect of pre-sowing treatment and sowing date on below ground parameters

Treatment	Parameter	Sowing date		Mean
		20th April	4th May	
Soaking drupes in GA_3 50 ppm for 24 hrs	LPR	20.20	11.40	15.80
	NSR	6.66	16.67	11.67
	FRW	55.65	45.80	50.75
	DRW	11.65	11.45	11.55
Soaking of drupes in GA_3 100 ppm for 24 hrs	LPR	26.13	22.13	24.13
	NSR	16.66	13.67	15.67
	FRW	59.45	42.32	50.88
	DRW	15.82	11.43	13.63
Soaking of drupes in conc. H_2SO_4 for 10 minutes	LPR	10.43	12.73	11.58
	NSR	13.00	10.00	11.50
	FRW	55.38	40.19	47.79
	DRW	11.60	14.10	12.85
Soaking drupes in H_2SO_4 for 15 minutes	LPR	30.23	11.20	20.72
	NSR	13.66	5.67	9.67
	FRW	100.30	37.18	68.74
	DRW	20.00	16.26	18.13
Mechanical scarification	LPR	30.20	22.13	26.17
	NSR	26.00	15.60	20.80
	FRW	131.50	29.23	80.37
	DRW	35.20	10.18	22.70
Cowdung	LPR	10.00	10.00	10.00
	NSR	18.00	4.00	11.00
	FRW	69.30	28.76	49.30
	DRW	16.68	10.35	15.52
Control- no treatment	LPR	10.00	4.70	7.35
	NSR	10.00	7.33	8.67
	FRW	52.45	25.09	38.77
	DRW	11.54	9.28	10.41
Mean	LPR	19.60	13.47	
	NSR	13.71	9.95	
	FRW	74.86	35.51	
	DRW	17.50	11.86	
Effect			$CD_{0.05}$	□SE(m)
Treatments	LPR		0.23	0.79
	NSR		1.41	0.48
	FRW		2.05	0.70
	DRW		1.54	0.53
Sowing date	LPR		0.12	0.04
	NSR		0.75	0.26
	FRW		1.11	0.37
	DRW		0.82	0.28
Treatment x Sowing date	LPR		0.33	0.11
	NSR		2.00	0.69
	FRW		2.90	1.00
	DRW		2.17	0.74

LPR- Length of primary root (cm), NSR-Number of secondary roots, FRW-Fresh root weight (g), DRW-Dry root weight (g)

Table 4. Effect of pre-sowing treatment and sowing date on whole seedling parameters

Treatment	Parameter	Sowing date		Mean
		20th April	4th May	
Soaking drupes in GA_3 50 ppm for 24 hrs	TSFW	184.08	196.57	190.33
	TSDW	49.15	50.65	49.90
	R:S ratio	0.31	0.29	0.30
	SQ	5.90	17.60	11.75
	SQI	8.62	2.28	5.58
Soaking of drupes in GA_3 100 ppm for 24 hrs	TSFW	204.18	193.70	198.94
	TSDW	49.98	49.28	49.63
	R:S ratio	0.46	0.29	0.37
	SQ	9.93	17.90	13.91
	SQI	4.41	2.36	3.25
Soaking of drupes in conc. H_2SO_4 for 10 minutes	TSFW	191.27	185.72	188.50
	TSDW	56.40	54.85	55.63
	R:S ratio	0.26	0.35	0.31
	SQ	16.39	19.51	17.95
	SQI	2.97	0.49	1.73
Soaking drupes in H_2SO_4 for 15 minutes	TSFW	125.31	182.25	153.78
	TSDW	78.50	49.63	64.07
	R:S ratio	0.30	0.45	0.37
	SQ	10.03	16.35	13.19
	SQI	6.03	2.78	4.40
Mechanical scarification	TSFW	476.50	143.56	310.03
	TSDW	149.06	47.91	98.49
	R:S ratio	0.32	0.33	0.33
	SQ	11.82	17.51	14.66
	SQI	12.07	2.56	7.32
Cowdung	TSFW	237.47	139.68	188.56
	TSDW	58.88	36.99	47.94
	R:S ratio	0.36	0.38	0.37
	SQ	2.37	11.98	7.18
	SQI	10.15	2.27	6.21
Control- no treatment	TSFW	219.71	113.54	166.63
	TSDW	60.81	29.60	45.21
	R:S ratio	0.27	0.45	0.36
	SQ	3.39	23.20	13.29
	SQI	0.95	1.19	1.07
Mean	TSFW	234.07	165.00	
	TSDW	71.83	45.56	
	R:S ratio	0.33	0.36	
	SQ	8.55	17.72	
	SQI	6.46	1.20	
Effect			CD (p=0.05)	±SE(m)

Cont...

Table 4. Effect of pre-sowing treatment and sowing date on whole seedling parameters

Treatment	Parameter	Sowing date		Mean
		20th April	4th May	
Treatments	TSFW		20.46	7.05
	TSDW		1.87	0.64
	R:S ratio		0.04	0.01
	SQ		5.08	1.75
	SQI		1.60	0.55
Sowing date	TSFW		9.98	3.80
	TSDW		1.00	0.34
	R:S ratio		0.02	0.01
	SQ		2.72	0.94
	SQI		0.85	0.29
Treatment x Sowing date	TSFW		29.66	10.23
	TSDW		2.65	0.91
	R:S ratio		0.06	0.02
	SQ		N.S	2.48
	SQI		2.27	0.78

TSFW-Total seedling fresh weight (g), TSDW-Total seedling dry weight (g), R:S- Root: shoot ratio, SQ-Sturdiness quotient, SQI- Seedling quality index

in enhancing fresh shoot weight, dry shoot weight, length of primary root, number of secondary roots, fresh root weight, dry root weight, total seedling fresh weight and total seedling dry weight. The maximum biomass parameters in mechanically scarified drupes in the current study might be due to early initiation of germination on account of faster absorption of water and gaseous exchange and consequently longer period of time for growth compared to remaining treatments. According to Jaenicke (1999) a small sturdiness quotient indicates a sturdy plant with higher expected chances of survival especially on windy or dry sites. Usually sturdiness quotient of less than six is desirable. In current study none of treatments had sturdiness quotient less than 6. The maximum root: shoot (0.37) was recorded in soaking of drupes in GA_3 100 ppm for 24 hours and was at par with soaking drupes in H_2SO_4 for 15 minutes, cowdung and mechanical scarification. Root:shoot ratio reflects the capacity of the roots to support the above ground biomass not only for anchorage but also in absorbing nutrients and water from the soil. A high root: shoot ratio indicates high absorption and storage capacity of water, which is an advantage, especially in conditions of limited soil moisture (Takoutsing et al 2016). In current study, all these treatments *i.e.* soaking of drupes in GA_3 100 ppm for 24 hours and soaking drupes in H_2SO_4 for 15 minutes, cowdung and mechanical scarification were equally good with respect to root:shoot ratio. The seedling quality index was highest in mechanical scarification in current study. Seedling quality index is overall indicator of seedling performance (Annapurna et al 2004). Since the majority of growth parameters were maximum in mechanical scarification, thereby, the seedling quality index was also highest in this treatment. This implies that overall the mechanical scarification is overall superior treatment.

CONCLUSION

The mechanical scarification of drupes of *Melia composita* needs to be carried out before sowing to enhance it's germination and growth. Sowing of the seeds in the month of April is appropriate than further delay.

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Feeding Ecology and Seasonal Changes in Food Habits of African Civet *(Civettictis civetta*, Schreber, 1776) In Aridtsy Forest, Western Ethiopia

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Abstract: The feeding ecology of the African Civet was investigated in the Aridstey forest Awi zone, Amhara region of Ethiopia during August 2017January 2018. Food items were identified by the naked eye and unidentifiable food items of plants and animal matters were identified by using microscope. During the present investigation, 17 food items were identified from the fresh droppings of the African Civets. Out of these, the main animal feed items identified were insects, millipedes/centipedes. *Cordia Africana*, *Ficus* sp. and *Zea mays* were main plant items recorded. Feeding habits of civets change with season and on the availability of food. During the dry season, African Civets eat *Cordia Africana* and *Ficus* sp., in high proportion. During the wet season, millipedes/centipedes and insects largely contributed for food. During both this seasons, insects, rodents and grasses were commonly observed as food items of civets. The scent markings were the height of 32-39 cm above the ground and the civets scent marked mostly on *Eucalyptus sp.*, *Clausenia anisata* and *Capsicum annuum*.

Keywords: African Civet, Civetry sites, Food habits, Scent marking, *Civettictis civetta,* Aridtsy forest

Ethiopia is located in the Horn of Africa within the tropics and is a relatively-vast country with a land area of 1.12 million square kilometers with a wide variety of topography and climatic patterns. There is a great variation in altitude ranges of different areas in Ethiopia, ranging from 116 m below sea level in the Danakil depression to 4620 m asl at the top of Ras Dashen. The great plains of Ethiopia lie along two massive highland plateaus, observed in the middle by the Great Rift Valley. Much of the interior of Ethiopia is dominated by highland plateaus, and are home to numerous endemic species of flora and fauna (Worku and Bale-Robe, 2019). Ethiopia is the home of diverse wild animal species, some of which are endemic. There are over 288 species of mammals in Ethiopia (Worku and Bale-Robe, 2019). Civets are distributed widely, not only limited in natural habitats but also found in villages, farmlands and human surroundings (Balakrishnan and Sreedevi, 2007). African civets are larger and more dog-like than the small Indian Civet (*Viverricula indica)*. African Civets tend to be most active just after sunset and tend to hunt in areas that provide plenty of cover. Civets do not possess carransial teeth, and are known to be omnivorous, eating fruits and carrion as well as a wide variety of small vertebrates and invertebrates. African Civet has a varied diet that consists of both animal and plant matters. They feed on snail, insects, millipedes, centipedes, birds, rodents and plant matters such as fruits with seeds (Morrongiello et al 2008). A study in Menegasha-Suba state Forest, Ethiopia revealed the most common food items of the Civets were meat of small animals such as rodents and birds, fruits of *Ficus* and *Maytenus,* millipedes, centipedes and insects. The diet also varied seasonally, based on the availability of food items (Morrongiello et al 2008).

MATERIAL AND METHODS

Study sites; For this study three habitat types were selected such us, plantation, natural forest and agricultural habitats. To study feeding ecology and seasonal changes both wet season August to October, 2017 and dry season November, 2017 to January 2018 data were incorporated. Fresh fecal samples were collected from the civetries and dried by sunlight, crushed in a mortar and washed using hot water to separate undigested materials in the feces such as, hairs, bones, cuticles of millipedes and other prey components. Separated materials were washed in acetone, dehydrated in 100% ethanol and dried on filter papers. Then it was observed under a stereo-microscope for identity. From each of the study habitats, three study sites were chosen based on their distance from the civetry. These sites were checked for 15 days/month for fresh droppings. Scent marked locations were also observed and assessed for frequency of marking. Perineal glandular secretions were removed from the scent marked sites to check whether the Civets remark on the same location, on the same object. The objects that were scent marked, path of marking and the color change of the "civet" were recorded.

During the present investigation to identify the food items of the African Civet, fresh droppings from civetries during both wet and dry seasons were collected. The droppings were checked for undigested food items such as, seeds, leaves, grass blades, shells, feather, hair and bone. The size and texture of the droppings were estimated to identify age groups of African Civet by using the method of Putman and Wratten (1984). The faces of young and adult African Civets were shown in (Fig. 1). The faces size of adult was large and the young were small. The population estimation of Civets in this study area was also made by counting the fresh droppings recorded.

Scent markings: The information was recorded from the scent marked objects: height of the object at which the marks were laid, GPS location, the color of the markings, the distance of the objects to the nearest latrine sites. All plants on which scent mark were located were identified.

Quadrats: To identify the preference of scent marking of the Civet on a specific plant species, quadrats of 5x5 m2 were laid in different parts of study areas. Based on the proximity to site, the quadrat was laid in the site by following the methods of (Sutherland 2006). Each plant species in the quadrat was counted.

Data analysis: Data analysis was performed by SPSS version 15, computer software to estimate the population variation and the food items from fresh droppings of African Civet.

RESULTS AND DISCUSSION

African Civet Population different Land Habitat

Forest: The population estimate of the African civet in the forest habitat was 5.38 per 60 hectare and the population density was 0.089/ hectare. Out of the total, 2.053 were young and 3.13 were adults (Table 1). The largest and the smallest number of adults were registered in December and in October respectively and largest and the smallest number of young was in November and December respectively. There was monthly variation of the counts of both the adult

Fig. 1. Faeces of a young African Civet on the left and adult on the right sides (Photo by author; September 2017)

and the young (χ2= 29.4 2) and (χ2=81 2,), respectively. The number of young declined from 3 during the wet season to 2.2 during the dry season. The number of adults increased marginally from 2.99 during the wet season to 5.88in the dry season. Over all, total of adult African Civet population in both seasons in forest habitat was significance The highest number of young was in November, being 3.33 of the population and this young African civet showed significance within months. The least number of young African Civets were in December and varied significantly within seasons. The total of adult African Civet population in both seasons forest habitat was significant.

Plantation habitat: The population estimate of the African Civet in the plantation habitat was 4.77per 20 hectares. The population density in the plantation habitat was 0.238/hectare. Out of these, the young contributed for 1.33and adults for 3.6 (Table 2). The maximum number of young were in December and the least was in August during wet and dry season. In this habitat, the total number of young African civets population in increased from 1.22 in the wet season to 1.44 in the dry season. There was more adults Civets in the plantation habitat in September and the least number was in January with significant difference. In this habitat, the total number of adult African civets population was significant and was 3.99 and 5.54 in wet and dry seasons.

Farm land habitat: The population estimate of the African Civet in the farmland habitat was 4.65 per 10 hectare and the population density was 0.465 per hectare (Table 3). Highest number of adult African Civet was recorded in January (5.6)

Table 1. African civet population in the forest habitat during wet and dry seasons

Season	Month	Young	Adult	Total
	August	2.33±.57	3.33±1.57	5.66±2.14
Wet	September	1.66±.57	4.33±2.08	5.99±2.65
	October	1.66±1.15	1.33±.57	2.99±1.72
	November	3.33±1.15	2.66±1.15	6.99±2.3
Dry	December	1.33±.57	5±2.64	6.33±3.21
	January	2±1	2.33±1.52	4.33±2.52
Mean		2.05±.83	3.13±1.58	5.38±2.42

Table 2. African civet population in the plantation habitat

Season	Month	Young	Adult	Total
Wet	August	1±1	1.66±.7	2.66±1.7
	September	1.33±.57	5±1	5.33±1.57
	October	1.33±1.15	2.66±.57	3.99±1.72
Dry	November	1.33±.57	2.33±.57	3.66±1.14
	December	1.66±1.15	3.33±1.52	4.99±2.67
	January	1.33±1.52	6.66±.57	7.99±2.09
Mean		1.33±.99	3.60±.82	4.77±1.81

and the least in November (1.33), with a significant difference. The population of the adult African Civets exhibited significant difference season's number increased from 2.22 during wet season to 3.19 during the dry season. The highest number of young African Civets was observed in January and young civets were not recorded in September in the farm land habitat. There were significant variation in the number of young Civets observed different months.

Food items of the African Civet: During the present investigation, a total of 17 different food items were identified from the droppings collected from civetries (Table 4). These food items were found in different proportions. A total of 467 food components were recorded from the samples of Civet droppings analyzed. These components belonged to 17 food categories. Even if the proportion of each these food items were different from sample to sample, all items were found in all habitats from the samples of droppings were collected for the study.

Food items in the droppings of African civets: Among the food items identified, insects formed a large proportion, (15.2 %) and the least consumed food item was *Sorghum vulgar,* (1.49 %). Seasonally, insects and *Sorghum vulgar* (showed significantly increased intake by civets.

Forest habitat during the wet season: During the wet season Civets in the forest habitat consumed more of insects (21%), followed by millipedes and centipedes (20.51 %) and the least consumed food item was hen (5.13%) (Table 5). Significant variation was observed based on seasonality of insects and hen food. But there was no significant variation in the consumption of millipedes/centipedes with the reference to season (20.51 %).

Forest habitat during the dry season: Civets consumed mostly *Cordia africana* (17.77 %) and *Ficus sur* (14.44 %) and the least consumed food item was *Eleusine coracana (*3.33%) (Table 6). However, there was no significant variation in the consumption of *Cordia africana* and *Ficus sur* with in seasons. However, the intake of *Eleusine coracana* showed significant variation within seasons.

Plantation habitat during wet season: During the wet season, in the plantation habitat, most frequently consumed food items were insects(25.71%) followed by rodents (22.85) and the least consumed food items were *Solanum tuberosum* and birds (2.85 and 5.71%, respectively) (Table 7). Significant variation was observed in the consumption of insects, *Solanum tuberosum* and birds within season. No significant variation was observed in the consumption of rodents within season.

Plantation habitat during the dry season: In the plantation habitat, most frequently consumed feed items were *Cordia africana*, and *Zea mays* which accounted for 15.0 % and

Table 3. African civet population in the farmland habitat

Season	Month	Young	Adult	Total
Wet	August	1.66±.57	3±1	4.66±1.57
	September	-	2.33±1.52	2.33±1.52
	October	1.33±.57	3.33±.57	4.66±1.14
Dry	November	2±1	1.33±1.52	3.33±2.52
	December	1.66±.57	2.66±2.08	4.32±2.65
	January	3±1	5.6±.57	8.6±1.57
Mean		1.93±.72	3.04±0.95	4.65±1.82

Table 4. Percentage of food items observed in the droppings of African Civet

Food items	Number of observations	Per cent
Zea mays	26	5.56
Eleusine coracana	11	2.35
Eragrostis teff	12	2.56
Capsicum annuum	28	5.99
Sorghum vulgar	7	1.49
Cordia africana	42	8.99
Ficus vasta	35	7.49
Insects	71	15.2
Ficus sur	35	7.49
Cyprus rigidifolius	32	6.85
Ensete venntricosum	28	5.99
Rodents hair and bone	48	10.27
Millipedes/centipides	42	8.99
Hen head	12	2.56
Bird feather	11	2.35
Solanum tuberosum	7	1.49
Snail	20	4.28
Total	467	100

Table 5. Percentage of food items observed in the droppings of African civet in forest habitat during the wet season

Food items	No. of observations	Percent
Millipedes and centipedes	16	20.51
Rodents hair and bone	13	16.66
Snail	7	8.97
Hen head	4	5.13
Bird feather	5	6.41
Insects	21	26.92
Cyprus rigidifolius	8	10.25
Solanum tuberosum (Potato)	4	5.13
Total	78	100

Table 6. Percentage of food items observed in the droppings of African civet in the forest habitat during the dry season

Food items	No. of observations	Percent
Zea mays	8	8.88
Eleusine coracana	3	3.33
Eragrostis teff	5	5.55
Capsicum annuum	8	8.88
Sorghum vulgar	4	4.44
Cordia africana	16	17.77
Ficus vasta	10	11.11
Insects	7	7.77
Ficus sur	13	14.44
Cyprus rigidifolius	4	4.44
Ensete venntricosum	8	8.88
Rodents hair and bone	4	4.44
Total	90	100

Table 7. Percentage of food items of African civet at plantation during wet season

Food items	No. of observations	Percent
Millipedes and centipedes	14	20
Rodents hair and bone	16	22.85
Snail	5	7.14
Hen head	5	7.14
Bird feather	4	5.71
Insects	18	25.71
Cyprus rigidifolius	6	8.57
Solanum tuberosum	2	2.85
Total	70	100

13.75% respectively. *Elusine coracana* was the least consumed food item (2.5%) (Table 8). There were no variation among the highest and the least consumed food items within the season, *Cordia Africana*, *Zea mays* and Elusine *coracana*.

Agricultural habitat during the wet season: In the farmland habitat, during the wet season, most frequently consumed food items were insects, which constituted for 26.22%, followed by millipedes and centipedes 19.67% and the least were covered of hen and *Solanum tuberosum* (4.91and 1.63 %, respectively (Table 9). Significance was observed in the consumption of insects and hen within the season. There was no variation in the consumption of millipedes/centipedes and *Solanum tuberosum* within the season.

Agricultural habitat during the dry season: In the agricultural habitat, 12 food items were identified during dry season from the fresh droppings of African Civet. Out of these dominantly consumed food items were *Cordia africana* and

Table 8. Food items of the African civet in the plantation habitat during the dry season

Food items	No. of observations	Percent
Zea mays	11	13.75
Eleusine coracana	2	2.5
Eragrostis teff	3	3.75
Capsicum annuum	9	11.25
Sorghum vulgar	2	2.5
Cordia africana	12	15
Ficus vasta	12	15
Insects	4	5
Ficus sur	10	12.5
Cyprus rigidifolius	3	3.75
Ensete venntricosum	9	11.25
Rodents hair and bone	3	3.75
Total	80	100

Table 9. Food items of African Civet in the agricultural habitat during the wet season

Food items	No. of observations	Percent
Millipedes and centipedes	12	19.67
Rodents hair and bone	10	16.39
Snail	8	13.11
Hen bone and feather	3	4.91
Bird feather	2	3.27
Insects	16	26.22
Cyprus rigidifolius	9	14.75
Solanum tuberosum	1	1.63
Total	61	100

Table 10. Food items of African Civet in the agricultural habitat during the dry season

Food items	No. of observations	Percent
Zea mays	7	7.95
Eleusine coracana	6	6.81
Eragrostis teff	4	4.54
Capsicum annuum	11	12.5
Sorghum vulgar	1	1.14
Cordia Africana	14	15.9
Insects	5	5.68
Ficus vasta	13	14.77
Ficus sur	12	13.63
Cyprus rigidifolius	2	2.27
Ensete venntricosum	11	12.5
Rodents hair and bone	2	2.27
Total	88	100

Table 11. African Civet defecation during both the wet and the dry seasons

	No. of days with droppings			
	Wet season		Dry season	
	Number	Percent	Number	Percent
Number of days with defecation	23	51.11	24	53.33
Number of days without defecation	22	48.88	21	46.66
Total	45	100	45	100

Ficus vasta. These food items constituted for 15.9 and 14.77%, respectively (Table 10). Least consumed food items were *Sorghum vulgar* (1.14 %), and rodents (2.27%). The consumption of *Cordia africana*, *Ficus vasta* and *Sorghum vulgar* not varied within the season.

Seasonality in the feeding of civets: During the wet season, eight food items were identified from the droppings of the African Civets in the present study area. Out of the 17 food items identified from the droppings in both seasons, the food items were not observed during the wet season were *Zea mays, Eleusina coracana, Eragrostis teff, Sorghum vulgar, Capsicum annuum, Cordia africana, Ficus vasta, Fius sur* and *Ensete venntricosum.* During the dry season, millipedes/centipedes, *Solanum tuberosum,* snail, hen and birds were not found in the droppings of the African Civet. The three food items (grass, insects and rodents) were consumed during both the dry and the wet seasons.

Defecation rate during the dry and the wet seasons: Out of the 45 days of observations on civetries there were 23 days when fresh droppings were observed during the wet season whereas during the dry season, there were fresh droppings on 24 days (Table 11). The frequency of defecation was high during the dry season and the amount and types of food were also observed in high proportion during the dry season than during the wet season.

CONCLUSION

During the present investigation, 17 food items of African Civets were identified from the Aridtsey forest, in Ethiopia which is unprotected area. Civets depended on the availability of different food items seasonally. Present investigation analyzes that marking frequency and the amount of faeces varied with the season.

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Productivity and Profitability of Indian Mustard (*Brassica juncea* L.) Influenced by Drip Irrigation and Micronutrient Application Methods

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Abstract: A field experiment was conducted in split plot design with drip irrigation levels (0.4, 0.6 and 0.8 IW/CPE ratios) in main plot and micronutrient application methods (control, soil, foliar and fertigation) in sub plot during *Rabi* season at S.K.N. College of Agriculture, Jobner (Rajasthan) during 2018. The scheduling of drip irrigation at 0.8 IW/CPE ratio recorded significantly higher plant height, dry matter accumulation, siliquae per plant, seeds per siliqua, test weight and seed yield over 0.4 IW/CPE ratios, which was statistically at par with 0.6 IW/CPE ratio. Drip irrigation at 0.8 IW/CPE ratio recorded higher monetary value. Among micronutrient application methods, fertigation significantly increased plant height at 80 DAS and at harvest, dry matter accumulation at all growth stages, siliquae per plant and seeds per siliqua, seed yield over all other application method. Higher net return and B: C ratio also under fertigation.

Keywords: Mustard, IW/CPE, Drip irrigation fertigation

Oilseed crops are main source of energy in the diet of Indians. Though, India has become self-reliant with respect to food grains but still lagging behind in the production of oilseeds. India is a key player in the global oilseeds scenario with 12-15 per cent of oilseeds area, 6-7 per cent of vegetable oils production, 9-11 per cent of the total edible oils consumption and 14 per cent of vegetable oil imports. Despite of being the largest cultivator of oilseeds at the global level, our country, who was an exporter of oil till fifties, has now become a major importer of edible oil which involves foreign exchange and thus increase the burden to government exchequer. Nutrient management and irrigation are the most important agronomic factors that affect the yield of Indian mustard (*Brassica juncea* L.). Drip irrigation is one of the most efficient methods of irrigation. It is viewed as a promising technology for its ability to support farmers in raising incomes and reducing poverty (IWMI Water Policy Briefing 2006). A number of benefits have been ascribed to the use of drip irrigation. In addition to saving of water these include increased yield and productivity of crops, labour cost savings, electricity savings, lesser pumping hours and hence easier irrigation, better crop growth and also better soil health. In IW/CPE approach, known amount of irrigation water is applied when cumulative pan evaporation reaches predetermined level. Multiple micronutrient deficiencies are emerging at a faster rate in intensively cultivated high production areas due to greater removal of soil micronutrients through annual biomass harvest. Data of 1.48 lakh surface soil samples revealed 45, 33, 8.3, 4.5 and 3.3 per cent deficiency of Zn, B, Fe, Mn and Cu, respectively (Singh, 2019). More or less similar trend in deficiencies of micronutrients in Maharashtra soils as that of Indian soils were noticed by Malewar and Syed (2016). The deficiency range of micronutrients especially Zn and B in oilseed growing soils emphasizes the need to focus immediate attention on balanced nutrient management practices. The production of mustard in the region, state and in country often suffers from a higher degree of variation in the annual production owing to their predominant cultivation under low and uncertain rainfall situations and further handicapped by input starved conditions with poor crop management. There is limited scope for expansion of area under mustard and also the irrigation. Increasing the vertical growth in productivity is the feasible option. Again, vertical growth by increasing the crop productivity demands higher inputs, which are costly and limited. Therefore, what is really needed is the increased input use efficiency.

Fertigation is a modern agro technique, combining water and fertilizer application through irrigation provides an excellent opportunity to both maximize yield and minimize environmental pollution. Fertigation is considered an integral part of plant nutrient management and generate a concentrated and space limited root system within the wetted soil volume. It localizes the water supply and this triggers the development of a restricted root system that requires frequent replenishment of the nutrients. Applying nutrients in the irrigation water may satisfy this requirement. In a fertigation system, the timing, amounts, concentrations and ratios of the nutrients are easily controlled. Due to this improved control, crop yields are greater than those produced by a simple fertilizer application and irrigation system. Such yield increases should not be attributed to fertigation only because the changes in the agro-technique are accompanied by other improvements in crop management. In drip irrigation, the wetted soil volume and thus the active root zone is reduced under drippers and this small volume does not allow the addition of all plant nutrients needed by the plants. Rather, fertiliser needed is to be applied frequently and periodically in small amount with the each irrigation to ensure adequate supply of water and nutrient in the root zone. Therefore, as a result of the shift from surface irrigation to drip method of irrigation, fertigation becomes the most common fertilisation in the irrigated agriculture. The use of soluble and compatible fertilisers, good quality irrigation water and application of actual crop water need are the prerequisite of the successful fertigation system.

MATERIAL AND METHODS

The experiment was conducted at S.K.N. College of Agriculture, Jobner. The region fall under Agroclimatic Zone IIIa of Rajasthan (Semi-arid Eastern Plains). The experimental soil was loamy sand in texture, alkaline in reaction (8.1), poor in organic matter (0.18), low in available nitrogen (129.50 kg ha^{-1}), medium in phosphorus (17.10 kg ha^{-1}) and potassium content (181.20 kg ha^{-1}). Field capacity and PWP of soil was 10.85 and 4.32 per cent, respectively. The experiment consisting of 12 treatment combinations with three levels of drip irrigation in main plot (drip at 0.4, 0.6 and 0.8 IW/CPE ratio) and four levels of micronutrient application method in sub plot (control, soil application, foliar application and fertigation). The experiment was conducted in split plot design and replicated four times. The seeds of mustard variety Laxmi @ 5 kg ha^{-1} was used for sowing in the experiment. Mustard seeds were sown at a spacing of 30 x 10 cm^2 apart. The experimental mustard crop was fertilized uniformly with 60:40 kg/ha of N and P respectively. Half of the nitrogen along with full amount of phosphorous was applied at the time of sowing as basal. Five plants for each treatment were taken for recording the various data. Data on yield attributes and yield were recorded as per standard process at harvest. Various indices were used to assess the effectiveness of water management practices *viz.,* Consumptive use of water by Dastane (1972) and Water-use-efficiency by Viets (1961). The economics of treatments was computed on the basis of prevailing market price of input and outputs for each treatment. Net returns and B: C ratio was calculated by following formulas.

Net returns (Rs ha^{-1}) = Gross returns (Rs ha^{-1}) - Total cost of cultivation (C3) (Rs ha^{-1})

$$\text{B: C ratio} = \frac{\text{Net return (Rs/ha)}}{\text{Cost of cultivation (Rs/ha)}}$$

RESULTS AND DISCUSSION

Effects of Drip Irrigation

Growth parameters: Scheduling of drip irrigation at 0.8 IW/CPE ratios, recorded significantly higher plant height (150.49 and 196.00 cm) as compared to 0.4 IW/CPE ratios at 80 DAS and at harvest, which remained statistically at par with 0.6 IW/CPE ratios (Table 1). The drip irrigation level at

Table 1. Effect of drip irrigation level and micronutrient application method on plant height and dry matter accumulation of mustard

Treatment	Plant height (cm)			Dry matter accumulation per meter row length (g)		
	40 DAS	80 DAS	Harvest	40 DAS	80 DAS	Harvest
Drip irrigation level						
0.4 IW/CPE	70.90	129.29	177.30	34.54	100.95	155.16
0.6 IW/CPE	71.99	143.59	193.70	38.98	110.60	175.39
0.8 IW/CPE	72.49	150.49	196.00	40.65	114.99	185.13
CD (P=0.05)	NS	10.99	14.72	2.95	8.44	13.37
Micronutrient application method						
Control	66.30	123.55	173.30	32.20	97.39	154.70
Soil application	70.80	137.15	185.90	37.08	105.96	168.45
Foliar application	74.60	147.55	197.30	40.90	113.76	178.95
Fertigation	75.48	156.25	199.50	42.05	118.27	185.46
CD (P=0.05)	3.91	7.91	10.52	2.14	6.07	9.67

NS=Non-significant

0.8 IW/CPE ratio, recorded significantly maximum dry matter accumulation (40.65, 114.99 and 196.00 g) as compared to 0.4 IW/CPE ratio at 40, 80 DAS and at harvest, while it remained statistically at par with 0.6 IW/CPE ratio (). The crop plants are able to maintain higher water potential with increasing IW/CPE ratio under drip irrigation which improves physiological and biochemical activities. This leads to improved growth of plant. Beside it, reduced water supply causes closure of stomata which raises the plant temperatures consequently increases respiration leading to higher break down of assimilates and ultimately poor growth and reduced dry matter accumulation. Similar results have also been reported by Bhunia et al (2004) and Choudhary et al (2005).

Yield attributes and yield: The drip irrigation level at 0.8 IW/CPE ratio recorded highest no. of siliqua plant^{-1} (288.80), no. of seed siliqua^{-1} (15.64), test weight (3.86 g), seed (18.06 q ha^{-1}), straw (69.66 q ha^{-1}) and biological yield (88.26 q ha^{-1}) remain at par on 0.6 IW/CPE ratio over 0.4 IW/CPE ratio (Table 2). This increase in seed yield might be due to maintenance of sufficient moisture in root zone during critical stages of the crop growth, resulting in higher yields. Higher seed yield with increasing IW/CPE ratio could be the resultant of cumulative beneficial effects of irrigation schedules first on vegetative growth and later on better partitioning of photosynthates towards the sink. These findings are in close conformity with those of Solanki et al. (2014) and Kunapara et al (2017).

Economics: The higher net returns and B: C ratio of (Rs. 42639 ha^{-1} and 1.87, respectively) at 0.8 IW/CPE ratio were significantly higher over 0.4 IW/CPE ratio (and remained statistical at par with 0.6 IW/CPE ratio (Table 3). The significantly higher net returns obtained under 0.8 IW/CPE ratio was due to higher seed and straw yields along with higher price of mustard. The total cost of production increased slightly with an increase in IW/CPE ratio for scheduling irrigation, because the irrigation charges were insignificant as compared with other expenses. The cost involved under this treatment was comparatively lower than its additional income, which led to more returns under this treatment. These findings are in accordance with the results reported by Mahalakshmi et al (2011) and Rajiv (2012).

Effects of Micronutrient Application Method

Growth: Among application method, fertigation recorded significantly higher plant height at 40, 80 DAS and at harvest (75.48, 156.25 and 199.50 cm, respectively) however, it remained at par with foliar application method (Table 1). The fertigation recorded maximum dry matter accumulation at 40, 80 DAS and harvest (42.05, 118.27 and 185.46 g, respectively) it remained at par with foliar application method as compared to control and soil application. Among the methods of nutrient application, foliar application is

Table 3. Effect of drip irrigation level and micronutrient application method on protein and oil content (%)

Treatment	Protein content (%)	Oil content (%)
Drip irrigation level		
0.4 IW/CPE	20.45	38.74
0.6 IW/CPE	21.95	39.24
0.8 IW/CPE	22.57	38.94
CD (P=0.05)	NS	NS
Micronutrient application method		
Control	18.50	38.42
Soil application	20.94	38.35
Foliar application	22.88	39.30
Fertigation	24.31	39.83
CD (P=0.05)	2250	NS

Table 2. Effect of drip irrigation level and micronutrient application method on yield attributes and yield of mustard

Treatment	No. of siliquae plant^{-1}	No. of seed siliqua^{-1}	Test weight (g)	Seed yield (q ha^{-1})	Straw yield (q ha^{-1})	Biological yield (q ha^{-1})
Drip irrigation level						
0.4 IW/CPE	257.90	13.32	3.20	15.78	57.63	73.41
0.6 IW/CPE	281.90	14.95	3.66	18.06	66.31	84.37
0.8 IW/CPE	288.80	15.64	3.86	18.60	69.66	88.26
CD (P=0.05)	21.56	1.14	0.28	1.38	4.17	5.30
Micronutrient application method						
Control	240.50	12.27	3.13	14.17	56.39	70.56
Soil application	267.90	14.45	3.46	17.37	62.90	80.27
Foliar application	289.80	15.5	3.74	18.65	68.18	86.83
Fertigation	306.60	16.34	3.97	19.73	70.66	90.39
CD (P=0.05)	15.42	0.83	0.20	1.00	3.65	4.65

Table 4. Effect of drip irrigation level and micronutrient application method on net returns, B: C ratio, consumptive use of water and water use efficiency in mustard

Treatment	Net return (Rs ha^{-1})	B:C ratio	Consumptive use of water (mm)	Water use efficiency (kg ha^{-1}-mm)
Drip irrigation level				
0.4 IW/CPE	30413	1.65	191.1	8.26
0.6 IW/CPE	40784	1.85	264.3	6.83
0.8 IW/CPE	42639	1.87	334.6	5.56
CD (P=0.05)	2555	0.12	20.06	0.53
Micronutrient application method				
Control	30382	1.77	263.33	5.58
Soil application	34271	1.67	263.33	6.84
Foliar application	41215	1.82	263.33	7.34
Fertigation	45914	1.9	263.33	7.77
CD (P=0.05)	2250	0.10	15.57	0.35

recognized as an important method of fertilization, since foliar spray usually penetrate the leaf cuticle or stomata and enters the cells facilitating easy and rapid utilization of nutrients. This leads to efficient utilization of micronutrients. The observed improvement in overall vegetative growth of the crop with the application method of micronutrient in the present investigation is in conformity with those of Sintupachee et al (2010) and Moosavi and Ronaghi (2011).

Yield attributes and yield: Micronutrient application method of fertigation recorded significant improvement in yield attributes and yield of mustard (Table 2). The fertigation recorded highest no. of siliqua/plant, no. of seed/siliqua and test weight (g) followed by foliar application over control. Same trend follow in yield i.e. fertigation recorded highest seed, straw and biological yield (q ha^{-1}) (19.73, 70.66 and 90.39, respectively) followed by foliar application. The combined application of micronutrients provided fertigation greater availability of nutrients for the development of reproductive structures and increase in the number of grains and grain weight. Since boron and combination of all micronutrients were responsible for the translocation of food materials in plants therefore it played a vital role in grain setting as well as higher number of grain. These results are in close conformity with the findings of Singh and Choudhari (2001).

Oil and protein content (%): The micronutrient application by all methods significantly increased the oil and protein content in mustard seed (Table 3). that fertigation (39.83 and 22.88 %), was at par with foliar application (39.30 and 22.88 %) and recorded significantly highest protein content in mustard seed over control and soil application Higher nitrogen in seed is directly responsible for higher protein because it is a primary component of amino acids which constitute the basis of protein. These results are in close conformity with the findings of Mona et al (2015).

Economics: Significantly higher net returns (Rs. 45914 ha^{-1}) and B: C ratio (1.90) was under fertigation over control, soil and foliar application (Table 4). The highest income obtained in fertigation due higher yield. Similar findings were also observed by Jabran et al (2011) and Shankar et al (2017).

Water use Parameters

Consumptive use of water: The higher consumptive use of water obtained in 0.8 IW/CPE ratio as compared to 0.4 IW/CPE ratios. The 0.6 IW/CPE ratios were statistically at par with 0.8 IW/CPE ratios. Water application with 0.8 IW/CPE provide higher water to crop, which leads to more water availability and consumptive use by crop.

Water use efficiency (kg ha^{-1}-mm): The higher water use efficiency was recorded in 0.4 IW/CPE ratio (8.26 kg ha^{-1}-mm) followed by 0.6 IW/CPE ratio (6.83 kg ha^{-1}-mm). Among different micronutrient application method, fertigation recorded higher water use efficiency (7.77 kg ha^{-1}-mm) statistically at par on foliar application (7.34 kg ha^{-1}-mm).

CONCLUSION

Productivity and profitability of mustard is significantly influenced by different drip irrigation levels and micronutrients application methods. Maximum growth, quality and seed yield was obtained with drip irrigation at 0.6 IW/CPE in conjunctions with micronutrient application method as fertigation.

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Stability Analysis of Plant Density and Frequency of Foliar Application of Nitrogen in *Gladiolus hybrida*

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Abstract: An attempt was made to find stable planting density and frequency of foliar nitrogen application using stability models. The data on various flowering and growth characteristics in gladiolus for four foliar nitrogen spray viz., 0, 3, 5 and 7 days and three planting density i.e. 100, 120 and 140 cormels m^{-2} were collected and experiment was repeated in four seasons over two years. Treatment combinations of 3 days + 120 cormels m^{-2} and 5 days + 120 cormels m^{-2} were found to be stable for number of corms per m^2; 3 days + 100 cormels m^{-2}, 3 days + 120 cormels m^{-2}, 3 days + 140 cormels m^{-2}, 5 days + 100 cormels m^{-2}, 5 days + 120 cormels m^{-2}, 5 days + 140 cormels m^{-2}, 7 days + 120 cormels m^{-2} and 7 days + 140 cormels m^{-2} were found to be stable for weight of corms m^{-2}. 3 days + 140 cormels m^{-2} was found to be stable for number of cormels $plant^{-1}$ and 5 days + 100 cormels m^{-2} was found to be stable for weight of cormels $plant^{-1}$.

Keywords: Gladiolus, Eberhart & Russell's model, Plant density, Frequency of foliar nitrogen application

Floriculture is gaining importance as a good source of income apart from giving pleasure and happiness. Particularly, gladiolus (*Gladiolus spp.*) a member of the family Iridaceae, has gained much importance as a cut flower because of its beautiful spikes. In the world, this genus occurs in Asia, Mediterranean Europe, South Africa, and tropical Africa. Moreover, India has suitable agro-climatic conditions for gladiolus cultivation; and is commercially cultivated in West Bengal, Himachal Pradesh, Sikkim, Karnataka, Uttar Pradesh, Tamil Nadu, Punjab and Delhi. Gladiolus responds well to balanced nutrition for better growth and maximum flower production. Inadequate plant nutrition causes serious disorders and may eventually lead to decline of plant vigor and flower yield. Nitrogen is one of the most important nutrient producing growth and yield responses in gladiolus. The quantity of phosphorus required by gladiolus is about one-tenth of the nitrogen expressed in terms of foliar analysis. Foliar nutrition with NPK in addition to soil application significantly affects vegetative growth and floral characters (Roy *et al.* 1995). Nutrition plays an important role in the overall growth performance of the gladiolus crop.

Foliar spray of nitrogen × planting density (N×D) interaction is a universal phenomenon when different frequency of foliar N application and planting density are evaluated across different seasons of different years. Most agronomically and economically important flower traits of Gladiolus species, such as number of days taken for sprouting, per cent sprouting, plant height and number of leaves/plant are quantitative in nature and routinely exhibit N × D interaction. Keeping in view this, an attempt was made to identify stable frequency of foliar spray of nitrogen and planting density in different seasons/years for various growth and flowering characteristics by using Eberhart & Russell's stability (1966).

MATERIAL AND METHODS

Data on various growth and flowering characteristics of Gladiolus cultivar "Solan Mangla" with four treatments of foliar spray of N and three treatments of planting density each replicated three times over two years and two seasons per year were taken from the field of Floriculture and Landscape Architecture, Dr. Y.S. Parmar University of Horticulture & Forestry, Nauni, Himachal Pradesh during year 2016-17. The area has an elevation of about 1250 m above mean sea level, with the coordinates as: latitude 30º50'30" to 30º50'0" N and the longitude $77^0$8'30" and $77^0$11'30" E.

Twelve treatment combinations i.e., control + 100 cormels m^{-2} (N_0D_1), control + 120 cormels m^{-2} (N_0D_2), control + 140 cormels m^{-2} (N_0D_3), 3 days + 100 cormels m^{-2} (N_1D_1), 3 days + 120 cormels m^{-2} (N_1D_2), 3 days + 140 cormels m^{-2} (N_1D_3), 5 days + 100 cormels m^{-2} (N_2D_1), 5 days + 120 cormels m^{-2} (N_2D_2), 5 days + 140 cormels m^{-2}(N_2D_3), 7 days + 100 cormels m^{-2} (N_3D_1), 7 days + 120 cormels m^{-2} (N_3D_2), 7 days + 140 cormels m^{-2}(N_3D_3) were experimented. The data on number of days taken for sprouting, per cent sprouting, plant height (cm), number of leaves $plant^{-1}$, cropping duration (days), number of cormels $plant^{-1}$, weight of cormels $plant^{-1}$, size of cormels(cm), number of corms plant^{-1}, weight of corms m^{-2} (g), size of corms(cm) were taken into consideration to draw the inference.

Eberhart and Russell's model was used to identify stable treatment combinations for various growth and flowering characteristics. Eberhart and Russell's Model (1966) has three parameters of stability and were calculated as

Phenotypic index (P_i)=

$$\frac{\Sigma_j^e xij}{e} - \frac{\Sigma_i^g \Sigma_j^e xij}{ge} \; and \; \Sigma_i^g P_i - 0, i = 1,2.....(g)$$

The regression coefficient (b_i)= $\frac{\Sigma_j^e xijI_j}{\Sigma_j^e I_j^2}$

Deviations from linearity (S^2_{di}) =g_iMSS – EMS ;

$$\text{where, } g_i\,MSS= \frac{\left[\left(\Sigma_j^e x_{ij}^2 - \frac{T_{gi}^2}{e}\right) - \left(\frac{\Sigma_j^e x_{ij} I_j}{\Sigma_j^e I_j^2}\right)^2\right]}{(e-2)}$$

The following inferences can be drawn from the following adaptive specificity for various environments:

Low yield, low sensitivity: Phenotypic index (P_i) less than zero and regression coefficient (b_i) < 1.

Low yield, high sensitivity: Phenotypic index (P_i) less than zero and regression coefficient (b_i) > 1.

High yield, low sensitivity: Phenotypic index (P_i) greater than zero and regression coefficient (b_i) < 1.

High yield, high sensitivity: Phenotypic index (P_i) greater than zero and regression coefficient (b_i) > 1.

A stable genotype is one which confirms to the following condition of three stability parameters i.e. P_i > 0; b_i = 1 and (S^2_{di}) is low.

RESULTS AND DISCUSSION

A single experiment will precisely furnish information about only one location or season or year in which the experiment is conducted. Therefore, it was necessary to repeat the same experiment either at different places or over a number of years to obtain valid recommendations taking into account place to place variation or variation over period. Average response of genotypes thus depends largely upon the absence or presence of genotype × season interaction, coupled with high yield indicated that the genotypes are suitable for general adaptation in the range of environment considered. But this ideal situation is rarely found because the stability of a genotype is inversely proportional to the mean yield. Genotypes with high stability are generally low yielders and vice-versa. Main objective is to identify stable genotype that interact less with the environment in which they are grown.

Treatment×season (T×S) interaction was found to be significant for number of corms per square meter, weight of corms per square meter, number of cormels per plant, weight of cormels per plant. Therefore stability analysis was conducted for these characters. Parameters of Eberhart & Russell's model along with conclusions are presented in Tables 1, 2, 3 and 4 for number of corms per square meter, weight of corms per square meter, number of cormels per plant, and weight of cormels per plant respectively.

Number of corms per square meter: The treatment combination N_1D_2 i.e. foliar spray of nitrogen (3 days) and plant density (120 cormels m^{-2}) and the treatment combination N_2D_2 i.e. foliar spray of nitrogen (5 days) and plant density (120 cormels m^{-2}) satisfied all three conditions i.e. P_i (7.45 and 4.11 respectively) greater than zero, regression coefficient b_i (1.27 and 1.23, respectively) nearly

Table 1. Parameters of Eberhart and Russell's model for number of corms m^{-2}

Treatment combinations	Mean	P_i	(b_i)	(S^2_{di})	Conclusion
T_1 (N_0D_1)	38.00	-16.22	0.24	5.258	Low yield, low sensitivity
T_2 (N_0D_2)	40.25	-13.97	0.28	4.926	Low yield, low sensitivity
T_3 (N_0D_3)	43.58	-10.64	0.26	3.282	Low yield, low sensitivity
T_4 (N_1D_1)	54.00	-0.22	0.64	53.348	Low yield, low sensitivity
T_5 (N_1D_2)	61.67	7.45	1.27	-0.365	Stable treatment combination
T_6 (N_1D_3)	71.75	17.53	2.05	48.201	High yield, high sensitivity
T_7 (N_2D_1)	50.67	-3.55	0.76	19.843	Low yield, low sensitivity
T_8 (N_2D_2)	58.33	4.11	1.23	1.942	Stable treatment combination
T_9 (N_2D_3)	67.58	13.36	1.87	26.006	High yield, high sensitivity
T_{10} (N_3D_1)	47.92	-6.30	0.73	9.835	Low yield, low sensitivity
T_{11} (N_3D_2)	53.667	-0.55	1.02	14.871	Low yield, high sensitivity
T_{12} (N_3D_3)	63.250	9.03	1.64	10.646	High yield, high sensitivity

equal to one and low S^2_{di} (Table 1). Thus, treatment combinations N_1D_2 and N_2D_2 identified as stable treatment combinations with respect to foliar nitrogen application and plant density and were suitable for general adaptations.

Weight of corms per square meter: The treatment combinations N_1D_1 (3 days foliar spray of nitrogen and 100 cormels m^{-2} plant density), N_1D_2 (3 days foliar spray of nitrogen and 120 cormels m^{-2}), N_1D_3 (3 days foliar spray of nitrogen and 140 cormels m^{-2} plant density), N_2D_1 (5 days foliar spray of nitrogen and 100 cormels m^{-2} plant density), N_2D_2 (5 days foliar spray of nitrogen and 120 cormels m^{-2}), N_2D_3 (5 days foliar spray of nitrogen and 140 cormels m^{-2}), N_3D_2 (7 days foliar spray of nitrogen and 120 cormels m^{-2}) and N_3D_3 (7 days foliar spray of nitrogen and 140 cormels m^{-2}) satisfied conditions of Eberhart and Russell's model i.e. P_i (0.03, 0.08, 0.00, 0.05 and 0.01, respectively) greater than zero, regression coefficients b_i's (1.02, 1.03, 1.04, 1.00, 1.01, 1.02, 0.99 and 1.00, respectively) nearly equal to one and low S^2_{di}(Table 2). Thus, these treatment combinations N_1D_1, N_1D_2, N_1D_3, N_2D_1, N_2D_2, N_2D_3, N_3D_2 and N_3D_3 identified as stable treatment combinations with respect to foliar nitrogen application and plant density and were suitable for general adaptations.

Number of cormels per plant: The treatment combination N_1D_3 (3 days foliar spray of nitrogen and 140 cormels m^{-2} plant density) satisfied all three conditions i.e. P_i ($_{0.90}$) greater than zero, regression coefficient b_i (1.03) nearly equal to one and low S^2_{di} (Table 3). The treatment combinations N_1D_3 was identified as stable treatment combinations with respect to number of cormels per plant and plant density and was suitable for general adaptations.

Weight of cormels per plant: The treatment combination

Table 2. Parameters of Eberhart and Russell's model for weight of corms m^{-2}

Treatment combinations	Mean	P_i	(b_i)	(S^2_{di})	Conclusion
T_1 (N_0D_1)	2.39	-0.10	0.96	0.00	Low yield, high sensitivity
T_2 (N_0D_2)	2.40	-0.09	0.96	0.00	Low yield, high sensitivity
T_3 (N_0D_3)	2.42	-0.06	0.97	0.00	Low yield, low sensitivity
T_4 (N_1D_1)	2.52	0.03	1.02	0.00	Stable treatment combination
T_5 (N_1D_2)	2.54	0.06	1.03	0.00	Stable treatment combination
T_6 (N_1D_3)	2.56	0.08	1.04	0.00	Stable treatment combination
T_7 (N_2D_1)	2.48	0.00	1.00	0.00	Stable treatment combination
T_8 (N_2D_2)	2.51	0.02	1.01	0.00	Stable treatment combination
T_9 (N_2D_3)	2.54	0.05	1.02	-0.00	Stable treatment combination
T_{10} (N_3D_1)	2.46	-0.02	0.99	0.001	Low yield, high sensitivity
T_{11} (N_3D_2)	2.48	0.00	0.99	0.00	Stable treatment combination
T_{12} (N_3D_3)	2.50	0.01	1.00	0.00	Stable treatment combination

Table 3. Parameters of Eberhart and Russell's model for number of cormels $plant^{-1}$

Treatment combinations	Mean	P_i	(b_i)	(S^2_{di})	Conclusion
T_1 (N_0D_1)	3.63	-1.56	0.65	0.000	Low yield, low sensitivity
T_2 (N_0D_2)	3.35	-1.84	0.25	0.000	Low yield, low sensitivity
T_3 (N_0D_3)	3.23	-1.96	0.28	0.001	Low yield, low sensitivity
T_4 (N_1D_1)	7.83	2.64	3.26	0.096	High yield, low sensitivity
T_5 (N_1D_2)	6.60	2.22	1.71	0.033	High yield, low sensitivity
T_6 (N_1D_3)	6.09	0.90	1.03	0.012	Stable treatment combination
T_7 (N_2D_1)	6.53	1.33	1.33	0.077	High yield, low sensitivity
T_8 (N_2D_2)	5.45	0.26	0.73	0.007	High yield, low sensitivity
T_9 (N_2D_3)	4.79	-0.40	0.65	0.000	Low yield, low sensitivity
T_{10} (N_3D_1)	5.32	0.13	0.72	0.028	High yield, low sensitivity
T_{11} (N_3D_2)	4.81	-0.38	0.77	0.005	Low yield, low sensitivity
T_{12} (N_3D_3)	4.61	0.58	0.62	0.002	High yield, low sensitivity

Table 4. Parameters of Eberhart and Russell's model for weight of cormels plant^{-1}

Treatment combinations	Mean	P_i	(b_i)	(S^2_{di})	Conclusion
T_1 (N_0D_1)	0.73	-0.34	0.87	-0.000	Low yield, low sensitivity
T_2 (N_0D_2)	0.67	-0.40	0.55	0.000	Low yield, low sensitivity
T_3 (N_0D_3)	0.65	-0.42	0.45	-0.000	Low yield, low sensitivity
T_4 (N_1D_1)	1.56	0.50	3.20	0.001	High yield, low sensitivity
T_5 (N_1D_2)	1.34	0.28	1.92	0.000	High yield, low sensitivity
T_6 (N_1D_3)	1.26	0.19	1.68	-0.000	High yield, low sensitivity
T_7 (N_2D_1)	1.30	0.24	1.32	0.002	Stable treatment combination
T_8 (N_2D_2)	1.11	0.05	0.44	0.000	High yield, low sensitivity
T_9 (N_2D_3)	1.04	-0.03	0.72	-0.000	Low yield, low sensitivity
T_{10} (N_3D_1)	1.09	0.02	0.07	0.000	High yield, low sensitivity
T_{11} (N_3D_2)	1.04	-0.02	0.34	-0.000	Low yield, low sensitivity
T_{12} (N_3D_3)	1.00	-0.07	0.45	-0.000	Low yield, low sensitivity

N_2D_1 (5 days foliar spray of nitrogen and 100 cormels m^{-2}plant density) satisfy conditions P_i (0.24) greater than zero, regression coefficient b_i (1.32) nearly equal to one and low S^2_{di} (Table 4). The treatment combination N_2D_1 was identified as stable treatment combination with respect to weight of cormels plant^{-1} and was suitable for general adaptations.

For all other characters i.e. number of days for sprouting, percent sprouting, plant height, number of leaves per plant, cropping duration, size of corms and size of cormels variances due to treatment×season (T×S) interaction were not found to be significant. Therefore stability analysis was not conducted for these characters. Stability analysis on 22 gladiolus cultivars for 20 characters was conducted by Nazir et al (2005). Raj and Misra (1998); Shamasundaran and Singh (2004) also performed stability analysis on gladiolus, while Naik et al (2005) and Kapil et al (2011) identified a suitable and stable varieties of marigold.

CONCLUSION

Three days foliar spray of nitrogen and 120 cormels m^{-2} and five days foliar spray of nitrogen and 120 cormels m^{-2} were found to be stable for number of corms m^{-2}. Whereas three days foliar spray of nitrogen and 140 cormels m^{-2} was found to be stable for number of cormels plant^{-1} and five days foliar spray of nitrogen & 100 cormels m^{-2} was found to be stable for weight of cormels plant^{-1}.

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Forms of Potassium and their Distribution under Prominent Cropping Systems of Chittoor District of Andhra Pradesh, India

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Abstract: An investigation was carried out to assess distribution of forms of potassium in soils and seven prominent cropping systems from Chittoor district of Andhra Pradesh viz., Groundnut + Redgram, Groundnut-Groundnut, Groundnut monocropping, Redgram monocropping, Sugarcane monocropping, Paddy-Groundnut and Bajra-Groundnut. The highest mean available K was recorded under groundnut + redgram intercropping system (126.41 mg kg^{-1}) in surface soils, while in sub-surface soils under groundnut monocropping system (89.32 mg kg^{-1}), water soluble K in surface soils under bajra-groundnut cropping system (38.70 mg kg^{-1}), while in sub-surface soils under groundnut + redgram intercropping system (23.29 mg kg^{-1}), exchangeable K under groundnut monocropping system in surface soils (102.63 mg kg^{-1}) and in sub-surface soils (72.17 mg kg^{-1}), non-exchangeable K under paddy-groundnut cropping system (517.83 mg kg^{-1}), while in sub-surface under bajra-groundnut cropping system (475.20 mg kg^{-1}). The mean lattice K and total K were under redgram monocropping system in surface soils (40313.16 mg kg^{-1} and 40794 mg kg^{-1}, respectively), while in sub-surface soils under groundnut+redgram intercropping system (35802.72 mg kg^{-1} and 36248 mg kg^{-1}, respectively).The different forms of potassium were positively and significantly correlated among themselves with each other in soils of indicating dynamic equilibrium among different forms K.

Keywords: Available K, Non-exchangeable K, Lattice K, Total K, Cropping systems

Potassium is third main pillar of balanced fertilizer use after nitrogen and phosphorus. It plays number of vital and crucial physiological roles in plant growth and development, but its importance is often under estimated, as it doesn't produce rapid growth like nitrogen. Among the essential plant nutrients, potassium (K) assumes greater significance because it is needed in comparatively larger amounts by plants and besides increasing the yield and immensely enhances the crop produce quality (Srinivasrao et al 2011). Potassium is neglected nutrient in an intensive agricultural production because of the general conception that Indian soils are rich in native-K resulted from the exclusion of potassium in balanced nutrition lead to the mining of soil reserve K. Exclusion of potassium in balanced nutrition leads to the mining of soil reserve K. The potassium in soil is enigmatic nutrient as its availability is governed by parent material, degree of weathering, application of fertilizers and manures, and losses due to crop removal, erosion and leaching (Lalitha and Dakshinamoorthy 2014). Crops response to added potassic fertilizers is more associated with shift in the dynamic equilibrium within the forms of K than quantity of available K in liable pool (Kishore et al 2020). The knowledge on the potassium forms in soils is crucial since it provides insight into the potassium distribution within soils. It can indicate the depletion as well as accumulation pattern of potassium in soil. Information on forms of potassium and their distribution in soil will help in assessing the long term potassium availability to crops. Keeping this in view, the present investigation was undertaken to study the distribution and dynamics of K under prominent cropping systems of Chittoor district of Andhra Pradesh.

MATERIAL AND METHODS

An investigation was carried out in S. V. Agricultural College, Tirupati, during 2019 to assess the forms of potassium in soils of Chittoor district of Andhra Pradesh, India, extending between 12° 37″ to 14° 8″ North latitude and 78° 33″ to 79°55″ East longitude. The district experiences both southwest monsoon and north east monsoon with mean annual rainfall of 934.0 mm. Seven prominent cropping systems of which six are legume based cropping systems of the district viz., Groundnut + Redgram, Groundnut – Groundnut, Groundnut mono cropping, Redgram mono cropping, Sugarcane mono cropping, Paddy - Groundnut and Bajra - Groundnut were selected and five soil samples from each cropping system at 0-15 cm and 15-30 cm depths were collected air-dried, ground and sieved through a 2 mm stainless steel sieve and stored in cloth bags. The soil samples used for analysing various forms of potassium by employing standard methods of analyses as detailed in Table

1. Simple correlation coefficients ('r') were also worked out for relationships among potassium forms using Statistical Package for Social Sciences (SPSS) software.

RESULTS AND DISCUSSION

Available K: The available K content of surface soils varied from 36.20 mg kg^{-1} in Paddy-Groundnut cropping system to 139.30 mg kg^{-1} in Groundnut+Redgram intercropping system with mean of 40.99 and 126.41 mg kg^{-1}, respectively and contribution of available K to total K ranged from 0.13 to 0.39 per cent. In sub-surface soils, available K content varied from 25.55 mg kg^{-1} in Paddy-Groundnut cropping system to 100.70 mg kg^{-1} in Groundnut monocropping system with mean 31.69 and 89.32 mg kg^{-1}, respectively (Table 2). The contribution of available K to total K ranged from 0.13 per cent in Paddy-Groundnut and Sugarcane mono cropping system to 0.29 per cent in Groundnut mono cropping system. The highest available K was observed in soils of Groundnut+Redgram intercropping system and Groundnut monocropping system in surface and sub-surface soils, respectively which might be due to application of potassic fertilizers in this cropping system and also may be due to the presence of clay rich minerals like illite and kaolinite. Harsha and Jagadeesh (2017) observed lowest available K was recorded in Paddy-Groundnut cropping system in both surface and sub-surface soils, which might be due to continuous removal of potassium by the Paddy-Groundnut cropping system. The highest available potassium was observed in surface soils than in sub-surface soils in all cropping systems, which might be attributed to application of potassic fertilizers in the previous crop as reported by Padhan et al (2015).

Water soluble K: The water soluble K content of surface soils varied from 6.55 mg kg^{-1} in Paddy-Groundnut cropping system to 41.20 mg kg^{-1} in Bajra-Groundnut cropping system with mean 7.93 and 38.70 mg kg^{-1}, respectively. The water soluble K contributed least to total K and ranged from 0.02 to 0.12. In sub-surface soils water soluble K content varied from 2.14 mg kg^{-1} in Paddy-Groundnut cropping system to 25.85 mg kg^{-1} in Groundnut + Redgram intercropping system with mean values of 7.19 and 23.29 mg kg^{-1}, respectively (Table 2). Contribution of water soluble K to total K ranged from 0.02 to 0.06 per cent. The highest water soluble K was observed in soils of bajra-Groundnut cropping system and Groundnut + Redgram intercropping system in surface and sub-surface soils, respectively. The similar trend was reported by Lakaria et al (2012) which might be due to external application of water soluble fertilizers under intensive farming system and lowest was observed in Paddy-Groundnut cropping system and Sugarcane monocropping system in surface and sub-surface soils, respectively which might be due to more uptake or utilization water soluble K fertilizers. Further in all cropping systems, surface soils had higher water soluble K than subsurface soils, which may be attributable to exposure of K bearing minerals to weathering, or upward translocation of K from subsurface layers through capillary rise, or due to K addition via plant residues, manures, and chemical fertilizers (Rao et al 2013).

Exchangeable K: The exchangeable K content of surface soils varied from 29.50 mg kg^{-1} in Paddy-Groundnut cropping system to 111.80 mg kg^{-1} in Groundnut monocropping system with mean values of 33.06 and 102.63 mg kg^{-1}, respectively. The exchangeable K contribution to total K ranged from 0.10 to 0.31 per cent. In sub-surface soils exchangeable K content varied from 23.08 mg kg^{-1} in Paddy-Groundnut cropping system to 81.20 mg kg^{-1} in Groundnut monocropping system with mean 24.50 and 72.17 mg kg^{-1}, respectively (Table 2). This fraction contributed 0.09 to 0.23 per cent to total K. The highest exchangeable K was observed in soils of Groundnut monocropping system in both surface and sub-surface soils, which might be due to application of fertilizers might resulted in higher buildup of K in these soils or lower utilization of applied K and however, lowest exchangeable K was observed in Paddy-Groundnut cropping system at both depths. Highest exchangeable K was observed in surface soils than in sub-surface soils in all cropping systems, which might be attributed to continuous application of fertilizers to surfaces layers only and also addition of higher root biomass. These results were similar to the findings of Lungmuana et al (2014).

Non-exchangeable K: The fraction of non-exchangeable K content in surface soils varied from 275.05 mg kg^{-1} in

Table 1. Analytical methods followed during chemical analysis

Properties	Methodology	Reference
Available potassium	Neutral *1N* NH_4OAC extraction	Jackson (1973)
Forms of potassium	Flame photometry	
Water soluble K	1:5 Soil water suspension	Jackson (1973)
Exchangeable K	Available K – Water soluble K	
Non-exchangeable K	Boiling *1N* Nitric acid extraction	Wood and De Turk (1941)
Lattice K	Total K – (Available K + Non-exchangeable K)	Wiklander (1954)
Total K	HF – $HClO_4$ extraction	Pratt (1965)

Groundnut monocropping system to 581.55 mg kg^{-1} in Paddy-Groundnut cropping system with mean 309.96 and 517.83 mg kg^{-1}, respectively. This fraction contribution to total K ranged from 0.82 to 1.93 per cent. In sub-surface soils, non-exchangeable K content varied from 227.25 mg kg^{-1} in Groundnut monocropping system to 495.90 mg kg^{-1} in bajra-Groundnut cropping system with mean values of 247.96 and 475.20 mg kg^{-1}, respectively (Table 2). Per cent contribution of non-exchangeable K to total K varied between 0.81 and 1.84. The highest non-exchangeable K was observed in soils of Paddy-Groundnut cropping system and bajra-Groundnut in surface and sub-surface soils, respectively which might be due to conversion of added water soluble K into non-exchangeable forms, increased fixation induced by high levels of K fertilization and the successive application which might have decreased utilization of non-exchangeable K leading to its accumulation (Rout et al 2017) and lowest non-exchangeable K was observed in Groundnut monocropping system at both depths, which might be due to the fact that more removal of exchangeable K by crop in order to replenish decreased exchangeable K, non-exchangeable K was resealed and thus dynamic equilibrium was maintained (Tomar et al 2017). The highest non-exchangeable K was observed in surface soils than in sub-surface soils in all cropping systems, except in bajra-Groundnut cropping system. Similar results reported by Jassal et al (2012), Kumari and Nisha (2014).

Lattice K: The lattice K content of surface soils varied from 16716.30 mg kg^{-1} in Groundnut-Groundnut cropping system to 42529.80 mg kg^{-1} in Redgram monocropping system with mean value of 19866.02 and 40313.16 mg kg^{-1}, respectively. Major portion of total K comprised of this fraction and contribution varied from 97.79 to 98.85 per cent. In sub-surface soils lattice K content varied from 20041.20 mg kg^{-1} in Paddy-Groundnut cropping system to 38496.60 mg kg^{-1} in Groundnut+Redgram intercropping system with mean 23618.92 and 35802.72 mg kg^{-1}, respectively (Table 2). Per cent contribution of lattice K to total K ranged from 98.03 to 98.91. The highest lattice K was observed in soils of Redgram monocropping system and Groundnut+Redgram intercropping system in surface and sub-surface soils, respectively which might be due to higher content of mica and feldspars in coarse fractions and illite mineral in clay (Elbaalawy et al 2016) and lowest lattice K was observed in Groundnut-Groundnut cropping system and Paddy-Groundnut cropping system in surface and sub-surface soils, respectively which might be due to nature of parent material from which soils were developed. The data further revealed

Table 2. Distribution of different forms of potassium under different cropping systems

Cropping systems		Available K (mg kg^{-1})		Water soluble K (mg kg^{-1})		Exchangeable K (mg kg^{-1})		Non-exchangeable K (mg kg^{-1})		Lattice K (mg kg^{-1})		Total K (mg kg^{-1})	
		0-15 cm	15-30 cm	0-15 cm	15-30 cm	0-15 cm	15-30 cm	0-15 cm	15-30 cm	0-15 cm	15-30 cm	0-15 cm	15-30 cm
Groundnut + Redgram	Min.	113.20	50.15	21.10	21.35	92.10	28.80	498.20	373.55	29128.60	31614.70	29740	32050
	Max.	139.30	60.00	30.85	25.85	108.45	34.45	539.10	413.40	35250.30	38496.60	35910	38970
	Mean	126.41	55.67	25.85	23.29	100.56	32.38	514.99	389.61	31994.60	35802.72	32636	36248
Groundnut - Groundnut	Min.	50.55	41.35	9.90	11.45	40.20	28.55	350.55	280.05	16716.30	29594.40	17190	29930
	Max.	61.80	48.05	18.40	14.10	45.65	36.25	418.00	330.50	22027.40	33637.40	22460	33970
	Mean	56.67	45.55	13.06	12.69	43.61	32.86	391.31	302.37	19866.02	31608.08	20314	31956
Groundnut monocropping	Min.	112.30	81.65	19.85	16.15	92.45	65.50	275.05	227.25	32407.40	28589.10	32810	28910
	Max.	136.35	100.70	25.40	19.50	111.80	81.20	336.35	271.70	41971.50	32537.90	42410	32890
	Mean	125.46	89.32	22.83	17.15	102.63	72.17	309.96	247.96	37398.58	30412.72	37834	30750
Redgram Monocropping	Min.	61.25	59.75	10.85	10.45	50.40	47.60	398.70	338.15	38423.60	29457.50	38920	29900
	Max.	78.30	72.95	18.50	15.25	60.35	57.70	433.05	422.55	42529.80	35485.80	42990	35890
	Mean	69.00	64.71	14.89	13.05	54.11	51.66	411.84	377.23	40313.16	32316.06	40794	32758
Sugarcane Monocropping	Min.	58.80	39.55	7.10	5.55	51.70	32.30	355.65	270.95	29948.00	29555.70	30370	29900
	Max.	82.95	47.40	9.80	7.25	74.60	41.65	396.15	452.00	38146.60	35720.60	38610	36220
	Mean	68.63	43.30	8.56	6.06	60.07	37.24	385.75	358.18	35083.62	32606.52	35538	33008
Paddy - Groundnut	Min.	36.20	25.55	6.55	2.14	29.50	23.08	444.50	381.40	28289.30	20041.20	28890	20450
	Max.	45.65	36.90	8.80	5.65	36.85	31.69	581.55	489.80	32937.20	27868.20	33520	28350
	Mean	40.99	31.69	7.93	7.19	33.06	24.50	517.83	443.39	31087.18	23618.92	31646	24094
Bajra - Groundnut	Min.	101.95	76.70	35.60	10.85	62.85	62.05	396.80	449.25	28137.60	30333.90	28670	30910
	Max.	115.25	94.00	41.20	17.30	76.10	78.10	431.95	495.90	36630.10	34305.50	37150	34870
	Mean	108.50	82.86	38.70	14.66	69.80	68.20	414.30	475.20	32959.20	32021.94	33482	32580

that in general highest lattice K was observed in surface soils than in sub-surface soils in all cropping systems, which on contrary with findings of Sawarkar et al (2013). However, higher values of lattice K in sub-surface soils was observed in Groundnut+Redgram intercropping system and Groundnut-Groundnut cropping system which might be due to fact that these soils may be rich micaceous parent material (Kundu et al 2014).

Total K: The total K content of surface soils varied from 17190 mg kg^{-1} in Groundnut-Groundnut cropping system to 42990 mg kg^{-1} in Redgram monocropping system with mean of 20314 and 40794 mg kg^{-1}, respectively. In sub-surface soils total K content varied from 20450 mg kg^{-1} in Paddy-Groundnut cropping system to 38970 mg kg^{-1} in Groundnut+Redgram intercropping system with mean 24094 and 36248 mg kg^{-1}, respectively (Table 2). The highest total K was recorded in soils of Redgram monocropping system and Groundnut+Redgram cropping system in surface and sub-surface soils, respectively which might be due to presence of sufficient quantity of potash bearing primary minerals like feldspar and mica and it seemed to be directly related with clay and organic matter content of these soils (Saini and Grewal, 2014) and lowest total K was in Groundnut-Groundnut cropping system and Paddy-Groundnut cropping system in surface and sub-surface soils, respectively. The data further revealed that highest total K was observed in surface soils than in sub-surface soils in all cropping systems, except in Groundnut+Redgram intercropping system and Groundnut-Groundnut cropping system, which might be attributed to weathering of primary K bearing minerals.

Correlation among various forms of potassium: In surface soils, available K was highly and significantly correlated with water soluble K, exchangeable K (non-exchangeable lattice K and total K (Table 3). Similar results were reported by Jadhao et al. (2018) indicating dynamic equilibrium among all the forms of potassium under sorghum-wheat cropping system. Water soluble K was highly and significantly correlated with available exchangeable K and non-exchangeable K (Table 3). Similar results reported by Dhakad et al (2017) observed similar trend in soils of Gwalior district of Madhya Pradesh. The good correlation between water-soluble K and other potassium forms signifies that water-soluble K is regulated by other forms of K such as non-exchangeable K and total K. Exchangeable K positively and significantly correlated with available K water soluble K, non-exchangeable K, lattice K and total K (Table 3). These results are on par with results of Kundu et al (2014) in soils of West Bengal. Non-exchangeable K was positively and significantly correlated with lattice K and total K. Lattice K was highly and significantly correlated with total K. High degree of correlation was noted among lattice K and total K. Similar results were reported by Mali et al (2016) under soils of soybean growing farmer's field in vertisols.

In sub-surface soils, available K was highly and significantly correlated with water soluble K, exchangeable K, lattice K and total K. Water soluble K was highly and significantly correlated with available K, lattice K and total K (Table 4). Similar results were reported by Jadhao et al

Table 3. Correlation among different forms of potassium in surface soils under different cropping systems

	Avl-K	WS-K	EX-K	NEX-K	Lattice-K	Total-K
Avl-K	1					
WS-K	0.779**	1				
EX-K	0.963**	0.592**	1			
NEX-K	0.837**	0.444**	0.893**	1		
Lattice-K	0.361*	0.208	0.376*	0.360*	1	
Total-K	0.374*	0.216	0.390*	0.374*	0.999**	1

** Correlation is significant at the 0.01 level (2-tailed); * Correlation is significant at the 0.05 level (2-tailed); N=35

Table 4. Correlation among different forms of potassium in sub-surface soils under different cropping systems

	Avl-K	WS-K	EX-K	NEX-K	Lattice-K	Total-K
Avl-K	1					
WS-K	0.541**	1				
EX-K	0.963**	0.298	1			
NEX-K	0.080	0.013	0.088	1		
Lattice-K	0.336*	0.506**	0.225	0.442**	1	
Total-K	0.338*	0.496**	0.233	0.437**	0.969**	1

** Correlation is significant at the 0.01 level (2-tailed); * Correlation is significant at the 0.05 level (2-tailed); N=35

(2018). Exchangeable K was highly and significantly correlated with available K and these findings were in accordance with Jassal et al (2012). Non-exchangeable K was highly and significantly correlated with lattice K and total K. Lattice K was highly and significantly correlated with available K water soluble K and non-exchangeable K and total K (Table 4). Total K was highly and significantly correlated with available K; water soluble K, non-exchangeable K and lattice K. Similar results were reported by Kundu et al (2014).

CONCLUSIONS

Soil K fractions in all cropping systems were in the order of total K > lattice K > non-exchangeable K > available K > exchangeable K > water soluble K. Under rainfed conditions all the forms of potassium were highest in groundnut+redgram intercropping system followed by groundnut monocropping system and redgram monocropping system while under irrigated conditions all the forms of potassium were highest in bajra-groundnut cropping system followed by sugarcane monocropping system, groundnut-groundnut cropping system and paddy-groundnut cropping system. The different forms of K were positively and significantly correlated with each other in soils at both layers indicating dynamic equilibrium among different forms.

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Leaf Litter Decomposition of *Melocanna baccifera* (Roxb.) Kurz under Field and Laboratory Microcosm in Northeast India

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Abstract: *Melocanna baccifera* (Roxb.) Kurz is one of the most abundant bamboo species of Mizoram, Northeast India contributing about 95% of the total bamboo resources. This study was aimed to assess the rate of leaf litter decomposition of *M. baccifera* leaves in natural forest (FS) and laboratory microcosm (MC). A total of 36 litter bags measuring (15 x 15 cm, 2 mm mesh) containing 10g of air-dried litter material were placed in FS, and 36 litter bags of 10 x 10 cm filled with ~5 g of litter material were placed in the MC. MC was made from bottom sealed PVC pipe of 12 cm diameter and 16 cm height and filled with layers of 2/3 mineral soil and 1/3 with organic soil from the forest. A total of 6 litter bags were retrieved from FS and MC at monthly intervals for 6 months. Litter decay rate was higher in FS as compared to MC and litter mass remaining at the end of the study was 7 % and 13 % in FS and MC, respectively. Consequently, carbon (C) and nitrogen (N) mass remaining were 11.2% and 11.8% in MC and 7.3% and 5.6% in FS. Annual decay constant (k) was 2.2 and 1.4, respectively in FS and MC. Overall, mass loss rate and C and N release from *M. baccifera* litter was significantly higher in FS compared to MC indicating more complex synergistic effects of abiotic and biotic factors in decomposition at the FS site compared to MC site.

Keywords: Bamboo leaf litter, Decay rate constant (k), Carbon and Nitrogen release, Northeast India

Bamboo is one of the fastest growing plants belonging to the family Poaceae. Various species of bamboo is widely distributed throughout the northeastern region. Bamboo forest represents ~57% of the total forest area in Mizoram. *Melocanna baccifera* is one of the most abundant bamboo species accountings for about 95% of the total bamboo resources of the state of Mizoram (Anon 2017). The species of bamboo are occurring naturally mixed with other forest species as well as planted by the villagers for its multiple uses at altitudes ranging from as low as 100 m amsl to 1500 m amsl depending on the types of bamboo (Singh et al 2015, Singha and Tripathi 2019). The studies on the litter decomposition of bamboo in the region are highly scarce. While the photosynthesis represents one of the important processes for building up of organic matter into the forest, the process of litter decomposition is equally important to recycle the organic matter in the forested ecosystems (Novara et al 2015, Lalnunzira and Tripathi 2018). Litter decomposition helps to restore organic matter and nutrients in the forest soils (Pandey et al 2007, Wapongnungsang et al 2017, Singh and Tripathi 2020 a, b). But the process of litter decomposition on the forest floor is influenced by number of factors such as initial litter quality (i.e. C, N, lignin, C/N), soil microbes and various abiotic variables (Tripathi et al 2012, Gautam et al 2019, Lalnunzira and Tripathi 2018, Singh et al 2021). Concentration of Carbon (C), nitrogen (N) and lignin in the initial litter has been reported to control the decomposition of litter in many forest sites (Gartner and Cardon 2004, Tripathi et al 2006). Further, it has been reported that the early phase of litter decomposition process is influenced by the concentration of N in the initial litter (Lalnunzira and Tripathi 2018), and in the later phase C becomes the limiting factor for the decomposition (Hauchhum and Tripathi 2019, Singh et al 2021). Rapid mass loss of litter has been reported in tropical forests as compared to the temperate forests (Thongkantha et al 2008, Nonghuloo et al 2020). This study was designed to assess the magnitude of litter decomposition and C and N release pattern in the natural forest and control laboratory condition.

MATERIAL AND METHODS

Experimental sites: The natural forest (FS) site was located at Sairang (23°49`18``N 92°39`33``E 91 m amsl) area of the Aizawl districts of Mizoram. The microcosm (MC) experiment was set up inside the mist chamber at the Department of Forestry, Mizoram University (23°44`14``N 92°39`39``E 763 m amsl). The MC is made of PVC pipe of 16 cm height sealed at the bottom with 12 cm wide opening on the top. The lower part MC was filled with 2/3 of mineral soil and the remaining 1/3 top portion was covered with organic soil from the forest (Fig. 1).

Soil sampling and analysis: Soil samples were collected

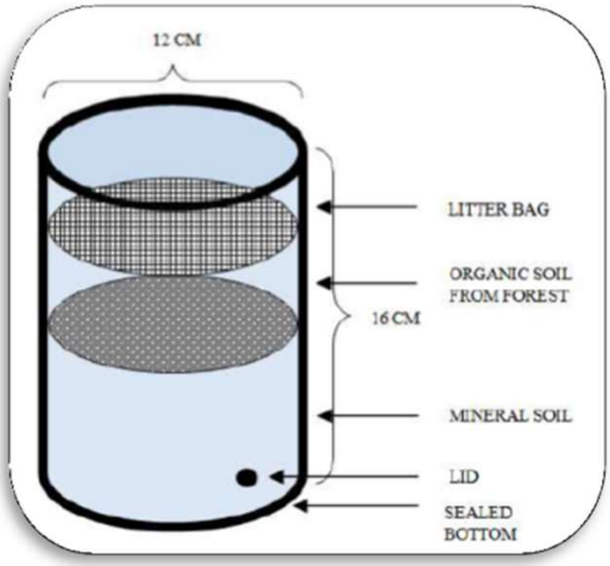

Fig. 1. Design of microcosm used for leaf litter decomposition

from 3 random locations approximately 25 m away from each other from upper soil layer (0 - 10 cm) using soil corer (4.2 cm wide). Bulk density (g cm^{-3}) was calculated using soil corer (4.2 cm wide and 10 cm high) and expressed on dry soil weight basis. Soil pH was determined using a standard pH meter (Mettler Toledo, Switzerland) at 1: 2.5 soil $water^{-1}$ suspensions. Hydrometer method was used for the determination of soil texture. The moisture content of the soil was determined by drying soil samples at 105°C for 48 h in hot air oven to constant weight (Hauchhum and Tripathi 2017). The available P was determined by the Bray-I-P method. Soil microbial biomass carbon (MBC) was estimated by chloroform fumigation extraction method (Brookes et al 1985) followed by the liquid oxidation. The difference in C content between fumigated and non-fumigated soil samples was multiplied by constant (K_{EC}) = 0.38 fixed (Vance et al 1987) and expressed in mg kg^{-1} (DW) soil. Air dried soil sample was ground and sieved at 1mm mesh, then analyst C and N using CHNS/O Elemental Analyzer with auto-sampler and TCD detector–Euro Vector Model: Euro EA 3000 at Central Instrumental Laboratory, Mizoram University.

Determining soil microbial population: Serial dilution technique was used to prepare 1 gm freshly collected soil solutions (10^{-1}, 10^{-2}, 10^{-3}, 10^{-4}, 10^{-5}, 10^{-6} and 10^{-7}) as described in Ghosh and Tripathi 2021. Colony building units (CFUs) are calculated according to the Dilution Plate Method. Different agar media were prepared separately; fungi, potato dextrose agar (PTA) supplemented with an antibiotic 0.08% penicillin, chloramphenicol and rose Bengal; actinomycetes, starch casein agar (SCA) mixed with nystatin (0.08%) and bacteria, nutrient agar (NA) added about 0.08% nystatin and actidione. Dilutions of 10^{-3} - 10^{-5}, 10^{-4} - 10^{-6} and 10^{-5} - 10^{-7} are used to isolate fungi, actinomycetes and bacteria, respectively. Dilution of 0.5 ml is placed on petri-plates containing solid media in triplicates. Media plates were incubated at 28 ± 1°C for fungal and 25 ± 1°C for both actinomycetes and bacterial growth. Colony count for actinomycetes and bacterial started after 24 h of incubation and fungal after 72 h of incubation. The microbial population was expressed in CFUs/g of soil.

Measuring litter decomposition: Freshly fallen (senescence) leaves of *Melocanna baccifera* was used for decomposition experiment using nylon net bags technique. A total of 72 litter bags were used for the two set of litter decomposition experiments. Litter bag measuring 15 x 15 cm (2 mm mesh) filled with ~10 g of air-dried litter was used for FS. Whereas, in MC litter bag measuring 10 x 10 cm filled with ~5 g of litter material was used. In FS, litter bags were prepared and placed randomly at six locations approximately ~25 m distances from each other. Six litter bags were recovered at monthly interval from both FS and MC. Litter bags were brought to the laboratory and cleaned to remove adhering soil particles. Litter was dried separately in hot air oven at 70°C for 24 h to constant weight. Weight of litter was recorded and litter samples were ground and sieved in 1.5 mm mesh for further analysis.

Analysis of litter material: Air dried litter samples were ground and sieved through 1mm mesh screen and analysed for C and N concentrations using CHNS/O Elemental Analyzer with auto-sampler and TCD detector–Euro Vector, Model. Euro EA 3000 at Central Instrumental Laboratory, Mizoram University. Litter lignin was determined using Fibrotron Automatic Fiber Analysis, Model FRB 6, Version 1, Tulin Equipments, Chennai, India.

Computations: The annual decay constant (k) was calculated using negative exponential decay model of Olson (1963). $W_t/W_0 = \exp^{(-kt)}$, where W_0 = initial weight and W_t = weight remaining after time t. As suggested by Olson (1963), the time required for 50% and 95% weight loss was calculated as $t_{50} = 0.693/k$ and $t_{95} = 3/k$.

Data were compared and analyzed statistically using SPSS ver-18, Pearson correlation (r) was performed to assess significant (p <0.01) correlation between litter mass remaining of FS and MC with time elapse and mass remaining with C/N ratio in both FS and MC.

RESULTS AND DISCUSSION

Soil physico-chemical analysis: Concentrations of C, N and C/N ratio in the soil were 2.4%, 0.21% and 11.2, respectively. P_{avail} and MBC were 4.26 mg kg^{-1} and 525 mg kg^{-1}. Soil pH was strongly acidic (4.8). Bulk density was 0.93 whereas percent sand, silt and clay content were: 69.3, 16.6

and 14 (Fig. 2). Soil physico-chemical properties such as bulk density and pH affects soil permeability and microbial activities during decomposition (Krishna and Mohan 2017).

Colony forming unit of soil microbes were 9 x 10^{-3}(fungi), 49 x 10^{-6} (actinomycetes) and 174 x 10^{-5} (bacterial), respectively (Table 1). Soil microbes play an important role in breaking down of litter, example in initial stage of decomposition, bacteria help in breaking labile substances followed by fungi in decaying complex substances in later stages (Singh and Tripathi 2020 b). However, activities of soil microbes depend on various abiotic factors like temperature, moisture and litter substrate quality (Sun et al 2019).

Initial litter chemical composition and litter mass loss through time: In *M. baccifera* litter, per cent concentration of lignin, C and N were 15, 37 and 2.2, respectively, whereas C/N ratio was 16.7 (Fig. 3). Temporal changes in mass loss as per cent ash-free mass remaining (natural logarithm) against time elapsed showed significant negative correlation in litter materials at both studies (Table 3). Correlation coefficient (r) value was 0.93 in FS and 0.99 in MC. Slope was higher (0.43) in FS compared to QF (0.34) (Fig. 4).

Mass loss in initial two months of decomposition was significantly higher (62%) in FS compared to MC (43%). At the end of the study (180 days) mass remaining was 7.3% at FS and 12.9% at MC (Fig. 4). Rapid decomposition in initial stage of decomposition was also reported by the other from different ecosystems (Pandey et al 2007, Bohara et al 2019). In *Tephrosia candida* litter decomposition similar trend was reported in shifting cultivation of Mizoram (Wapongnungsang and Tripathi 2017, Ghosh and Tripathi 2021). Such rapid degradation of litter material in initial stage of litter decomposition is mainly due to loss of easily decomposable labile substances like sugar, starch (Aerts and Chapin 2000).

Annual decayed constant k was higher in FS (2.16) compared to MC (1.42). Using the Olson model (1963) time (days) required (117 days) for 50% mass loss was under

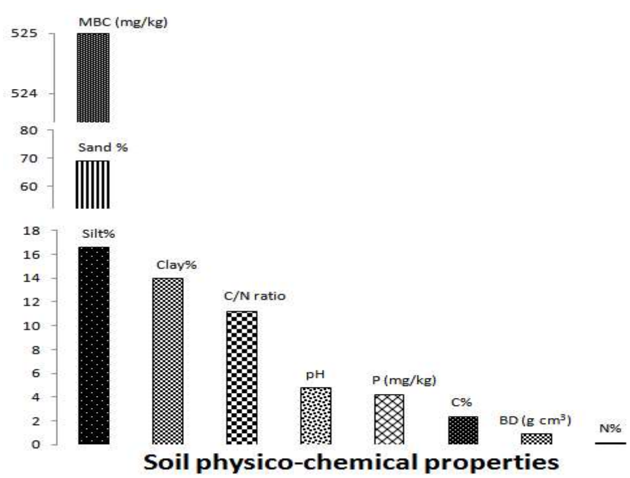

Fig. 2. Initial soil physico-chemical properties from forest site at 0-10cm depths

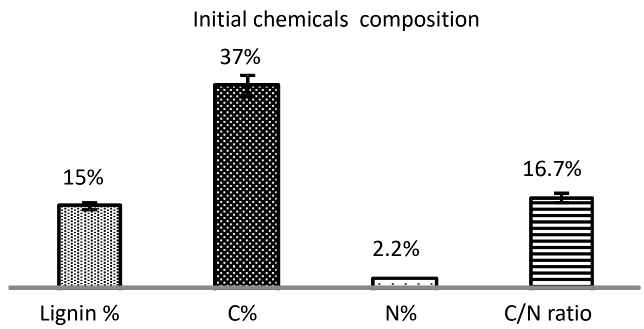

Fig. 3. Original chemical composition of *Melocanna baccifera* leaf litter

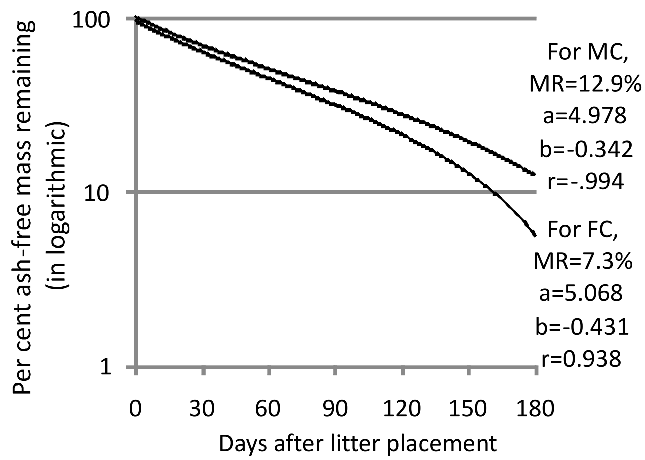

Fig. 4. Mass remaining (MR) at the end of experiment in FS and MC. Relationship between *ln* of per cent ash-free mass remaining (y) with time (days, x) with correlation coefficients (r), intercept (a) and slope (b) of the linear regression equation y = a + bx

Table 1. Colony forming units (CFUs) of various soil microbes viz. fungi, actinomycetes and bacteria from initial collected soil

Types of soil microbes	Dilution factor	Microbial count	Obtained soil microbes	CFU^{-9}
Fungi	10^3	(CFU x 10^3) colonies g^{-1}	9	9 x 10^{-3}
Actinomycetes	10^6	(CFU x 10^6) colonies g^{-1}	49	49 x 10^{-6}
Bacteria	10^5	(CFU x 10^5) colonies g^{-1}	174	174 x 10^{-5}

predicted and (505 days) for 90% mass loss was over-predicted for FS and was almost same for 178 days for 50% decomposition and 769 days for 90% decomposition in MC (Table 2). The present k value was considerably higher compared to understory dwarf bamboo (*Sasa kurilensis*) in young secondary forest of northern Japan (Tripathi et al 2006). However, k value was lower compared to recent finding in four agroforestry tree species in western Himalaya reported for *C. australis* (2.3) but comparable to *G. optiva* (2.12) with FS (Singhal et al 2019). Variations in litter mass loss in two litter decomposition set ups were likely affected by abiotic factors (i.e. temperature, precipitation etc.) along with soil microbial activities (Powers et al 2009).

Changes in C, N and C/N ratio during litter decomposition: Carbon and N release in both FS and MC decreased consistently throughout the decomposition period. C and N release almost followed the pattern similar to that of mass loss showing higher mass loss in first two months. C and N release in FS (i.e. 69.8% & 73.6%) was faster as compared to MC (i.e. 53.7% & 53.1%) (Fig. 5). C remains at the end of experiment were 7.3% in FS and 11.3% in MC, whereas N remains were 5.6% in FS and 11.8% in MC, respectively (Fig. 5). The C and N mass remaining at the end of experiment (180 days) was considerably lower compared to reported C and N value in *Tephrosia candida* (22 – 24% for C, 6 – 13 % for N) in Mizoram (Wapongnungsang and Tripathi 2017).

Increase in litter C/N ratio up to 120 days was observed in FS followed by continuous decrease in the later period of the decomposition. However, it was almost stable in MC (Fig. 6). Lower C/N ratio in initial litter has been reported to speed

Table 2. Annual decay rate constant (k), time (days) required to achieve 50% (t_{50}) and 95% (t_{95}) decompose of bamboo litter mass in FS and MC

Study types	k	t_{50}	t_{95}
FS	2.16	117	505
MC	1.42	178	769

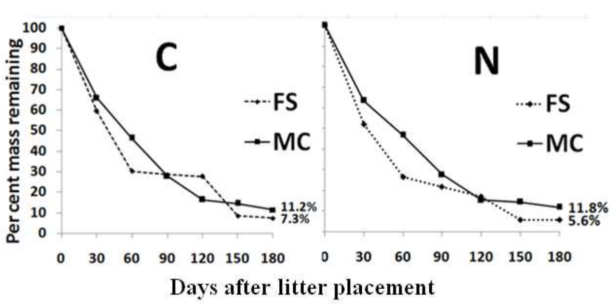

Fig. 5. Per cent mass remaining of C and N during the course of litter decomposition of bamboo in FS and MC

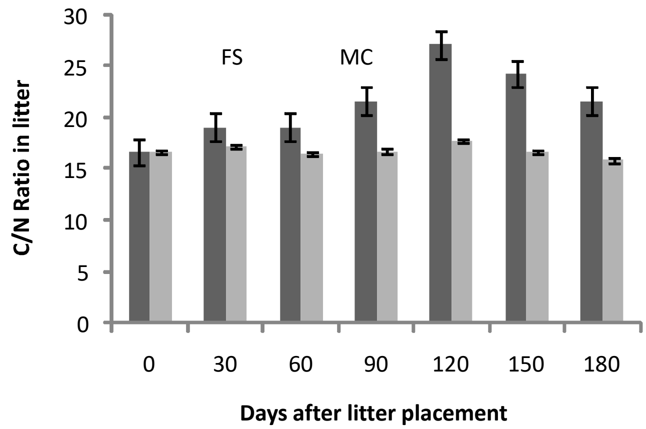

Fig. 6. Temporal changes in litter C/N ratio during litter decomposition

Table 3. Correlation coefficient (r) between leaf litter mass remaining of FS and MC, mass remaining and C/N ratio in FS, mass remaining and C/N ratio in MC

Interaction	Correlation	*p*-value
Decomposition days Vs Mass remaining of FS	-0.939**	0.002
Decomposition days Vs Mass remaining of MC	-0.969**	0.00
Mass remaining of FS Vs Mass remaining of MC	0.97**	0.00
Mass remaining of FS Vs C/N ratio in FS litters	-0.726	0.065
Mass remaining of MC Vs C/N ratio in MC litters	0.137	0.796

up the process of litter decomposition (Krishna and Mohan 2017, Ghosh and Tripathi 2021) and similar value (16.6) was observed in present finding which explain quicker decomposition. Litter ash-free mass remaining in both FS and MC was significantly negatively correlated with time duration. Significantly positive correlation was observed between mass remaining of both sites (Table 3).

CONCLUSIONS

The study demonstrates that the pattern of litter mass loss, and carbon and nitrogen release varied during decomposition from same species in natural and control environment under laboratory condition. Further, study suggests that the same litter material when decomposing under different environments (i.e. variations in temperature, moisture, humidity etc.) and soil microbial composition (changes in bacteria, fungi and actinomycetes populations) in natural and under laboratory conditions shows varied rates of organic matter decomposition and nutrient release as these are the triggering factors for the decomposition kinetics in two experimental set ups.

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Effect of Integrated Nutrient Management on Growth, Yield Attributes, Yield and Quality Parameters of Groundnut (*Arachis hypogaea*) in an Acidic Upland of Odisha

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Abstract: Field experiment was conducted during *Rabi* 2019-2020 at Agricultural Research Station, IAS, Siksha 'O' Anusandhan, Bhubaneswar, Odisha, India in a sandy loam soil. There were seven treatments of different levels of nutrient managements. The experimental results revealed that significantly higher values of growth parameters, yield attributes, pod yield and quality factors under the application of 125% RDF (STBR) [N, P_2O_5, K_2O (25:50:50 kg ha^{-1}) + Combo i.e., [FYM 5t ha^{-1}+ Gypsum @250 k g ha^{1} + *Rhizobium* seed inoculation + PSB soil application @ 2Kg ha^{-1}] followed by application of 100% RDF + Combo , 75% RDF + Combo over application of inorganic fertilizer levels (125%, 100 and 75 % RDF) only.

Keywords: Groundnut, INM, *Arachis hypogaea,* Acidic soil

Groundnut (*Arachis hypogaea* L.), one of the principal economic crops, ranked as the second most important cultivated grain legume and the fourth largest edible oilseed crop in the world is grown in more than 100 countries. India is the second largest producer of groundnut in the world (Tiwari et al 2018, Hauser 2018). In India, though the area and production of groundnut are high, but great variation in productivity is observed. The productivity of groundnut in India is much less as compared to other leading countries due to soil heterogeneity, imbalanced fertilization, uncertainty of monsoons, poor cultural practices adopted by farmers, growing the energy crop groundnut under energy starved conditions like marginal and sub-marginal lands (mainly under rainfed condition), shortage of calcium, low soil pH, biological limitations, biotic and abiotic stress and many socio- economic factors. (Kamara et al 2011, Kumar, 2012, Gashti et al 2012). Improving the soil fertility by providing adequate nutrients to the crop could be a viable option to raise the productivity of groundnut. Various researchers working in this area opined that none of the inorganic and organic sources of nutrients alone can meet the total plant nutrient needs of the crop adequately. Hence, an integrated use of nutrients from chemical, organic manures, biofertilizers is the most efficient way to supply plant nutrients for sustained crop productivity and improved soil fertility (Dhadge and Satpute 2014, Vala et al 2018). Integrated nutrient management (INM) ensures the plant nutrient supply through optimization of benefits from all possible sources of plant nutrients in an integrated manner to achieve as well as sustain the desired crop productivity while maintaining soil fertility and can be considered as an important tool for sustainable agriculture to achieve the sustainable development goals (SDG) to ensure sustainable consumption and production patterns. This experiment was planned to study the effect of different nutrient management practices on growth attribute, yield, yield attributes and quality of groundnut.

MATERIAL AND METHODS

The field experiment was conducted with groundnut variety Smruti at Institute of Agricultural Sciences, Siksha 'O' Anusandhan, Bhubaneswar, Odisha during Rabi (2019-2020) which was laid out at 85.7920°E longitude and 20.2588°N latitude with an elevation of 50.6 meter above mean sea level. The site comes under East and South Eastern Coastal Plain Agro-climatic zone of the state of Odisha, India. The climate is hot and humid with mean annual rainfall of 1467 mm. About 70% of total rainfall is received from July to September. The mean maximum and minimum temperatures were 33.2^{0}C and 21.4^{0}C, respectively. The experiment was laid out in randomized block design (RBD) with three replications and seven treatments. The treatments were viz.; T_1 [Control], T_2 =75% RDF [N, P_2O_5, K_2O (15:30:30 kg ha^{-1})], T_3 =100% RDF [N, P_2O_5, K_2O (20:40:40 kg ha^{-1})], T_4 = Soil Test Based Recommendation (STBR i.e.125% RDF) equal to N, P_2O_5, K_2O (25:50:50 kg ha^{-1})], T_5 =75% RDF[N,

P_2O_5, K_2O (15:30:30 kg ha^{-1})] + Combo- [FYM 5t ha^{-1} + Gypsum @250 kg ha^1 + *Rhizobium* seed inoculation + PSB soil application @ 2Kg ha^{-1}], T_6 =100% RDF[N, P_2O_5, K_2O (20:40:40 kg ha^{-}1 + Combo,T_7 =STBR [N, P_2O_5, K_2O (25:50:50 kg ha^{-1})]+ Combo. The soil of the experimental plot was sandy loam in texture, acidic (pH -4.21) in soil reaction, non-saline (electrical conductivity-0.56 dSm^{-1}), bulk density 1.55 g/cc, particle density 2.60 g/cc and porosity 39.92%, cation exchange capacity 4.8 mol (P+) kg^{-1} of soil with 24% moisture content. The soil was also low in organic carbon (0.49%), available N (248 kg ha^{-1}) sulphur (13.62 kg ha^{-1}), medium in available phosphorus (11.6 kg ha^{-1}) and potassium (162 kg ha^{-1}). Lime was applied @1.2 t ha^{-1} with soil before 25 days of sowing. Well decomposed farmyard manure applied @ 5 t ha^{-1} to the soil which contains 0.5 % nitrogen, 0.2% P and 0.4% K as organic source. The recommended dose of fertilizers @ 20:40:40 kg NPK ha^{-1} was considered as 100% RDF. Fertilizers were given in the form of urea, diammonium phosphate, and muriate of potash. Gypsum @ 250 kg ha^{-1} was applied at peg initiation stage. Seeds were treated with *Rhizobium* culture @ 1.5 kg ha^{-1} and PSB culture applied to soil @ 2Kg ha^{-1} before sowing. The seed rate of groundnut was @125 kg ha^{-1} sown in rows with 30 cm apart and 10 cm plant to plant spacing. Regularly biometric observations were recorded at specific time intervals by selecting randomly five plants in each treatment. The initial soil samples at 10-15 cm depth and organic manures were analysed for different parameters by following standard methods (Jackson 1968). Yield and yield attributing parameters were recorded during harvest. Yield components in groundnut that composed of pod and kernel yield per unit area was collected from data analysis after harvest of the crop. Pod index (g) [The weight of 100- pod samples, drawn randomly and index (g) 100-kernel samples, drawn randomly from shelling of the pod samples were calculated by standard procedure. Protein content in kernel (seed) of groundnut was calculated by multiplying percent kernel nitrogen with a factor of 6.25 and oil was extracted from kernel of groundnut of each plot with the help of Soxhlet's (Socs plus) apparatus or solvent extractor using n-hexane as solvent (AOAC 1960).

RESULTS AND DISCUSSION

Effect of Integrated Nutrient Management

Growth attributes: Application of soil test based recommendation of fertilizer (STBR) (N, P_2O_5, K_2O @ 25 :50: 50 kg ha^{-1} respectively i.e. 125% RDF) + Combo [FYM 5 t ha^{-1} + Gypsum @ 250 kg ha^{-1} + Rhizobium seed inoculation + PSB @ 2Kg ha^{-1} as soil application], (T_7) significantly registered higher values of all the growth parameters, plant height, plant spread, number of branches at harvest, total number of root nodules per plant, number of effective nodules per plant, number of pods per plant, root length, root volume and pod weight per plant over all the treatments including control followed by T_6. T_5 was at par with T_6 in all growth attributes, except number of pods per plant, and root volume (ml). The plant spread, number of branches at harvest, number of pods per plant, root length and root volume increased significantly in T_4 (STBR) as compared to T_3 and T_2. The pod weight per plant in T_7 out yielded all the treatments, however, T_4 STBR and T_5, 75% RDF and combo remained at par with each other.The integrated application of STBR (N, P_2O_5, K_2O @ 25 :50: 50 kg ha^{-1} respectively) with Combo (FYM 5t ha^{-1}+ Gypsum @250 kg ha^{-1}+ Rhizobium seed inoculation + PSB @ 2Kg ha^{-1} as soil application) showed advantageous effect on growth parameters which may be due to the flattering effect of FYM in improving physical, chemical and biological environment as well refining the activity of applied and native Rhizobium (nitrogen fixation) and phosphate solubilizing bacteria (phosphate solubilization) of soil, favourable for better plant growth. Beneficial microorganisms also involved in decomposition of cellulose, production of antibiotics, vitamins and hormones that also adds to the positive impact to produce larger cells with thinner cell wall and influence cell division and cell elongation which enhanced vegetative growth and eventually enlarged plant height, plant spread, number of branches per plant, root length and number, total and effective root nodules per plant. These findings agree with the results of earlier workers (Kamalakannan 2017, Kulkarni et al 2018, Umadevi et al 2018).

Yield attributes: Increase in RDF fertilizers from 75% to STBR (125% RDF) alone and integrated with combo pack produced significantly higher pod number and pod weight of groundnut in comparison to lower levels. Significant higher pod number and pod weight were recorded with T_7 trailed by T_6. Higher test kernel weight (g) and shelling (%) were recorded in the same treatment (T_7). Significant increases were among 75, 100, 125% respectively as well as their combination with combo. The effects of treatments on pod index and seed index appeared to be less evident through significant differences were observed between very low and very high doses of fertilizers together with combination of combo. Highest pod index (75.28 g) and seed index (52.16 g) were also recorded with (T_7) followed by T_6 with pod index (g) and seed index (g). In case of pod index T_4 and T_5 were at par. Improved values of various yield attributes such as pod number, pod weight per plant, test weight and shelling percentage, pod index and seed indexes might have been due to development of vegetative growth and nodulation, which constructively prejudiced the flowering and fruiting and eventually caused into augmented number of pods and pod weight per plant. These findings are in agreement with Patil et al (2018) and Vala et al (2017).

Yield: There was improvement with respect to biological; pod, kernel and haulm yield as well as harvest index of groundnut among various integrated nutrient packages (Table 3). Maximum biological yield (68.63 kg ha^{-1}), pod yield (3195 kg ha^{-1}), kernel (2398.10 kg ha^{-1}) and haulm yield (3668 kg ha^{-1}) were in T_7 which received STBR (125% RDF) and combo [FYM 5t ha^{-1}+ Gypsum @250 kg ha^{1} + Rhizobium seed inoculation + PSB soil application @ 2Kg ha^{-1}] followed by T_6 [00% RDF + combo] with 6372 kg ha^{-1} biological yield, 2896 kg ha^{-1} pod yield, 2128.28 kg ha^{-1} kernel yield and 3476 kg ha^{-1} haulm yield. With respect to biological yield treatment T_7 and T_6 significantly out yielded other treatment and T_7 was significant over T_6. Pod, kernel and haulm yields increased with different RDF levels alone and combination of RDF levels with combo also, showing thereby a significant effect of RDF and its combination with combo on groundnut. Use of different levels of RDF was also found inferior to combined application of RDF levels and combo. No significant relationship existed among T_3 and T_4 with respect to pod and kernel yield whereas significant relationship expressed among T_7 and T_6, T_6 and T_5. The harvest index of groundnut in various treatments varied due to application of different levels of fertilizers and their combination with combo. The maximum harvest index (48.23%) was recorded under 75% + combo (T_5) followed by 125% (STBR) + combo (T_7) (46.55%), 100% RDF + combo (T_6) 45.44 %), 100% RDF (T_3) (47.31%), 75% RDF (47.12%) (T_2), 125% RDF (STBR) (47.11%) and the minimum harvest index (40.97%) was recorded in control but all treatments significantly superior over control and they remain at par with each other. Earlier reports of several workers indicated that combination of inorganic fertilizers and organic fertilizers together with biofertilizers enhanced the pod, kernel and haulm yield of groundnut. Biological yield, pod yield, kernel yield and haulm yield were expanded, due to the combined nutrient use of organic (FYM), inorganic fertilizers, gypsum and bio-fertilizers by providing cooperative effect and in turn upgraded the soil condition, stimulate root system with healthier absorption of nutrients, water from lower layers and expressed superior progress of plant growth resulting in higher photosynthetic activity and translocation of

Table 1. Effect of integrated nutrient management on growth attributes

Treatment	Plant height (cm)	Plant spread (cm)	Number of branches on harvest	Total number of root nodules per plant	Number of effective nodules per plant	Root length (cm)	Root volume (ml)
T_1 Control	9.8	15.48	4.88	65.95	16.85	9.86	13.26
T_2 75% RDF	10.7	17.53	6.22	71.67	19.47	10.92	16.86
T_3 100%RDF	11.0	19.87	6.96	74.16	20.25	12.97	19.60
T_4 STBR	11.7	21.56	7.86	76.88	20.96	13.45	23.36
T_5 T_2 + Combo	12.1	23.89	8.11	80.27	22.66	13.98	25.66
T_6 T_3 + Combo	12.7	24.66	8.65	82.75	23.92	14.32	29.43
T_7 T_4 + Combo	13.5	26.45	9.38	84.42	25.72	15.92	31.53
CD (p=0.05)	0.64	1.04	0.60	3.13	1.44	0.42	1.48

100% RDF = Recommended dose of fertilizer = [N, P_2O_5, K_2O (20 :40:40 kg ha^{-1})], STBR = Soil Test Based Recommendation =[N, P_2O_5, K_2O (25 :50: 50 kg ha^{-1})], Combo = (FYM 5t ha^{-1}+ Gypsum @250 kg ha^{1} + Rhizobium seed inoculation + PSB soil application @ 2Kg ha^{-1})

Table 2. Effect of INM on yield attributes of groundnut

Treatment	Number of pods per plant	Pod weight per plant (g)	100 Kernel weight (g)	Shelling (%)	Pod index (g)	Seed index (g)
T_1 Control	7.66	6.8	36.56	62.18	66.52	42.66
T_2 75% RDF	9.11	8.35	41.76	65.72	68.45	44.42
T_3 100% RDF	11.55	9.77	43.78	68.62	70.72	46.58
T_4 STBR	12.88	10.85	44.16	70.65	71.94	47.56
T_5 T_2 + Combo	13.92	11.36	44.92	72.28	72.15	48.92
T_6 T_3 + Combo	15.21	12.06	45.53	73.48	73.76	50.07
T_7 T_4 + Combo	17.28	12.92	46.65	75.06	75.28	52.16
CD (p=0.05)	1.16	0.55	0.93	1.44	1.44	1.03

See Table 1

Table 3. Effect of integrated nutrient management on yield of groundnut

Treatment	Biological yield kg ha^{-1}	Pod yield kg ha^{-1}	Kernel yield kg ha^{-1}	Haulm yield kg ha^{-1}	Harvest index (%)
$T_{1.}$ Control	3320	1360	845.68	1960	40.97
$T_{2.}$ 75% RDF	5105	2406	1581.35	2699	47.12
$T_{3.}$ 100%RDF	5326	2520	1728.88	2806	47.31
$T_{4.}$ STBR	5454	2570	1816.04	2884	47.11
$T_{5.}$ T_2 + Combo	5727	2762	1996.53	2965	48.23
$T_{6.}$ T_3 + Combo	6372	2896	2128.28	3476	45.44
$T_{7.}$ T_4 + Combo	6863	3195	2398.10	3668	46.55
CD (p=0.05)	270.53	98.93	97.04	75.32	3.55

See Table 1

Table 4. Effect of integrated nutrient management on quality parameters of groundnut

Treatment	Protein content (%)	Protein yield kg ha^{-1}	Oil content (%)	Oil yield kg ha^{-1}	Saponi-fication value	Acid value	Iodine number
$T_{1.}$ Control	20.93	177.09	42.65	360.61	88.4	1.87	0.27
$T_{2.}$ 75% RDF	21.99	348.03	44.92	710.06	90.2	1.82	0.29
$T_{3.}$ 100% RDF	23.56	407.38	46.47	803.21	92.8	1.67	0.31
$T_{4.}$ STBR	24.87	451.74	47.88	869.44	93.6	1.70	0.32
$T_{5.}$ T_2 + Combo	26.68	532.70	49.42	986.83	94.3	1.75	0.34
$T_{6.}$ T_3 + Combo	29.12	619.62	51.62	1099.02	95.5	1.69	0.36
$T_{7.}$ T_4 + Combo	31.12	746.21	53.76	1289.26	96.8	1.64	0.41
CD (p=0.05)	0.98	31.1	1.92	63.49	1.89	0.12	0.03

See Table 1

photosynthates to the sink which resulted in higher pod and haulm yields. The present findings are in close agreement with the results obtained of earlier (Joshi et al 2018, Purbajanti et al 2019, Kamalakann and Elayaraja 2020)

Quality parameters: The maximum crude protein content (32.12%), protein yield (746.21 kg ha^{-1}), oil content of kernels (53.76 %), oil yield (1289.26 kg ha^{-1}), saponification value (96.8) and iodine number (0.41) were with application of 125% RDF (STBR) + Combo (T_7) and were significant better on all treatments followed by T_6. The improved values of quality parameters of groundnut in T_7 and T_6 may be due to favourable effect of FYM, *Rhizobium*, phosphate solubilizing bacteria (PSB) and gypsum that enhanced higher photosynthetic rate, uptake of nutrients, particularly nitrogen, nitrogen fixation and better translocation of assimilates, the accessibility of calcium, sulphur and phosphorus to plants, which might have used by the crop in improving root expansion and nodulation that in turn ensued in higher uptake of N, P, K, S and other nutrients. These findings are in agreement with finds of earlier workers (Chaudhari et al 2015, Swamy et al 2019).

CONCLUSION

Application of fertilizers as per soil test in this case 125% of RDF [N, P_2O_5, K_2O (25:50:50 kg ha^{-1})] together with other combinations of organic and inorganic nutrients such as FYM 5t ha^{-1}, Gypsum @250 kg ha^{1} , *Rhizobium* seed inoculation and PSB soil application @ 2Kg ha^{-1} could provide significantly higher values of all the growth and yield attributes as well as biological, pod and haulm yields of Rabi groundnut with higher shelling percentage, protein and oil yields as compared to other nutrient packages followed with incorporation of 100% RDF [N, P_2O_5, K_2O (20:40:40 kg ha^{-1})] with FYM 5t ha^{-1}+ Gypsum @250 kg ha^{1} + *Rhizobium* seed inoculation + PSB soil application@ 2Kg ha^{-1} which farmers can use without much reduction in yield. However, these results are only indicative and require further investigation to arrive at more consistent and final conclusion.

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Effect of Active Silica on Growth and Profitability of Maize under Organic Farming

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Abstract: Irrational use of agro chemicals decreases the ecological diversity and increases the biotic and abiotic stresses, ultimately affects the crop yield. The use of active silica counters such ill effects and also enhances the crop yield especially under organic farming. Therefore, a field experiment was conducted during the *Kharif* season of 2018 and 2019 at Organic Unit of Instructional Farm, Rajasthan College of Agriculture, Maharana Pratap University of Agriculture and Technology, Udaipur (Rajasthan). The experiment consisting of six soil application in main plots (0, 50, 75, 100, 125 and 150 kg ha^{-1}) and six foliar application of active silica in sub plots (no spray, water spray, 0.25, 0.50, 0.75 and 1.0%) was carried out in split plot design. The significantly higher chlorophyll content, plant height, dry matter accumulation, leaf area index, crop growth rate, relative growth and net assimilation rate was observed with 150 kg ha^{-1} active silica application. Similarly, higher biological yield, net return, B C ratio and available P in soil was recorded at 150 kg ha^{-1} active silica application. Among foliar application, the spray of 1.0% active silica significantly enhanced the chlorophyll content, plant height, dry matter accumulation, leaf area index, crop growth rate between 60 to 75 DAS, net assimilation rate, biological yield, economics and available P in soil in maize under organic production system. Overall, the use of 150 kg ha^{-1} active silica through soil or 1.0% foliar spray may be recommended to increase the maize growth and economics under organic farming condition.

Keywords: Active silica, Growth, Maize, Organic farming, Profitability

Maize is the third most important cereal crop in the world after rice and wheat (Arunjith and Arthanari 2021). Irrational use of chemical fertilizers and other agro-chemicals creates several harmful effects and poor quality of crops (Kumar et al 2021) which enhances the demand of organic farming based agricultural products (Lal et al 2021). In organic production, natural sources of Si can be used to increase the growth and yields of crops. Si is one of the second most abundant elements found in the earth's crust (27.72%), but it mostly inert and only slightly soluble. Although Si has not been classified as an essential element for higher plants but it is a naturally occurring beneficial nutrient which modulates plant growth and development events. Si has a key role in improving crops abilities to withstand biotic and abiotic stresses, such as disease and pest resistance, alleviation of heavy metal (Al, Mn, and Fe) toxicities, salinity resistance, resistance to drought stress and alleviation of freezing stress (Xiang et al 2012). In cereals develops narcosis, disturbance in leaf, photosynthetic efficiency, growth retardation by reduce amount of Si in plant. Si has does not play significant for vegetative growth but it support in healthy development under stresses. Si increases drought tolerance by maintaining plant water balance, erectness of leaves, photosynthetic activity, structure of xylem vessels and high transpiration rate in plant by application of Si resulted increasing in dry matter accumulation and grain yield. Si benefits in maize have been related to its effect on the improving of population quality, effective leaf area, and photosynthetic efficiency as well as the delay of leaf senescence. Photosynthesis is a determinant factor for crop growth and development as maximum photosynthesis contributes toward more yield and production, and it is the most basic and critical physiological process directly related to maize yield, especially at late developmental stages (Ahmed et al 2012). Crop yield potential can be increased by 50% by raising photosynthetic capacity (Covshoff and Hibberd 2012). Consequently, in cereals it can help in enhancing the growth and productivity and it can be used as 100% organic inputs. Optimum amount of Si is necessary for cell development and differentiation and significantly increased plant height stem diameter, number of leaves of maize. The production of aboveground biomass of wheat was enhanced by Si fertilization. The rise in biomass production was mainly caused by a substantial increase of straw biomass. The highest positive influence of Si application was observed with the use of Si both at the tillering and anthesis stages which provided higher resistance to drought by maintaining cellular membrane integrity and increasing chlorophyll content in wheat (Maghsoudi et al 2015; Prajapat et al 2021). The use of active silica counters such ill effects (biotic and abiotic effect) and also enhances the crop yield under organic farming.

MATERIAL AND METHODS

Field experiment was conducted at Maharana Pratap University of Agriculture and Technology, Udaipur (Rajasthan) during the *Kharif* season of 2018 and 2019. The experiment consisting of 36 treatment combinations of six active silica of soil application in main plots *viz.,* 0 (S_1), 50 (S_2), 75 (S_3), 100 (S_4), 125 (S_6) kg/ha and six foliar application of active silica in sub plot *viz*., No spray (F_1), water spray (F_2), 0.25 (F_3), 0.50 (F_4), 0.75 (F_5) and 1.0% (F_6). The experiment was in in split plot design with three replication. Soil application of active silica was done before sowing and foliar spray of active silica was done at 30 DAS and initiation of tasseling. Chlorophyll content was estimated from sampled plants by the method suggested by Arnon (1949).

$$\text{Chlorophyll content (mg/g fresh weight leaves)} = \frac{A(652) \times \text{Total volume (ml)}}{\alpha \times 1000 \times \text{Weight of sample}}$$

Where, α is the path length = 1 cm

Crop growth rate (CGR) represents dry weight gained by a unit area of crop in a unit time, expressed as g/m²/day (Watson 1958).

$$\text{Crop Growth Rate (g/m}^2\text{/day)} = \frac{(W_2 - W_1)}{(t_2 - t_1)\,A}$$

Where, W_1 and W_2 indicate the total dry weight (g) of the plants at the time t_1 and t_2, respectively. A indicates land area over which the dry weight was recorded in m².

The mean relative growth rate and net assimilation ratio of the crop were calculated by using the following relationship (Redford 1967).

$$\text{Relative growth rate (g/g/day)} = \frac{(\log_e W_2 - \log_e W_1)}{(t_2 - t_1)}$$

$$\text{Net assimilation rate (g/cm}^2\text{/day)} = \frac{(W_2 - W_1)\,(\log_e L_2 - \log_e L_1)}{(t_2 - t_1)\,(L_2 - L_1)}$$

Where, L_1 and W_1 indicate the leaf area in cm² and dry weight of plant in g at time t_1. L_2 and W_2 indicate the leaf area in cm² and dry weight of plant in g at time t_1.

Available N, P and K in soil were estimated by colorimetric method using alkaline permanganate method (Subbiah and Asija 1956), Olsen's method (Olsen et al 1954) and Flame photometer (Richards 1968), respectively.

RESULTS AND DISCUSSION

Effect on growth parameters: Soil application of active silica revealed that chlorophyll content was significantly higher at 150 kg ha^{-1} which was at par with 125 kg/ha at 45 DAS and 100 and 125 kg ha^{-1} at 60 DAS. Plant height was also significantly higher at 150 kg ha^{-1} however, it was par with 100 and 125 kg ha^{-1} at 60 and 75 DAS and 125 kg ha^{-1} at harvest. Significantly higher dry matter accumulation was at 150 kg ha^{-1} which remained at par with 125 kg ha^{-1} at 60, 75 DAS and at harvest. Leaf area index (LAI) was significantly higher at 150 kg ha^{-1} but did not differ significantly from 125 kg ha^{-1} (Table 1). Crop growth rate (CGR) between 60 to 75 DAS and 75 DAS to harvest were significantly higher at 150 kg ha^{-1} which was at par with 125 kg ha^{-1}. The significantly higher relative growth rate (RGR) between 60 to 75 DAS and 75 DAS to harvest with 150 kg ha^{-1} was observed, however, it remained at par with 75, 100 and 125 kg/ha between 60 to 75 DAS and it was par with 125 kg ha^{-1} between 75 DAS and harvest. Net assimilation rate (NAR) between 60 to 75 DAS and 75 DAS to harvest were higher at 150 kg ha^{-1} and remained at par with 125 kg ha^{-1} between 60 to 75 DAS and 75 DAS to harvest (Table 2). Similar results were also reported by Patil et al (2018) and Jan et al (2018).

Among foliar application, 1.0% sprays of active silica recorded significantly higher chlorophyll content over control. However, chlorophyll content remained at par with 0.75% spray at 45 DAS and 65 DAS (Table 1). Plant height was significantly higher at 1.0% spray; however and was at par with 100 and 125 kg ha^{-1} at 60 DAS and 125 kg ha^{-1} at 75 DAS and at harvest. Significantly higher dry matter accumulation was recorded at 1.0% spay; however, was at par with 0.50 and 0.75% at 60, 75 DAS and at harvest. LAI was significantly higher at 1.0% which found at par with foliar application with 0.50 and 0.75% at par with 60, 75 DAS and at harvest. CGR between 75 DAS to harvest was recorded higher at 1.0% spray. RGR between 75 DAS to harvest was higher at 0.50% foliar spray. The significantly higher NAR was at 1.0% spray and was at par with 0.25, 0.50 and 0.75% spray between 60 to 75 DAS (Table 2). This might be owing to deposition of Si at cellular parts such as cell wall, cell lumens and intercellular space, and its deposition below and above cuticle layer that's why enhanced cell division and cell elongation than tissue parts more elongated and erect, cause erectness of leaves and stem which enhanced towards plant height and also increase in chlorophyll content. Further, these improvements resulted better leaf area index leads to better light interception and photosynthesis activity which enhanced higher dry matter accumulation. (Bassiouni et al 2020).

Effect on biological yield: Soil application of active silica revealed that biological yield was significantly increased with increasing dose of active silica up to 150 kg ha^{-1}. The biological yield were at par with 125 kg/ha (Table 3). In foliar spray, significantly higher biological yield were with 1.0% foliar application (Table 3) and remained at par with 0.75% for

Table 1. Effect of active silica on chlorophyll content, plant height, dry matter accumulation and leaf area index of maize under organic farming (Pooled of two years)

Treatments	Chlorophyll content (mg g^{-1} fresh weight of leaves)		Plant height (cm)			Dry matter accumulation (g $plant^{-1}$)			Leaf area index		
	45 DAS	65 DAS	60 DAS	75 DAS	Harvest	60 DAS	75 DAS	Harvest	60 DAS	75 DAS	Harvest
Soil application											
S1	2.212	2.017	132.65	149.31	158.45	66.40	95.15	109.47	3.14	3.27	3.48
S2	2.232	2.037	136.67	153.01	162.25	67.30	96.97	112.44	3.21	3.41	3.62
S3	2.272	2.108	138.16	155.56	164.02	69.40	101.17	118.73	3.28	3.48	3.70
S4	2.303	2.128	144.99	161.16	170.62	71.59	105.17	124.76	3.47	3.68	3.90
S5	2.363	2.168	145.92	163.31	172.85	74.80	113.18	135.71	3.48	3.69	3.91
S6	2.373	2.178	147.12	164.45	178.01	76.10	113.99	137.52	3.51	3.72	3.94
CD (p=0.05)	0.055	0.060	4.97	6.22	7.08	3.81	4.23	5.48	0.09	0.08	0.09
Foliar application											
F1	2.205	2.205	134.03	150.59	160.28	65.38	99.71	117.46	3.13	3.32	3.53
F2	2.283	2.283	138.15	154.89	164.71	68.92	102.37	120.72	3.22	3.41	3.62
F3	2.280	2.280	140.86	157.73	167.07	70.96	104.57	123.17	3.28	3.47	3.69
F4	2.294	2.294	143.01	159.61	169.54	72.56	105.59	124.86	3.49	3.67	3.89
F5	2.343	2.343	144.29	161.42	171.59	73.74	106.55	125.41	3.48	3.68	3.91
F6	2.351	2.351	145.17	162.57	173.01	74.02	106.83	127.00	3.49	3.69	3.91
CD (p=0.05)	0.035	0.035	2.80	2.91	3.34	2.09	2.04	2.56	0.07	0.06	0.07

Table 2. Effect of active silica on CGR, RGR and NAR of maize under organic farming (Pooled of two years)

Treatments	CGR (g m^{-2} day^{-1})		RGR (g g-^{1} day^{-1})		NAR (g cm^{-2} day^{-1})	
	Between 60 to 75 DAA	At between 75 DAS to harvest	Between 60 to 75 DAS	At between 75 DAS to harvest	Between 60 to 75 DAS	At between 75 DAS to harvest
Soil application						
S1	12.78	6.36	0.0247	0.0092	33.52	17.65
S2	13.19	6.88	0.0247	0.0099	35.97	19.63
S3	14.12	7.80	0.0251	0.0107	39.13	22.65
S4	14.92	8.71	0.0259	0.0114	43.07	26.33
S5	17.06	10.01	0.0279	0.0121	49.37	30.29
S6	16.84	10.46	0.0270	0.0125	49.02	31.83
CD (p=0.05)	0.97	0.56	0.0019	0.0004	2.73	1.78
Foliar application						
F1	15.26	7.89	0.0282	0.0107	40.65	22.21
F2	14.87	8.15	0.0264	0.0109	40.71	23.43
F3	14.94	8.27	0.0258	0.0108	41.47	24.09
F4	14.68	8.56	0.0250	0.0111	42.59	25.92
F5	14.58	8.38	0.0250	0.0108	42.30	25.45
F6	14.58	8.97	0.0249	0.0114	42.36	27.28
CD (p=0.05)	NS	0.27	0.0012	0.0002	1.42	0.70

Table 3. Effect of active silica on biological yield, economics and available N, P and K on soil of maize under organic farming (Pooled of two years)

Treatments	Biological yield (kg ha^{-1})	Net return (ha^{-1})	B C ratio	Available N (kg ha^{-1})	Available P (kg ha^{-1})	Available K (kg ha^{-1})
Soil application						
S1	5640	36687	1.27	238.92	33.46	306.97
S2	6245	42501	1.45	239.20	33.50	307.34
S3	6442	44549	1.51	239.98	34.86	307.56
S4	6861	49831	1.67	241.30	35.79	309.09
S5	7095	52786	1.76	242.25	38.73	309.24
S6	7165	53205	1.76	242.75	41.18	311.22
CD (p=0.05)	247	2657	0.09	NS	1.275	NS
Foliar application						
F1	5658	36861	1.26	238.53	35.45	307.58
F2	6348	44023	1.48	239.40	35.67	308.67
F3	6498	45734	1.54	241.00	35.96	308.48
F4	6865	49638	1.67	241.65	36.77	308.78
F5	6990	51242	1.72	241.79	36.65	309.03
F6	7089	52059	1.75	242.03	37.00	308.88
CD (p=0.05)	164	1809	0.06	NS	NS	NS

biological yield. This might be due to Si accumulation in plant parts which reduce its lodging and enhanced resistance against biotic and abiotic stress, ultimately resulted into higher biological yield (Patil et al 2017, Sarma et al 2017).

Effect on economics: Soil application of active silica revealed that net return were significantly increased with increasing dose of active silica up to 150 kg ha^{-1}. The net return was at par with 125 kg ha^{-1}. Significantly higher B C ratio was at 150 kg ha^{-1} which found at par with 100 and 125 kg ha^{-1}. The Jawahar and Vaiyapuri (2013) and Rao et al (2018) also observed same trend. In case of foliar spray, significantly higher net return was with 1.0% foliar application (Table 3) and was remained at par with 0.75%. Maximum B C ratio was recorded higher at 1.0% spray and was at par with 0.75% spray. Similar results were also reported by Pooja et al (2019).

Effect on available N, P and K on soil: Available P was significantly higher with soil application of 150 kg ha^{-1} active silica (Table 3). There non-significant difference was observed with different doses of active silica in soil as well as foliar application on N, K and P foliar application. With increasing of doses of soil applied active silica available P content in soil also increase over control. This might be owing to silicate anion (monosilicic acid) adsorbs on the labile phosphates of calcium in alkaline soil and desorbs (releases) the phosphate anion into soil solution increasing the total amount of soluble phosphorus available to the plant. The negative charge of the silicate anion repels the phosphate anions, keeping dissolved phosphorus in a soluble form in the soil solution (Daniela et al 2006).

CONCLUSIONS

Soil application of 150 kg ha^{-1} active silica significantly enhances the growth, net return, B C ratio and post harvest available P of soil. Among foliar application, spray of 1.0% active silica improves the growth and net returns. Overall, 150 kg ha^{-1} active silica through soil application or 1.0% foliar spray may be recommended to increase the maize growth and profitability under organic farming condition.

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Diversity of Coastal Sand Dune (CSD) Vegetation along the Coast of Maharashtra, India

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Abstract: The sand dunes vegetation in coastal regions of Maharashtra is important ecosystems because of their small size, the different species found in habitat, and the beautiful landscapes they create. The current study investigated the vegetative status of sand dunes on Sindhudurg and Raigad district, west coast of Maharashtra. A survey of sand dune flora along coastal sand dune areas was done from October to December 2020 and 55 species belonging to 46 genera and 26 families are identified from study sites. The families like Fabaceae, Rubiaceae, Poaceae, Asteraceae, Lamiaceae and Malvaceae are dominant in study areas which show halophytic and xerophytic nature. The heavy pressure of tourism and development in coastal area shows negative effects on sand dune vegetation are seen during study.

Keywords: Ecosystems, Coastal sand dunes, Maharashtra, Halophyte, Diversity

Coastal zones are the most productive and invaluable areas of coastal water and adjacent land forms and are the places of high priority interest of people, commerce, military and variety of industries. Coastal sand dune (CSD) serves as an ecological niche between terrestrial and marine life, and form important conservation sites. These are extensions of beach into the land and acts as a home for specialized plants and animals and protects the beaches form erosion, control the sea level rise and acts as filter for rainwater and groundwater (Heslenfeld et al 2008). Coastal sand dune flora protects the coastal environment by absorbing energy from wind, tide and wave action. These species played a crucial role in protecting the coast from erosion and flooding, sediments accumulation, sand binding and land building processes. India has an approx 7500 km coastline along the Arabian Sea on west and bay of Bengal on the east with 2.02 million Km^2 exclusive economic zone and 0.13 million Km^2 continental shelf with numerous types of plants, lagoons, beaches, estuaries and mangrove swamps. However, these habitats have been severely affected by natural and anthropogenic activities resulting in loss of habitat and dependent flora and fauna. Because it contains a dense population, the coast undergoes environmental modification and deterioration through reclamation, dredging, pollution, industry, and anthropogenic activities (Ingole 2005). Invasion of alien species in coastal sand dune vegetation also threatened the coastal environment (Gallego-Fernandez et al 2019).

The western coastal planes is of 720 Km lie in between the Western Ghats and Arabian Sea and distributed into the coastal districts such as Mumbai, Thane, Mumbai suburbs, Palghar, Raigad, Ratnagiri and Sindhudurg. The Sahyadri mountain range and Western Ghats run parallel to the coast. The 17% of the total coast is sandy nature, 37% is rocky and 46% are mudflats. In 2004, 263 km. length of west coastline is affected by erosion, which about 40% of the Maharashtra coast (Lakshmi et al 2012). The CSD plants act as bio shield against coastal erosion and have many ecological importances. The objective of the current study was to understand the distribution of coastal sand dune plant and to identify the anthropogenic impacts on the CSD flora.

MATERIAL AND METHODS

Study area: Field visits were conducted at Shiroda (15°45'38.10"N 73°39'49.60"E), Malvan (16°03'00.73"N 73°28'07.93"E) and Achara (16°11'49.04"N 73°26'13.67"E) of Sindhudurg district and Kashid (18°27'24.21 "N72°53'54.68"E) and Revdanda (18°33'30.45"N 72°55'13.85"E) from Raigad districts (Fig. 1) during the winter season of month October and November 2020. Generally, the climate of study sites is humid and hot. In winter, the average temperature is in between 22-25^{0}C with annual rainfall is 300 to 800 mm.

Sampling: Diversity of plant species were studied by random quadrat method. In each quadrat, sub quadrats of 10x10 m for trees, sub quadrats of 5x5 m for shrubs and 2.5x2.5 m for the herbs. Each quadrat was systematically surveyed by identifying and measuring all trees, shrubs and herbs.

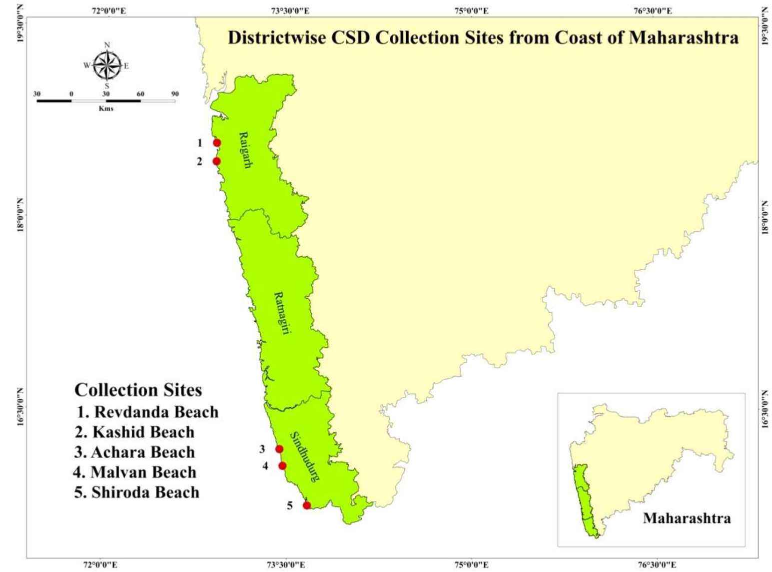

Fig. 1. Location map of the study area

Specimens of individual plant species were collected from each site and were identified using various regional flora and monographs (Cook 1967, Joshi 2011).

RESULTS AND DISCUSSION

The coastal ecosystem consist 338 species belonging to 69 families of which the west coast consists 267 species and east coast has 163 species indicating more diversity on west coast. Ramarajan and Murugesan (2014) reported 55 species and 26 families from Tamilnadu coast. Silambarasan and Senthilkumaar (2015) reported 39 species belonging to 33 genera and 28 families from Marakkanam Coast, Southeast coast of India. Jana (2016) reported the 82 coastal sand dune species from east Midnapore District, West Bengal, India. Arulmoorthy and Srinivasan (2017) reported 154 species belonging to 108 genera and 41 families from southeast coast of India. Qureshi and Rathod (2020) reported six new algal species from coastal areas of Karwar. During the present work 48 species recorded form different coastal sand dune ecosystems form thewest coast of Maharashtra. *Brachiaria distachya, Casuarina equisetifolia, Ipomoea pes-caprae, Sesuvium portulacastrum* are the common species found along all the study areas whereas *Ammannia baccifera, Calophyllum inophyllum, Pedalium murex* are less common and found on only one site. The Shiroda beach shows more diversity (46 species) than the other beaches and Malvan and Kashid beach is less diverse with 23 and 16 species respectively indicating the human intervention. Malvan and Kashid beach are popularly known tourist centres and the CSD plants largely affected by the tourists visiting these places.

The Revdanda and Kashid beach of Raigad district are popularly known tourist centers throughout Maharashtra. These beaches have direct connectivity through private vehicles and public transportation; hence the number of tourists visiting these sites is comparatively more. It was observed that, during the visits to the beaches the tourist pass across the sand dune vegetation and damaging the flora. In Kashid, Revdanda, Malvan and Shiroda, vehicles used for the exploration of beach, which caused more damage to CSD vegetation as compared to human trampling. The other harmful impacts of vehicles includes instability of substrate, disturbing and destruction of vegetation and killing and injuring coastal sand dune associated fauna (Kindermann and Gormally 2010). The tourist use to dump the domestic waste and plastic containers along the sides of beaches that also alters the dunes textures which ultimately leads in the disturbance of CSD flora. Similar observations were recorded for Malvan and Shiroda beach. Comparatively, Achara beach, which is longest but less affected (37 species) may be because of geographical situations, as it is located in the interior and the road and transportation facility is poor hence low trampling activity leads into less destruction of dune vegetation.

CONCLUSIONS

The current work indicates high number of coastal sand dune flora which strongly affected by tourism industry and other anthropogenic activities. The rate of developments through urbanization is high which in the study area leads into severe destruction of coastal sand dune vegetation. Hence, the effective management strategy for conservation of CSD

Table 1. Site wise distribution of CSD vegetation of the Maharashtra coast

Species name	Family	Locations				
		Sindhudurg			Raigad	
		Sd	Mn	Aa	Kd	Rd
Aeluropus spp.	Poaceae	+		+		+
Ammannia baccifera L.	Lythraceae	+				
Anacardium occidentale L.	Anacardiaceae	+	+	+		+
Barringtonia acutangala (L.) Gaertn.	Lecythidaceae	+		+		
Borreria articularis (L. f.)F.N.Will.	Rubiaceae	+		+		+
Brachiaria distachya (L.) Stapf.	Poaceae	+	+	+	+	+
Caesalpinia cristata Prowazek	Fabaceae	+		+		
Calophyllum inophyllum L.	Calophyllaceae			+		
Calotropis gigantean (L.) R. Br	Apocynaceae	+	+	+	+	+
Senna tora (L.) Roxb	Fabaceae	+	+	+	+	+
Casuarina equisetifolia Forst.	Casuarinaceae	+	+	+	+	+
Chenopodium album L.	Amaranthaceae	+				+
Chromolaena odorata (L.) R. King	Asteraceae	+		+		+
Clerodendrum inerme (L.) Gaertn	Lamiaceae	+	+	+		+
Cocos nucifera L.	Arecaceae	+	+	+	+	+
Colocasia esculenta (L.) Schott	Araceae	+	+			+
Cyperus rotundus L.	Cyperaceae	+	+	+	+	+
Cyperus arenarius Retz.	Cyperaceae	+		+		
Dactyloctenium aegyptium (L.) Willd.	Poaceae	+	+	+	+	+
Hydrophylax maritime L.f.	Rubiaceae	+				
Indigofera spp.	Fabaceae	+				
Ipomoea pes-caprae (L.) R. Br.	Convolvulaceae	+	+	+	+	+
Ixora arborea Roxb. Ex. Sm.	Rubiaceae	+		+		+
*Lantana camara*L.	Verbenaceae	+	+	+	+	+
Launaea procumbens (Roxb.) Ramayya & Rajgopal	Asteraceae	+		+		
Launea sarmentosa (Willd.) Alston	Asteraceae	+		+		+
Mollugo disticha (L.) Ser	Molluginaceae	+				
Morinda citrifolia L.	Rubiaceae	+	+	+		
Oldenlandia biflora L.	Rubiaceae	+				+
Opuntia spp.	Cactaceae	+		+	+	+
Pandanus fascicularis Lam.	Pandanaceae	+		+		+
Pedalium murex L.	Pedaliaceae					+
Physalis minima L.	Solanaceae	+	+	+		+
Pongamia pinnata (L.)Pierre	Fabaceae	+	+	+	+	+
*Premna obtusifolia*R.Br.	Lamiaceae	+				
Rothia indica (L.) Druce	Fabaceae	+	+	+		+
Sesuvium portulacastrum (L.) L.	Aizoaceae	+	+	+	+	+
Sida cordifolia L.	Malvaceae	+	+	+	+	+
Spinifex littoreus (Burm.f.) Merr.	Poaceae	+		+		
Suaeda maritime (L.) Dumort.	Amaranthaceae	+				
Tephrosia pupurea (L.) Person.	Fabaceae	+	+	+	+	+
Terminalia catappa L.	Combretaceae	+	+			
Thespesia populnea (L.) Soland. ex Correa	Malvaceae	+	+	+	+	+
Tridax procumbens L.	Asteraceae	+	+	+	+	+
Vernonia cinerea (L.) Less.	Asteraceae	+		+		+
Vitex negundo L.	Lamiaceae	+		+		+
Waltheria indica L.	Malvaceae	+	+	+		+
Ziziphus jujube Miller	Rhamnaceae	+		+		+
Total	27	46	23	37	16	35

Sd-Shiroda, Mn-Malvan, Aa-Achara, Kd-Kashid, Rd-Revdanda

Table 2. Morphological observations of the study site beaches

Name of study sites	Length (M)*	Type of beach	Connectivity	Tourist attraction	Environmental Characteristics	Pollution	Beach services	Dune** type
Revdanda (Raigad)	4350	Rural-Urbanized	Private vehicle Public Transportation Easy Access by walking and bike	Beach camping Sun Bathing Fishing	Soft waves. Baby dune presence *Casurina* vegetation. Mangroves	Litter Domestic sewage Fishing waste	Restaurants Accommodation Parking space	Incipient dune
Kashid (Raigad)	3319	Rural-Tourism center	Private vehicle Easy Access by walking and bike	Beach camping Beach Sport Horse Ride	Strong waves. Signs of tourism disturbance. *Casurina* vegetation. Coconut farmingalongside beach	Litter Domestic sewage by local restaurant. Plastic waste	Restaurants Accommodation Parking space Sport gear Lifeguard Changing rooms.	Incipient dune
Achara (Sindhudurg)	12880	Rural	Private vehicle Easy Access by walking and bike	Small scale Beach tourism	Soft waves. Sign of coastal erosion *Spinifix* vegetation.	Plastic waste	Small Restaurants Parking space	Incipient dune
Malvan (Sindhudurg) Commercially active beach	1506	Urban Tourism center	Private vehicle Public Transportation Easy Access by walking and bike	Tourist hotspot. Ferry service to Sindhudurg fort. Scuba diving. Snorkeling & Beach safari Beach Tourism.	Soft waves. Signs of tourism disturbance. Anthropogenic activities. Fishing disturbance. Less vegetation.	Litter,Domestic sewage and waste by local restaurant and residents Open sanitation on beach.Plastic waste	Restaurants & beach resorts. Parking space Accommodation Water sport gears Local guide Ferry services. Lifeguard	Incipient dune
Shiroda (Sindhudurg)	4464	Rural Tourism center	Private vehicle Easy Access by walking and bike	Beach camping Sun Bathing Foreign tourist attraction. Water sport.	Strong waves. Signs of tourism disturbance. *Casurina* &*Spinifix* vegetation. Anthropogenic activities. Large CSD area.	Litter Domestic sewage and waste by local restaurant and residents. Plastic waste	Restaurants & beach resorts. Bars Parking space Accommodation Water sport gears	Incipient dune & Foredune, blowouts

*Maharashtra Maritime Board, Government of Maharashtra Report, 2017
** Classification based on Short & Hasp (1982)

through strong implementation of laws, modification of coastal conservation policies and appropriate plantation program is the need of time. It is very important to conserve and protect the coastal sand dune vegetation for coastal protection and ecosystem management.

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Residual Effect of Preceding Rice Herbicide on Weed Control, Growth and Productivity of Succeeding Okra in Madurai District of Tamil Nadu

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Abstract: An experiment was conducted at Agricultural College & Research Institute, Tamil Nadu Agricultural University, Madurai during *rabi* 2016 with a view to study the residual effect of preceding rice herbicide on weed control efficiency, growth and productivity of succeeding okra. Rice herbicide residue exerted significant difference in grasses, sedges and broad leaved weeds density at 20 DAS. In grass, the lowest weed density of 11.67 weeds/m^2 was registered under residual effect of butachlor at 1.25 kg ha^{-1} on 3 DAT *fb* HW on 40 DAT in rice + HW twice at 20 and 40 DAS in okra. Similar trend was also observed in sedges and broad leaved weeds. The same treatment recorded higher plant height of 21.7, 53.1 and 92.7 cm and DMP of 624, 3296 and 9481 kg ha^{-1} at 30, 60 and 105 days respectively and the fruit yield of 15.37 t ha^{-1} were recorded. It is registered 83.0 and 97.8% higher fruit yield than residual effect of oxadiargyl loaded with zeolite on 3 DAT and oxadiargyl loaded with biochar on 3 DAT respectively.

Keywords: Herbicide residue, Okra, Weed density, Weed control efficiency, Yield

Okra is most important vegetable crop in tropical and sub-tropical climatic condition of the world. India ranks first in production of okra. The production is 6.47 million tonnes from a cultivable area of 5.28 million hectares with productivity of 11.63 m tonnes per hectare (NHB 2019) and productivity is lower owing to many reasons, of which poor input use efficiency, biotic and abiotic stresses are more important. Among biotic stress, weeds cause yield reduction of 40 to 90% because of its slow growth during initial stage, weeds take advantage of moisture, nutrient and environmental conditions to suppress the growth (Jalendhar et al 2016, Sah et al 2018), crop remains week and unhealthy, this results in the reduction of yield and quality of fruit. Increasing population pressure has forced to enhance food productivity with limited resources. Intensive agriculture is an alternative way to meet the food demand of growing population. In tropical condition, weeds are major constraint in the food production. Manual weeding is more effective method of weed control in okra, but its time consuming and costlier during critical stage. Because of that, most of the farmers switch over to adopt chemical weed control methods which reduced the drudgery and cost of weeding. The increased use of chemical herbicides has polluted the environment, adversely affects the soil microbes and caused herbicide resistance among weeds (Bhullar et al 2017, Sharma et al 2021). Herbicide usage has created several health and environmental impacts and may disrupt the ecological balance of pest control by natural enemies and led to secondary weed upsurges. Farmers should be taken care while selecting the succeeding crops in rotation. Based on these facts, the present study was carried out to find out the residual effect of preceding rice herbicide on weed control efficiency, growth and productivity of succeeding okra.

MATERIAL AND METHODS

Experimental details: An experiment was conducted at Agricultural College & Research Institute, Tamil Nadu Agricultural University, Madurai during *rabi* 2016 with a view to study the residual effect of preceding rice herbicide on weed control efficiency, growth and productivity of succeeding okra. The soil was sandy loam in texture with low in available nitrogen, medium in available phosphorus and potash. Preceding rice crop experiment lay out in randomized block design was used for succeeding okra with eight treatments and replicated thrice (Table 1).

Agronomic practices: After harvest of rice, Okra hybrid of CO-4 was sown in rice stubbles with the spacing of 45 cm x 30 cm during the 1st week of January. Gap filling and thinning was done at 10 DAS and leaving a single healthy plant per hill. Recommended dose of fertilizer 200:100:100 kg NPK ha^{-1} was applied in the form of urea, super phosphate and muriate of potash. The crop was irrigated immediately after sowing and followed by life irrigation was given on 3rd DAS and subsequent irrigation was given as and when crop required.

All the other recommended packages were adopted as per the schedule. Observations on crop growth and yield were recorded as per standard procedures. The height of the plant was measured from the bottom of the plant to the tip of the growing point on 30and 60 DAS and at harvest stage of the crop and when the okra fruits attained the stage suitable for vegetable purpose, the fruits were harvested. The yield obtained from each picking was weighed, accounted and summed up to obtain the total fruit yield per plot from which the yield per hectare was worked out and expressed as t ha^{-1}.

Weed density: The weed count was recorded species wise using 0.5 m x 0.5 m quadrate from four randomly fixed places in each plot and the weeds falling within the frames of the quadrate were counted, recorded and the mean values were expressed in weeds/m^2. The density of grasses, sedges and broad leaved weeds and the total weeds were recorded at 20 DAS.

Weed dry weight: The weeds falling within the frames of the quadrate (0.5m x 0.5m) were collected, categorized into grasses, sedges and broad leaved weeds, shade dried and later dried in hot-air oven at 80°C for 72 hrs. The dry weight of grasses, sedges and broad leaved weeds were recorded separately at 20 DAS and expressed in g m^{-2}.

Weed control efficiency: Weed control efficiency was computed by adopting the formula suggested by Mani et al (1973).

$$\text{WCE}(\%) = \frac{\text{Wpc - Wpt}}{\text{Wpc}} \times 100$$

Where, Wpc- weed dry weight in unweeded control plot (g m^{-2}), Wpt- weed dry weight in treated plot (g m^{-2}).

Root volume and dry weight: As standard procedure suggested by Ahmet and Ali (2009) for the estimation of root volume, the roots of the randomly selected plants were dug out from the plots carefully at 30 and 60 DAS, washed and roots were measured by the volume of water displaced in the measuring cylinder, the root volume was measured and expressed in cm^3. The roots after the assessment of volume were sun dried and then oven dried for 8 hours at 65±5°C and the dry weight of samples were recorded and expressed in g $plant^{-1}$.

Statistical analysis: The data pertaining to weeds were transformed to square root of √x+2 and statistically analyzed by following the method of Gomez and Gomez (2010). All the observations were statistically analyzed for its test of significance in the individual treatment wise and mean data is presented.

RESULTS AND DISCUSSION

Weed density and weed control efficiency: Rice herbicide residue exerted significant difference in grass, sedges and broad leaved weed (BLW) density at 20 DAS (Table 2). Weed free check was recorded distinctly the lowest grass, sedges and BLW weed density at 20 DAS. Among the weed control treatments, residual effect of oxadiargyl loaded with zeolite on 3 DAT recorded significantly lower grass weed density of 11.67 weeds m^{-2} which at par with residual effect of butachlor at 1.25 kg ha^{-1} on 3 DAT *fb* hand weeding (HW) on 40 DAT in rice + HW twice at 20 and 40 DAS in okra. In sedges, the lowest weed density of 5.67 weeds m^{-2} was registered in residual effect of butachlor at 1.25 kg ha^{-1} on 3 DAT *fb* HW on 40 DAT in rice + HW twice at 20 and 40 DAS in okra. This was followed by residual effect of oxadiargyl loaded with zeolite on 3 DAT (12.00 weeds m^{-2}). Similar trend was also observed in broad leaved weed.

Residual effect of butachlor at 1.25 kg ha^{-1} on 3 DAT *fb* HW on 40 DAT in rice + HW twice at 20 and 40 DAS in okra recorded 83.1, 87.5 and 92.9% reduced grass, sedges and BLW weed density respectively as compared to weedy check. It might be due to effective control of weeds in preceding rice followed by two hand weeding reduced the soil weed seed bank. Similar findings were reported by Bommayasamy et al (2018). Weed control efficiency of grass was higher in residual effect of oxadiargyl loaded with zeolite on 3 DAS whereas, residual effect of oxadiargyl encapsulated with water soluble polymer on 3 DAT recorded higher sedges and BLW weeds control efficiency.

Table 1. Rice and okra crop experiment lay out in randomized block design

Rice herbicide residue (RHR)	Succeeding okra crop
T_1- Oxadiargyl loaded with biochar at 3 DAT	T_1- Residual effect of preceding rice herbicide
T_2-Oxadiargyl loaded with zeolite on 3 DAT	T_2- Residual effect of preceding rice herbicide
T_3-Oxadiargyl encapsulated with starch on 3 DAT	T_3- Residual effect of preceding rice herbicide
T_4-Oxadiargyl encapsulated with water soluble polymer on 3 DAT	T_4- Residual effect of preceding rice herbicide
T_5- Oxadiargyl at 100 g ha^{-1} on 3 DAT	T_5- Residual effect of preceding rice herbicide
T_6-Butachlor at 1.25 kg ha^{-1} on 3 DAT *fb* hand weeding on 40 DAT	T_6-Hand weeding at 20 & 40 DAS
T_7-Weed free check	T_7-Weed free check
T_8-Weedy check	T_8-Weedy check

Plant height: Weed control treatments significantly altered the plant height of okra (Table 3). At 30 DAS, residual effect of butachlor at 1.25 kg ha^{-1} on 3 DAT *fb* HW on 40 DAT in rice + HW twice at 20 and 40 DAS in okra recorded the highest plant height of 22.6 and 52.4 cm on 30 and 60 DAS respectively. The least plant height was registered with weedy check treatment and was followed by treatments were residual effect of oxadiargyl encapsulated with water soluble polymer on 3 DAT recorded and it was comparable with residual effect of oxadiargyl loaded with zeolite on 3 DAT. Similar trend was observed at harvest stage of the crop.

Plant dry matter production: Weed free check exhibited its superiority by registering the highest DMP of 731, 4005 and 13133 kg ha^{-1} at 30, 60 DAS and 105 DAS, respectively. Among various weed control treatments, at 30 DAS, residual effect of butachlor at 1.25 kg ha^{-1} on 3 DAT *fb* HW on 40 DAT in rice + hand weeding twice at 20 and 40 DAS in okra recorded higher DMP of 624 and 3120 kg ha^{-1} on 30 and 60 DAS respectively. It was on par with residual effect of oxadiargyl encapsulated with water soluble polymer on 3 DAT, oxadiargyl loaded with zeolite on 3 DAT and oxadiargyl loaded with biochar on 3 DAT. These treatments were on par with one another. Similar trend was also observed at harvest stage of the crop. It might be owing to controlled release of encapsulated herbicide reduced movement of herbicide in soil and keeping the sizable portion of the active ingredient in the surface soil layer for longer period of time. Better vegetative growth in terms of plant height and more canopies

Table 2. Residual effect of preceding rice herbicide of oxadiargyl on weeds density and weed control efficiency at 20 DAS of succeeding okra

Treatments	Weed density (weeds m^{-2})			Weed control efficiency		
	Grass	Sedges	BLW	Grass	Sedges	BLW
T_1-Oxadiargyl loaded with biochar on 3 DAT	4.72 (20.33)	4.58 (19.00)	2.23 (3.00)	84.2	50.6	47.0
T_2-Oxadiargyl loaded with zeolite on 3 DAT	3.70 (11.67)	3.74 (12.00)	3.05 (7.33)	90.2	56.3	63.5
T_3-Oxadiargyl encapsulated with starch on 3 DAT	6.08 (35.00)	5.29 (26.00)	3.00 (7.00)	90.9	43.8	49.4
T_4-Oxadiargyl encapsulated with water soluble polymer on 3 DAT	4.72 (20.33)	4.20 (15.67)	2.51 (4.33)	84.0	56.7	66.1
T_5-Oxadiargyl at 100 g ha^{-1} on 3 DAT	6.27 (37.33)	6.57 (41.33)	4.00 (14.00)	75.4	34.1	23.1
T_6-Butachlor at 1.25 kg ha^{-1} on 3 DAT *fb* HW on 40 DAT in rice + HW twice at 20 and 40 DAS in okra	3.70 (11.67)	2.77 (5.67)	1.97 (2.00)	82.7	74.6	59.5
T_7 -Weed free check	1.41 (0.00)	1.41 (0.00)	1.41 (0.00)	100.0	100.0	100.0
T_8 –Weedy check	8.40 (69.00)	6.88 (45.33)	5.47 (28.00)	-	-	-
CD (P=0.05)	0.46	0.38	0.56	-	-	-

Figures in parentheses are mean of original values; Data subjected to $\sqrt{x+2}$ transformations

Table 3. Residual effect of preceding rice herbicide of oxadiargyl on plant height, dry matter production at 30, 60 and 105 DAS of succeeding okra

Treatments	Plant height (cm)			Dry matter production (kg ha^{-1})		
	30 DAS	60 DAS	105 DAS	30 DAS	60 DAS	105 DAS
T_1	19.6	26.3	66.2	569	1482	4948
T_2	20.2	35.4	67.8	577	1950	6913
T_3	18.5	29.4	63.6	572	1426	4868
T_4	20.8	34.9	69.9	576	2776	5043
T_5	16.6	30.6	56.4	562	1938	4088
T_6	21.7	53.1	92.7	624	3296	9481
T_7	24.4	70.2	106.2	741	4147	13022
T_8	14.4	24.6	43.4	551	1424	3873
CD (P=0.05)	2.26	3.61	10.57	71	274	1316

Table 4. Residual effect of preceding rice herbicide of oxadiargyl on LAI and root dry weight at 30 and 60 DAS and fruit yield of succeeding okra

Treatments	Leaf area index		Root volume (cm^3 $plant^{-1}$)		Root dry weight (g $plant^{-1}$)		Fruit yield (t ha^{-1})
	30 DAS	60 DAS	30 DAS	60 DAS	30 DAS	60 DAS	
T_1	0.84	1.24	5.33	11.19	1.84	3.16	7.55
T_2	0.90	1.26	5.60	12.20	2.04	4.09	8.40
T_3	0.83	1.68	5.12	9.39	1.54	3.41	7.17
T_4	0.81	1.13	5.11	10.55	1.83	4.00	7.59
T_5	0.86	1.34	5.16	11.20	1.93	3.72	5.97
T_6	0.97	1.84	5.62	16.05	2.31	4.73	15.37
T_7	1.15	2.33	6.41	21.16	3.01	6.38	24.19
T_8	0.82	1.13	5.00	9.12	1.41	2.74	3.27
CD (P=0.05)	0.08	0.22	0.54	2.45	0.26	0.24	1.20

which reflected through dry matter accumulation of plants. Similar findings were observed by Arjun et al (2018) and Bommayasamy and Chinnamuthu (2019).

Leaf area index: Preceding rice herbicide residue later the leaf area index, distinctly at 30 and 60 DAS (Table 4). Higher leaf area index of 1.15 and 2.33 was recorded at 30 and 60 DAS respectively under weed free check and was followed by residual effect of butachlor at 1.25 kg ha^{-1} on 3 DAT *fb* HW on 40 DAT in rice+ HW twice at 20 and 40 DAS in okra and residual effect of oxadiargyl loaded with zeolite on 3 DAT and might be due to reduction in weed survival and weeds gets covered by soil, while using manual weeding and desiccation of soil surface might have inhibited the weed regeneration. Similar finding was reported by Arunjith and Murali Arthanari (2021) and Bommayasamy and Chinnamuthu (2021).

Root characters: It plays important role in soil water and solute dynamics by modifying the moisture and nutrient uptake pattern in the root zone. The root systems link the plant and soil which is more responsible for the absorption of water and nutrient, anchorage and synthesis of some plant hormones. Root volume and root dry weight of okra was found to be significantly influenced by preceding rice herbicide residue on succeeding okra (Table 4). The highest root dry weight and root volume of 6.41, 21.16 cm^3 and 3.01, 6.38 g $plant^{-1}$ was recorded under weed free check at 30 and 60 DAS respectively followed by residual effects of butachlor at 1.25 kg ha^{-1} on 3 DAT *fb* HW on 40 DAT in rice+ HW twice at 20 and 40 DAS in okra, oxadiargyl loaded with zeolite on 3 DAT, oxadiargyl loaded with biochar on 3 DAT. This might be due to higher nutrient uptake of okra could be attributed to increased root dry weight and root volume which might have enabled more absorption area reported by Bommayasamy and Durairaj (2018). Selva Rani and Mariappan (2019) reported that adequate quantity of nutrients coupled with adequate moisture might have resulted in higher root proliferation in bhendi under manize-bhendi cropping sequence.

Effect on fruit yield: Weed control treatment showed significantly influenced on okra fruit yield (Table 4). Weed free check recorded significantly higher fruit yield of 24.19 t ha^{-1}. Among the weed control treatments, the higher fruit yield of 15.37 t ha^{-1} was recorded under residual effect of butachlor at 1.25 kg ha^{-1} on 3 DAT *fb* HW on 40 DAT in rice + HW twice at 20 and 40 DAS in okra which was 83.0 and 97.8% higher fruit yield than residual effect of oxadiargyl loaded with zeolite on 3 DAT and oxadiargyl loaded with biochar on 3 DAT respectively. The higher yield may be attributed to less competition of weeds and decrease in their population that helped in increasing the yield attributes which ultimately led to higher yield and also increase number of nodes $plant^{-1}$ yielding maximum number of fruits. Similar results were reported by Rajasree et al (2017). The least fruit yield of 3.27 t ha^{-1} was recorded in weedy check. It might be due effective weed control results in reduced the crop weed competition to a greater extent and removal of nutrient by weeds. Thus higher nutrient uptake by crops helps in faster growth and development of fruits. Similar results were reported by Patel et al (2017).

CONCLUSION

The residual effect of oxadiargyl loaded in zeolite applied to the previous rice crop resulted in enhanced weed control efficiency, crop growth attributes, and yield of the okra crop under the manpower scarcity scenario of manual weeding.

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Allelopathic Effect of *Anogeissus pendula* Edgew. and *Grewia flavescens* A. Juss on *Desmodium* Species in Alwar district of Rajasthan

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Abstract: The effect of leaf leachates of *Anogeissus spendula* Edgew. and *Grewia flavescens* A. Juss was evaluated on growth of the three species of *Desmodium* in Alwar district of Rajasthan (27°4' to 28°4'N and 76°7' to 77°13'E). *Anogeissus pendula* reduced the percent seed germination of *D. repandum* from 85 in control to 43 at 2% concentration, *D. gangeticum* from 80 in control to 50 at 6% concentration and *D. triflorum* from 78 in control to 28 at 0.1% concentration of leaf leachates. However, the leaf leachates of *Grewia flavescens* had similar effect on the former, whereas, it has more adverse effect on the seed germination of later two species. The leaf leachates of both the species also reduced the elongation of radicle and plumule of three *Desmodium* species; however, the adverse effect of leaf leachates of *Grewia flavescens* was more severe than that of the other species. Among the three *Desmodium* species, the allelopathic effect of *Grewia flavescens* and *Anogeissus pendula* was more severe on *Desmodium triflorum* as compared to the other two species. Thus it may be suggested that the population of three species of *Desmodium* is partly regulated by the allelopathic effect of *Anogeissus pendula* and *Grewia flavescens* in this tropical dry deciduous forest.

Keywords: *Alleopathic, Anogeissus pendula* Edgew, *Grewia flavescens* A. Juss, *Desmodium* species, Seed germination

Muller (1969) has suggested that competition as well as allelopathy comes in to play, such that, the pattern of herb distribution established at the time of germination is maintained throughout the growing season. The allelopathy phenomenon has received considerable attention as a fundamental ecological function (Nakano et al 2003, 2004, Ambika et al 2003, Kohli et al 2004). Chung et al (2001) and Inderjit et al (2002) reported that allelochemicals and their mixture inhibited seed germination in grasses. Sharma et al (2009) investigated the effect of the extract of several weeds on seed germination of different varieties of wheat. *Desmodium repandum* (Vahl.) DC. is an annual herb which grows on the hill slopes, *Desmodium gangeticum* (L.) *DC.* a perennial robust herb grows commonly at the base of hill slopes and in the valleys and *Desmodium triflorum* (L.) *DC.* a perennial herb grows in disturbed forest areas and wastelands in Alwar district of Rajasthan (27°4' to 28°4' N and 76°7' to 77°13' E). The tropical dry deciduous thorn forest is dominated by a tree species, *Anogeissus pendula* and a shrub species, *Grewia flavescens* in this region. Both the species, produce enormous amount of leaf litter which is added to the soil every year and it remains undecomposed until rains commences in July. The low population density (stems m^{-2}) of *Desmodium repandum, Desmodium gangeticum* and *Desmodium triflorum* is 12, 4 and 9, respectively in their natural habitats (Prasad 2015), which indicates that associated vegetation may suppresses their growth. Hence, it may be inferred that these dominant species may adversely affect the growth of *Desmodium* species through leachates released from leaf litter in the rainy season. An attempt has, therefore, been made in the present study to evaluate the allelopathic effect of *Anogeissus pendula* and *Grewia flavescens* on seed germination and seedling growth of the three species of *Desmodium* which commonly grow in Alwar district of Rajasthan.

MATERIAL AND METHODS

Fallen dry leaves of *Anogeisss pendula* and *Grewia flavescens* were collected from their natural growing sites. The aqueous leaf leachates of 0.1, 0.2, 0.5, 1.0, 2.0, 4.0, 6.0 per cent concentration were prepared by soaking for 48 hours in 50 ml distilled water. Aqueous solution of leachates was filtered through a muslin cloth for each concentration. Each of these aqueous leachate was made to 100 ml by adding distilled water. Before germination experiment, *Desmodium gangeticum* and *Desmodium triflorum* seeds were treated with H_2SO_4 for one minute to break the seed coat dormancy and then thoroughly washed with distilled water. The effect of leaf leachates on seed germination was studied by soaking the seeds of *Desmodium repandum, D. gangeticum* and *D. triflorum* in different concentrations for 24 hours. Thirty soaked seeds were kept for germination on filter paper underlined by cotton moistened with the respective leaf leachate solution in the three petridishes for each concentration of every dominant plant species. The petridishes were kept for seed germination at 30°C temperature in a seed germinator and observations were taken. A control was run using distilled water as soaking medium.

Aqueous leachates of leaves of *Anogeissus pendula* and *Grewia flavescens* in distilled water were also tested for their effect on radical and plumule growth of *D.repandum*, *D.gangeticum* and *D.triflorum*. Leachates solution of 0.1, 0.2, 0.5, 1.0, 2.0, 4.0, 6.0 per cent concentration were used. For studying the effect of leachates on growth of *Desmodium* species length of seedlings radicle and plumule were measured after 15 days.

RESULTS AND DISCUSSION

The leaf leachates of *Anogeissus pendula* reduced the percent seed germination of *Desmodium repandum* from 85 in control to 43 at 2% concentration of leaf leachates (Table 1). The adverse effect of leaf leachates of *Anogeissus pendula* on seed germination and seedling growth was from 0.5% concentration of onwards. The leaf leachates of *Anogeissus pendula* have less effect on seedling growth as the reduction in radicle elongation was from 6.4 cm in control to 4.1 cm at 2% concentration while the reduction in plumule elongation was slightly less than radicle elongation. *Grewia flavescens* reduced seed germination of *Desmodium repandum* from 85 in control to 40 at 2% concentration while the elongation of radicle from 6.4 cm to 4.8 cm and plumule elongation from 3.4 cm to 2.24 cm with increase in concentration of leaf leachates (Table 1). Gupta and Yadav (2007) also reported that leaf leachates of *Cassia tora* inhibits seed germination and seedling growth of the grass species of the Sariska Tiger Reserve forest. The leaf leachates of *Holoptelea integrifolia,* a local tree of this region, have little effect on seed germination of *Indigofera trita* (Dey and Yadav (2010). The harmful effect on radicle and plumule elongation begins after 0.2% concentration of leaf leachates in this species. However, the intensity of adverse effect of *Grewia flavescens* was slightly higher on seed germination and seedling growth of *Desmodium repandum* than that of leaf leachates of *Anogeissus pendula.*

In *Desmodium gangeticum,* the adverse effect of leaf leachates of *Anogeissus pendula* was higher on seed germination than on seedling growth (Table 1). The per cent seed germination decreased from 80 in control to 50 at 6% concentration of leaf leachates. Similarly the radicle and plumule elongation is reduced from 3.1 to 2.0 cm and 1.8 cm to 0.7 cm, respectively with increase in concentration. The

Table 1. Allelopathic effect of leaf leachates of *Anogeissus pendula* and *Grewia flavescens* on seed germination and seedling growth of *Desmodium* species. [A=Concentration (%), B= Seed germination (%), C= Plumule elongation(cm) and D= Radicle elongation(cm) (±SE)]

Leaf leachates (A)	*Desmodium repandum*			*Desmodium gangeticum*			*Desmodium triflorum*		
	Seed (B)	Plumule (C)	Radicle (D)	Seed (B)	Plumule (C)	Radicle (D)	Seed (B)	Plumule (C)	Radicle (D)
Allelopathic effect of *Anogeissus pendula*									
0.1	74.99±5.9	5.64±0.1	3.34±0.2	61.66±3.5	3±0.1	1.6±0.2	28.33±1.2	2.26±0.1	1.5±0.2
0.2	63.33±11.8	5.5±0.2	3.2±0.2	59.99±4.7	2.86±0.1	1.36±0.1	18.33±1. 2	1.8±0.2	1.34±0.2
0.5	48.33±10.6	5.14±0.1	2.46±0.2	63.33±2.4	2.66±0.2	1.24±0.1	16.66±2.4	1.44±0.2	1.16±0.1
1	46.67±9.4	4.44±0.2	2.34±0.2	65.16±1.1	2.64±0.2	1.08±0.3	14.99±1.2	1.34±0.3	1±0.2
2	43.33±7.1	4.14±0.1	2.2±0.1	56.66±2.4	2.24±0.1	0.96±0.2	11.67±1.2	1.14±0.3	0.82±0.1
4	*	*	*	53.33±4.7	2.14±0.1	0.84±0.2	8.33±1.2	0.82±0.2	0.74±0.1
6	*	*	*	49.99±2.4	1.98±0.1	0.74±0.2	0±0	0±0	0±0
Allelopathic effect of *Grewia flavescens*									
0.1	66.66±4.7	5.9±0.2	2.9±0.5	49.995±2.4	2.9±0.2	1.38±0.2	46.665±2.3	2.12±0.2	1±0.2
0.2	61.66±10.6	5.5±0.2	2.84±0.2	46.665±2.4	2.68±0.1	1.32±0.2	34.995±1.2	1.88±0.2	0.94±0.2
0.5	56.83±4.8	5.44±0.3	2.7±0.2	28.33±1.2	2.54±0.1	1.24±0.2	21.665±1.2	1.78±0.3	0.9±0.2
1	48.33±1.2	5.24±0.2	2.6±0.3	24.995±1.2	2.42±0.2	1.08±0.1	14.995±1.2	1.68±0.2	0.76±0.2
2	40±7.1	4.84±0.2	2.24±0.1	23.33±2.4	2.2±0.2	0.92±0.2	9.995±2.4	1.14±0.3	0.66±0.2
4	*	*	*	18.33±1.2	1.9±0.2	0.82±0.1	0±0	0±0	0±0
6	*	*	*	9.995±2.4	1.52±0.2	0.68±0.1	0±0	0±0	0±0
Control									
Distilled water	84.995±1.2	6.4±0.5	3.4±0.4	79.99±2.4	3.1±0.2	1.76±0.2	78.33±1.2	2.76±0.2	1.56±0.3

*Observation could not be recorded

growth of seedlings was adversely affected only at higher concentration of leaf leachates of *Anogeissus pendula,* however the reduction of plumule elongation was more as compared to radicle elongation. Dey and Yadav (2010) also reported that the adverse effect of allelochemicals was more on plumule than on radicle elongation in *Indigofera trita*. The leaf leachates of *Grewia flavescens* caused greater reduction in per cent seed germination of *Desmodium gangeticum* from 80 in control to 50 even at 0.1% concentration which was further reduced to 10 at 6% concentration of leachates (Table 1). Similarly the radicle and plumule elongation was also reduced from 3.1 cm to 0.7 cm, however, the plumule elongation is more sensitive to leaf leachates than the radicle elongation.

Leaf leachates of *Anogeissus pendula* reduced per cent seed germination of *Desmodium triflorum* from 78 in control to 28 at 0.1% concentration, which was further reduced to complete inhibition of germination with increase in leaf leachates concentration from 0.1% to 6.0%. Similarly, the elongation of radicle was reduced from 2.8 cm to 2.2 cm at 0.1% concentration which further decreased to nil with increase in 0.2% to 6.0% concentration. The adverse effect of leaf leachates of *Grewia flavescens* was more severe on the seed germination and seedling growth of *Desmodium triflorum*. The percent seed germination was reduced from 78 in control to 21 at 0.5% concentration and at more than 2% there was complete inhibition of seed germination. Similar adverse effect of leaf leachates was observed on elongation of radicle and plumule of this species. These observations suggest that the leaf leachates of the shrub, *Grewia flavescens* have more adverse effect on seed germination and seedling growth of the three species of *Desmodium.* Dey and Yadav (2010) have also observed that the leaf leachates of indigenous shrub, *Capparis sepiaria* exhibited higher inhibitory effect on seed germination and seedling growth of *Indigofera trita* than that of *Holoptelea integrifolia* a tree species of this region. Among the three *Desmodium*s pecies, the allelopathic effect of *Grewia flavescens* and *Anogeissus pendula* was more severe on the seed germination and seedling growth of *Desmodium triflorum.*

CONCLUSION

The growth and distribution of three species of *Desmodium* is partly regulated by the allelopathic effect of *Anogeissus pendula* and *Grewia flavescens* in the tropical dry deciduous forest of Alwar in Rajasthan. The shrub has more adverse allelopathic effect on *Desmodium* species than the tree species. Comparatively severe allelopathic effect of *Grewia flavescens* on *Desmodium triflorum* may be one of the causes of its complete absence in protected areas in this forest.

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Geographical Distribution of Malvaceae: *Lavatera maritima*=*Malva subovataa* in Coastal Region of Tlemcen, Algeria

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***Abstract*:** The végétation of the Tlemcen region, presents the study of plant diversity. In order to give an overview of the location of *L.maritima*, developed a map of the stations (Chaib rasso, Marsa ben m'hidi, Bider Mouskarada). The dominance of therophyte species compared to chamaephytes and phanerophytes, which testifies to a very strong anthropogenic action.

***Keywords*:** *Lavatera maritima*, Chaib rasso, Mouskarda, Bider, Marsa ben m'hidi, Therophyte

Mapping is the basis of ecological management of ecosystems (Ferka 2006) and remains necessary tool for all forms of development and understanding of an ecosystem, allowing in-depth knowledge of the environment, its potential and its optimal uses. Cartographic representations of the vegetation cover are essential working documents for many studies. A vegetation map can be viewed in different ways, as a physiognomy map showing the present state of vegetation, or as a land use map. Thematic maps remain necessary tools for all forms of development and understanding of an ecosystem**. (**Belhassini 2011). The purpose of this article, is to show that the coastal region of Tlemcen has a very diverse flora and very related to the different disturbance factors. The map we have made includes the coastlines of the four stations (Marsa ben m'hidi 1 and 2, Bider and Mouskarda) on the northern slopes of the Tlemcen region. It gives us a general overview of the range of our lavatère and also allows us to highlight the current state of the study areas.

MATERIAL AND METHODS

Concerning the mapping of the types of plant groups in L. maritima relating to this zone, the maps were drawn up which are used vegetation formation maps, Floristic surveys carried out in the field. The Map.info 7.5 data procession software was used . The choice of the scale of the map is delicate and requires a lot of attention. If the chosen scale is too small, it is not possible to represent complex phenomena without the risk of making the map confusing and difficult to read and if the scale is too large, the territory represented has only a small extent and it is not possible to obtain a synthetic view of the main lines of the vegetation of the region studied. For this reason, medium scales are the most widely used, except in special cases. (Barka 2016). The zone 2 is made up of: *Lavatera maritima, Aegilops triuncialis, Ferula communis, Convolvulus althaeoides, Scolymus hispanicus, Withania frutescens, Olea europea, Papaver rhoeas, Reseda alba, Lavendula dentata, Inula viscosa, Hordeum murinum.* The flora used for the identification of the taxa collected include the new flora of Algeria (Quezel and Santa 1963) and The great flora of France and neighboring countries Bonnier and Douin (1990).

RESULTS AND DISCUSSION

As biological types are conditioned by environmental factors and physiognomic expression, reflects the environmental conditions. The enumeration of species by biological type is carried out on all the species inventoried in each station (Kerzabi 2017). In present study retained five forms ofr biological types (Table 2, Fig. 2), from the global list of recorded species, and can determine the number of each biological type.

Bider msirda fougara: Therophytes and hemicryptophytes are best represented with the same percentage of (40%), followed by chamaephytes (15%), Geophytes (5%) and absence of Phanerophytes.

Marsa Ben-mehidi 1: The therophytes are represented with a percentage of (57.69%), Chamaéphytes and the hemicryptophytes (19.23%) and low percentage of the phanerophytes of (3.84%).

Marsa Ben-mehidi 2: The therophytes are represented with a percentage of (50%), the followed by chamaéphytes and the hemicryptophytes (15.78%), Geophytes (10.52%),finally

Table 1. Geographical data for Zone 2

Code	Longitude	Latitude
Bider msirda fougara	002°02 W	35°03N
Marsa ben mehidi 1	002°11 W	35°04 N
Marsa ben mehidi 2	002°11 W	35°04 N
Mouskarda	002°11 W	35°05 N

Table 2. Number of biological types for each station

Station biological type	Phanerophyte Ph	Chamaephyte Ch	Hemicryptophyte He	Geophyte Ge	Therophyte Th
Marsa ben m'hidi 1	01	05	05	00	15
Marsa ben m'hidi 2	04	06	06	03	19
Mouskarda	03	08	06	05	23
Bider	00	03	08	01	08

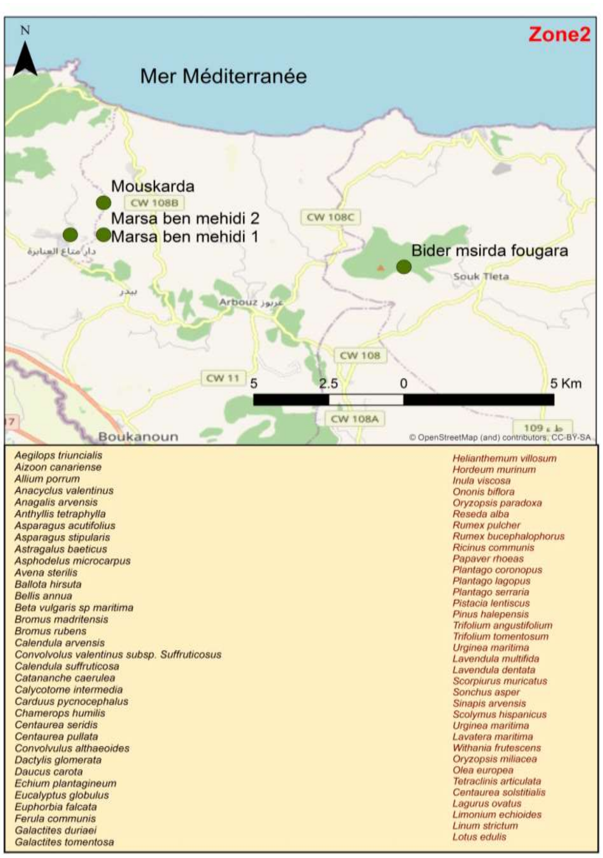


Fig. 1. Presence of *L.maritima* in zone 2

a very low percentage of Phanerophytes of (7.89%).

Mouskarda: The therophytes are represented with a percentage (51.11%), followed by chamaéphytes (17.77%), hemicryptophytes (13.33%), Geophytes (11.11%), finally a very low percentage of Phanerophytes with (6.66%). Despite the low participation of phanerophyte species in study area, they are dominant by their biomass, they thus constitute forests and preforests,

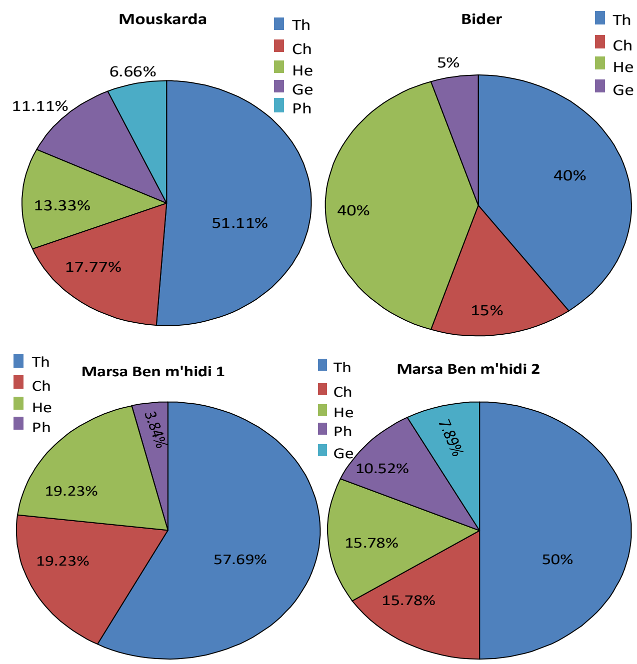
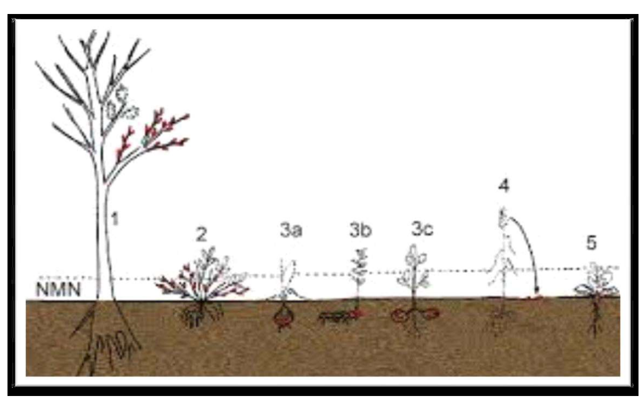


Fig. 2. Percentage of biological types from each station



1: Phanerophytes - 2: Chamaephytes - 3: Geophytes (3a with bulb, 3b with rhizome and 3c with tuber) 4: Therophytes - 5: Hemicryptophytes

Fig. 3. The biological types (Raunkiaer 1934)

CONCLUSION

The dominance of the Therophytization trait is linked to the invasion of annual species disseminated by the striking action of man and his herds, especially in the study area .The production of a distribution map of the groups in *Lavatera maritima* in the region of North West Algeria helps us to identify the current state of the natural distribution area of this taxon. Finally the cartographic study has shown the importance of the floral procession linked to Malva subovata or Lavatera maritima in the coast with a very large number.

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Evaluation of Suitability of Sand Sheet as Sand Filters for Water Treatment, West Al-Sharqat Area, Iraq

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Abstract: The main objective of this study to assess the properties of Sand sheet in Al- Sharqat City, Iraq, to determine their suitability to be used as water filters. Five stations (1, 2, 3, 4 and 5) were selected according to the variation in the lithological properties, gradation and accessibility to the materials source. Laboratory tests included grain size analysis, water content, specific gravity and chemical analysis. Tests results showed that the moisture content, specific gravity, gypsum content, total dissolved salt, organic matter content, and pH ranged from 0.90 to 5.48%, 2.63 to 2.66, 2.16 to 14.68%, 4.21 to 20.21, 3.81 to 9.41%, and 7.77 to 8.01, respectively. The test results vary due to a variety of factors such as sampling depth, secondary gypsum content, and so on. The results showed, according to Indian standard 1993 and Iraqi typical standard (1555 in 2000), the sand sheets in the study area are not appropriate as water filters.

Keywords: Sand sheet, Water filtration, Uniformity coefficient, Physiochemical analyses

Water is required in all human activities, whether for agriculture, trade, industry, electricity generation or daily use (Allawai and Ahmed 2019) but water quality is decreasing due to the rapid growth of population, industries as well as other infrastructures. These human activities have a significant effect on the water quality (Kumar and Vipin 2021). Drinking water must be free of chemical and biological contaminants and toxic material (Montana et al 2013). Many of the water sources used by humans contain some vectors of disease that may cause long-term problems. The main problem in most parts of the world is the supply of drinking water to the population as a result of the increase in human population. As the gap between drinking water supply and requirements expand and reach dangerous levels in most parts of the world, it can be a threat to human existence with the reports that the coming wars will be because of water (WHO 2017). Therefore, the scarcity of fresh water can cause serious problem around the world, especially in areas of dry climates with less than 100 mm of rain. Due to the increase in demand supply needs to meet specific standards. Several purification techniques have been adopted to meet the standards (Ambashta and Sillanpaa 2010). One of the approved methods of water purification is the use of sand filters. Infiltration can be achieved through a sublime barrier that prevents the passage of solid material and allows only liquids to pass without the occurrence of any chemical interaction during the separation process (Jiang et al 2021). The main aim of the filtration process is to remove impurities, solids materials, viruses, bacteria and germs from the water. Normally, a layer of sand, coal, or another granular substance is utilized in public water supply filters (Diwakar et al 2020). Sand proved its adequacy as compared to other materials as a filtering material (Droste and Gehr 2018). Most of the researchers confirmed that the infiltration thickness should be (60- 100 cm, and the effective size range of 0.5- 0.7) mm, and uniformity coefficient ranged from 1.2 to 1.7 mm (Viessman and Hammer 1985). Gravel is used as a supporting layer to prevent sand from getting through during the infiltration process. It should be solid and globular in shape and it should not contain thin and long pieces, and it should not contain mud and glutinous materials. In present study focus is on the studying properties of the sand sheet and their suitability to be used as water filters to make water safe for drinking.

MATERIAL AND METHODS

Study area: The area is located in Al- Sharqat City, Salahuldin Governorate, north of Iraq, between longitudes (43°15' 12"- 43°11' 48"), and latitudes (35°29' 05" - 35°33' 21") (Fig. 1).

Infiltration and sand filters: The process of infiltration includes the following steps (Khalil 2007):

1. The adhesion of some suspended materials on the sand grains surface and depositing some of them in sand cavities with the help of water meandrous paths which increase the centrifugal force.

2. Deposition of some solid materials in sand gaps.
3. Sand cavities function as a filter used to prevent suspended material, especially big size.
4. A gelatinous layer of small suspended materials is formed on the sand surface and might have been formed of small living entities that help in preventing suspended material from getting through.
5. The difference in electrical charges between suspended materials and sand grains helps to adhesion these materials to sand grains.

The filters were classified according to filtering speed into two types, rapid sand filters and slow sand filters (Cescon and Jiang 2020).

The first step was to the study area for one month (August- September) to identify the geomorphological effect and the rockoutcrops of the geological formations, and to determine the different field measurements. The second step included a field survey of the study area to determine the locations (where samples were taken at 30-50 cm in depth) and coordinates of the five stations using GPS, and collecting of sand sheet samples (Fig. 2). Physiochemical test and chemical analyses of samples were performed department of chemical engineering, Tikrit University.

Physical Tests

Moisture content and specific gravity: It is the ratio of the weight of the water to the total dry weight of the rock (ASTM-D 2216) and is calculated according to the following equation.

$W\% = M_{wet} - M_{dry} / M_{dry} x100 = M_w / M_{dry} x100$…..(1)

Where: W% = water content of the soil

M_{wet} = weight of wet soil,

M_{dry} = mass of dry soil, obtained at 45 °C unless otherwise specified

M_w = mass of water, with oven temperature maintained at 105-110°C for 24 hours. Here, 45°C is adopted for drying until the weight stabilizes. It was examined in the semi dry season (August-September) according to the American quality (ASTM D 2216 2004) (ITS 2002).

Specific gravity the ratio between the weights of a certain volume of the sample in the air to the weight of the same volume of water was estimated (ASTM- D, 854-02, 2002).

Dry apparent specific gravity (App. GS) = Wd / (Wsat-Wsub) …….(2)

This test was carried out on the study area samples (ASTM D 854 2002), Specific weight is considered a criterion is measuring soil volumetric analysis according to the standard classification to define the soil type (Das 1982).

Volumetric analysis: For successful soil analyses and interpretation, soil sampling is essential. First and foremost, a sample must be appropriate for the purpose of the experiment. Second, because the physical and chemical characteristics of soils in fields are varied, taking a representative sample might be challenging (JICA 2014). Samples were test according to the American qualities (ASTM-D 422 2004).

Chemical analyses: Some chemical analyses tests were done to estimate the rate of impurities and harmful material

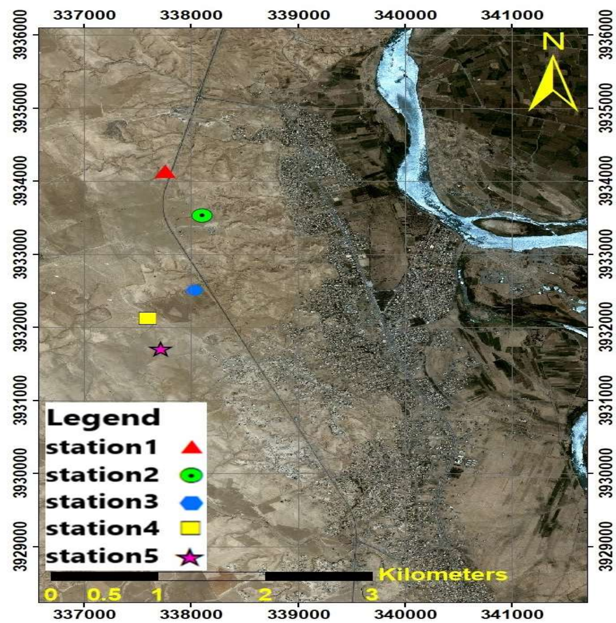

Fig. 1. Location map of the study area

Fig. 2. Sand sheet stations in the study area (sampling from leeward side)

which affect the architectural structures in which scree is used such as concrete, brick work and water filters (Al-fahdawi and Al-nuaymy 2021). These tests included T.D.S., gypsum content, organic l content, and pH (ASTM-D, 422-63., 2004).

RESULTS AND DISCUSSION

Moisture content and specific gravity: Moisture content and specific gravity results obtained from the present study are summarized in Table 1.

Volumetric analysis: The results of the volumetric analysis for all the five investigated stations are presented in Table 2 and Figure 3. The have indicated that all samples of the study area stations are not compatible with the standard measure which is specified for grain gradation of the filtration medium (12-25 mm, and 6-12 mm) mentioned on the ASTM (C136, 2014) and the Iraqi specification 2002. The poorly graded sand particle where the grain size is no more than 1 mm. When compared the grain size (1 mm) to the values in the specifications mentioned above, considered a great difference. Moreover, all of the investigated contained mud and alluvium with a varied proportion, which have a negative effect in filtration work. The uniformity coefficient results were as 1.7, 2.1, 1.9, 2 and 2.3 in the five stations respectively, that doesn't not conform with the typical requirements of the uniformity coefficient (not exceed 1.5) according to the Iraqi specifications (Iraqi standard 2002). The soil specific gravity values ranged from 2.63 to 2.66.

Chemical analyses: The chemical tests results obtained from this study are summarized in Table 3. The organic material are incompatible in four stations in accordance with Iraqi specifications (Iraqi standard 2002), but only in station No. 2 (3.81) does not exceed 5%, thus compatible with that standard. There is incompatibility in gypsum content and the rate of sulfur salts (TDS) solvable in water which affects human health, according to the Iraqi typical specifications

Table 1. Moisture content and specific gravity of the study area

Stations No.	Specific gravity	Moisture content (%)
1	2.65	4.39
2	2.64	2.98
3	2.65	1.01
4	2.66	5.48
5	2.63	0.90

Table 2. Volumetric analysis results of study area precipitations

Station	Sand (%)	Mud (%)	Uniformity coefficient
1	93.6	6.40	2.3
2	97.09	2.91	2
3	97.72	2.28	1.9
4	96.25	3.75	2.1
5	98.33	1.67	1.7

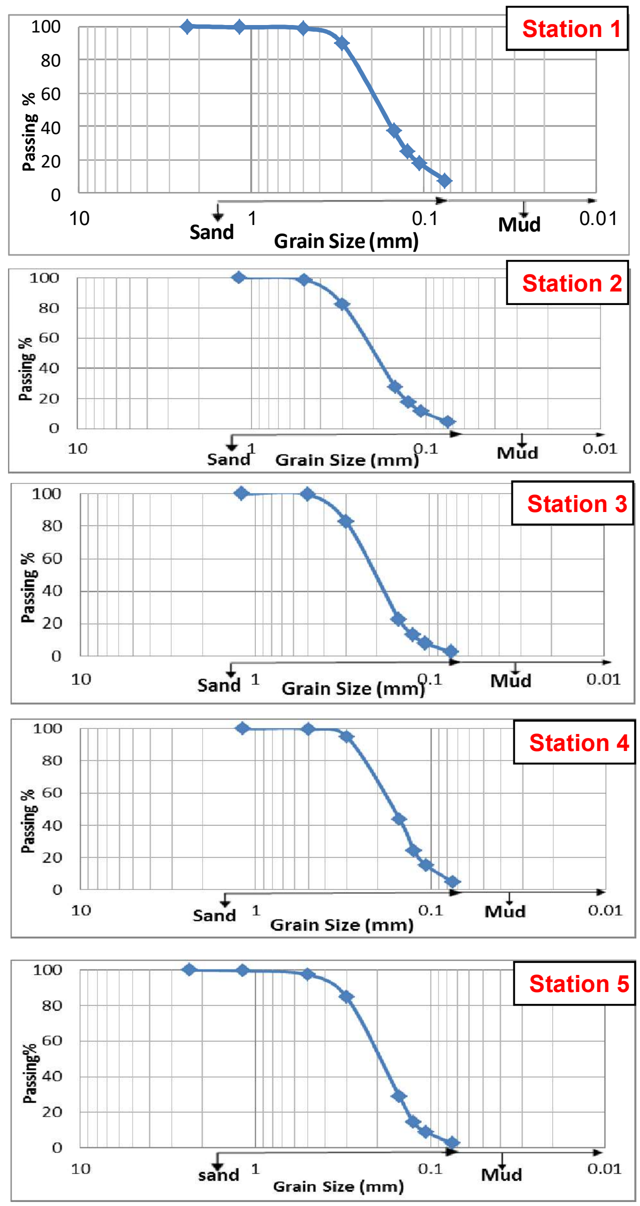

Fig. 3. Volumetric analyses of the study area samples

Table 3. Chemical tests of the study area samples

Station no.	Gypsum content (%)	TDS	Organic matter content (%)	pH
1	3.16	4.21	5.47	7.91
2	2.14	4.77	3.81	8.00
3	14.68	20.21	7.21	7.81
4	11.68	14.46	9.43	7.77
5	2.16	5.21	6.05	8.01

which should not exceed 1%. The results vary due to a variety of factors such as sampling depth and secondary gypsum content. According to Indian standard (1993) and Iraqi typical standard (1555 in 2000), the sand sheets in the research area are not appropriate as water filters.

CONCLUSIONS

The grain size analysis results showed abundance in the sand SP type and a decreasing rate of fine types (silt and clay). The chemical tests showed incompatibility with the Iraqi and ASTM standards. The moisture content was low. The results of Volumetric analysis are incompatible with the conditions required in the sand and gravel of water filters. The sand sheet in the study area does not meet the standard specifications thereby; it is not suitable as a water filter. It is recommended conducting a study of the mineral structure of these sand sheets to specify their effects on the surrounding infrastructure and agricultural farms as well as study of geotechnical properties to investigate the property of sand sheet. It is recommended performing other similar scientific studies over many sand dune areas exposed in Iraq.

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GIS-Based Assessment of Groundwater Quality for Drinking in Perambalur District of Tamil Nadu

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Abstract: Water quality parameters such as TDS, Ca^{2+}, Mg^{2+}, Na^{+}, K, Cl, So_4^{2}, F, pH and TH were used to determine the groundwater quality in the Perambalur district of Tamil Nadu. The BIS scale is used to determine the water quality index based on standard weight. The chemical ion indicates that an alkali exceeds alkaline earth and weak acids exceed strong acids in both monsoon periods. The highest numbers of wells where the chemical constituents were above the permissible limit with Mg^{2+}, TDS and total hardness and the lowest was in Ca^{2+}. In 2018, poor water quality covered 1345 sq km in pre-monsoon and 1203 sq km in the post-monsoon season. Therefore, it is imperative to improve water quality using proper water purification and pollution control in areas where poor water quality is noted.

Keywords: Ca^{2+}, BIS standards, Groundwater, Drinking water quality, Monsoon

The groundwater chemistry is unique and its quality is determined by the geological formation, climatic condition and anthropogenic activities. The groundwater is a valuable resource for drinking, agriculture and industrial activities around the world (Adimalla Narsimha et al 2018). Groundwater accounts for nearly 65, 20 and 15% of drinking, irrigation and industrial activities respectively based on recent research (Salehi et al 2018). In India, 90% of the rural community be influenced by groundwater for drinking and domestic purposes (Arya et al 2019). Generally, the groundwater is less vulnerable to contamination but once the groundwater gets polluted it is difficult to retain its original content (Vinothkanna et al 2020). However, the geochemistry of groundwater determines its utilization whether for domestic or agriculture (Vinothkanna 2019). Many studies on groundwater using standard techniques and plots were carried out by various researchers (Divahar et al 2020 for Kalingarayan canal of Erode district; Vinothkanna et al 2020 for Dharmapuri district of Tamil Nadu; Ramprasad et al 2021 for river Cauvery and Vaigai upstream and downstream locations of Tamil Nadu). Water quality index (WQI) is a widely used technique to assess quality (Gorgij et al 2017). The WQI is a frequently used method because of considering important chemical parameters to determine the water quality. The use of a Geographic Information System (GIS) in water resources provides commendable information to the research. Many researchers used GIS techniques in water quality studies (Jasmin and Mallikarjuna 2014 for Araniar River Basin; Vinothkanna et al 2016 for Namakkal district). The main purpose of this study is to assess the quality of groundwater for domestic purposes in the Perambalur district of Tamil Nadu. Understanding groundwater chemistry helps to use this resource optimistic and make it sustain.

MATERIAL AND METHODS

Study area: The spatial extent of Perambalur district is 1757 sq.km and located in the interior part of Tamil Nadu with a geographical extent of 10°54" to 11°30"N and 78°40" to79°30"E (Fig. 1). River Vellar and Pachmalai hill in the north and Kollidam River in the south are the prominent physical features. Sugarcane is one of the main crops cultivated in this district. The major factors which define the geomorphology of the study area are denudational, structural and fluvial processes. Black, alluvial and red loamy soils are the major soil categories distributed in the district. Hydro geologically the aquifer system is constituted by Basalt crystalline rocks comprising Charnockites, Granites and Gneisses of Archean age and sedimentary formation from Cretaceous to recent.

Methods: The groundwater data for 2018 were collected from the state ground and surface water resources data centre, Chennai is the primary source for this analysis. The 19 common groundwater wells from different monsoon seasons (pre and post) were identified using Microsoft Excel and attributed to the ArcGIS platform to show spatially. Based on the Bureau of Indian Standard (BIS) a total of ten water quality parameters *viz*., TDS, Ca^{2+}, Mg^{2+}, Na^{+}, K^{+}, Cl, SO_4^{2}, F, pH and Total hardness were considered to identify the groundwater quality for domestic purposes (Narsimha Adimalla 2019). The weight was assigned from 1 to 5 (Table 1.) based on the importance of drinking purpose and by using the arithmetic index method relative weight was calculated (Chaurasia et al 2018).

WQI = Σqiwi

Where qi (ground water quality ranking) = 100 X (Va-Vi) / (Vs-Vi),

When Va = authentic value found in the groundwater sample

Vi = ideal value (pH and DO have 7.0 and 14.6 mgL^{-1} respectively and 0 for all other parameters).

Vs = standard value.

Wi (unit weight) = KSn^{-1}

$$\text{Where K constent} = \frac{1}{\frac{1}{Vs1} + \frac{1}{Vs2}\frac{1}{Vs3}\frac{1}{Vs4}........ + \frac{1}{Vsn}}$$

Sn = 'n' number of standard values.

GIS analysis: The district boundary was digitized using Topographic sheets collected from the Survey of India with a scale of 1:50,000 using UTM coordinates. The spatial map for water quality was prepared using the interpolation technique in ArcGIS mainly the Inverse Distance Weight (IDW) method because it is easy to perform. This method gives weightage to the observed point and predicts a value for an unknown location (Elumalai et al 2017).

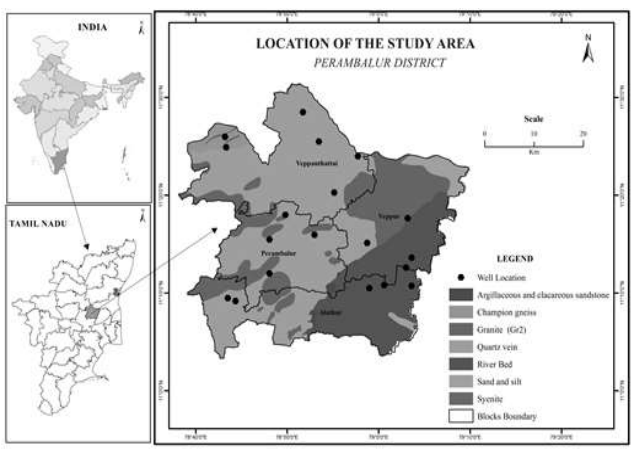

Fig. 1. Location of the study area – Perambalur District

Table 1. Standard limits and their relative weight

Parameters	BIS standards (2012) acceptable limit	WHO limit (2011)	Weight (Wi)	Relative weight
Ca^{2+}	75	100	2	0.068
Cl	250	250	3	0.103
F	1	1.5	5	0.172
K^+	12	12	1	0.034
Mg^{2+}	30	50	2	0.068
Na^+	50	200	3	0.103
pH	6.5-8.5	6.5-8.5	3	0.103
Sulfate	200	400	3	0.103
TDS	500	1000	5	0.172
TH	200	500	2	0.068

RESULTS AND DISCUSSION

Groundwater chemistry controlling mechanism: On the left side of the plot are cations that constitute Mg^{2+}, Ca^{2+}, Na^+ and K^+ and the right-side triangle is anions comprise of Cl, SO^2_4, CO^3 and HCO^3 (Fig. 2). The presence of Na^++K^+ions in the groundwater is due to silicate weathering (Lakshmanan et al 2003). Similarly, the anions are dominated by bi-carbonates and were in the order of HCO^3>Cl> SO^2_4. Generally, the diamond field is divided into 4 geochemical categories such as a) Ca^{2+}-Mg^{2+}-HCO^3, b) Ca^{2+}-Mg^{2+}-Cl-SO^2_4, c) Na+-K+-Cl-SO^2_4 and d) Na^+-K^+-HCO^3. The chemical ions are presented in the order of Na^+-K^+-Cl-SO^2_4>Na^+-K^+-HCO^3>Ca^{2+}-Mg^{2+}-HCO^3>Ca^{2+}-Mg^{2+}-Cl-SO^2_4 indicates alkalis exceeds alkaline earth and weak acids exceed strong acids in both monsoon period.

Characteristics of Chemical Parameters

Calcium: The mean value of Ca^{2+} ranged between 10 to 80 mgL^{-1} and 8 to 60 mg L^{-1} during pre-monsoon and post-monsoon season respectively (Table 2 & Fig. 3a). During pre-monsoon seasons, 18 wells (95%) were in the desirable range and only 1 well located in Esanai village exceeds the desirable limit which is located in the central part depicted on the spatial map. During the post-monsoon season, almost all the wells are under desirable limits during the study.

Chloride: The chloride level in the pre-monsoon season varied from 35 to 596 mg L^{-1} and during the post-monsoon season it is 28 to 709 mg L^{-1} (Fig. 3b). The chloride level in pre-monsoon and post-monsoon season show that 79 and 74 percent of wells are under the desirable limit.

Fluoride: The fluoride in pre monsoons season (0.05 to 1.4 mg L^{-1}) are having an average of 0.48 mg L^{-1}. About 84 percent of pre-monsoon sample wells are under the desirable limit as prescribed by BIS standards (2012). Pasumbalur village of Veppanthattai taluk, Sirumathur and Chittali village of Kunnam taluk fluoride were above the desirable limit. But in the post-monsoon, fluoride values are range from 0.13 to 1.22 mg L^{-1} having a mean value of 0.56 mg L^{-1} (Fig. 3c). The desirable range was in 16 and 3 wells (Mettupalayam village of Veppanthattai taluk, Sirumattur and Kilumattur village of Kunnam taluk) exceeds desirable value during the study period.

Potassium: The concentration of potassium was 0.1 to 196 mg L^{-1} for pre-monsoon and 18 to 98 mg L^{-1} for post-monsoon was noted during the study period (Fig. 3d). The mean values of potassium are observed as 43.2 mg L^{-1} for pre-monsoon and 50.3 mg L^{-1} for the post-monsoon season. Among the total samples, 58 percent in pre-monsoon and only 16 percent in post-monsoon are under the desirable limit. The samples found beyond the desirable limit are 42 percent (pre-

Table 2. Groundwater chemical parameters - Perambalur district

Parameter	Desirable limit (mgL^{-1})	Pre-monsoon			Post-monsoon			Classification	Pre-monsoon		Post-monsoon	
		Mean	Maximum	Minimum	Mean	Maximum	Minmum		Total well	%	Total well	%
Ca	75	42.7	80.0	10.0	34.21	60.0	8.0	WL	18	94.74	19	100
								AL	1	5.26	0	0
Cl	250	188.9	596.0	35.0	214.68	709.0	28.0	WL	15	78.95	14	73.68
								AL	4	21.05	5	26.32
F	1.0	0.4	1.4	0.05	0.56	1.2	0.1	WL	16	84.21	16	84.21
								AL	3	15.79	3	15.79
K	20	43.2	196.0	0.1	50.37	98.0	18.0	WL	11	57.89	3	15.79
								AL	8	42.11	16	84.21
Mg	30	72.6	167.6	24.3	58.38	98.42	21.8	WL	3	15.79	3	15.79
								AL	16	84.21	16	84.21
Na	200	183.5	621.0	12.0	166.32	495.0	24.0	WL	13	68.42	13	68.42
								AL	6	31.57	6	31.58
pH	6.5-8.5	8.3	8.6	8.1	8.11	8.3	7.7	WL	17	89.47	19	100
								AL	2	10.53	0	0
So4	200)	254.5	864.0	24.0	156.00	600.0	29.0	WL	9	47.37	15	78.95
								AL	10	52.63	4	21.05
TDS	500	1048.3	2697.0	226.0	920.74	1925.0	276.0	WL	3	15.79	5	26.32
								AL	16	84.21	14	73.68
TH	200	405.7	840.0	150.0	325.79	510.0	125.0	WL	4	21.05	4	21.05
								AL	15	78.95	15	78.95

(WL - Within Limit, AL - Above Limit)

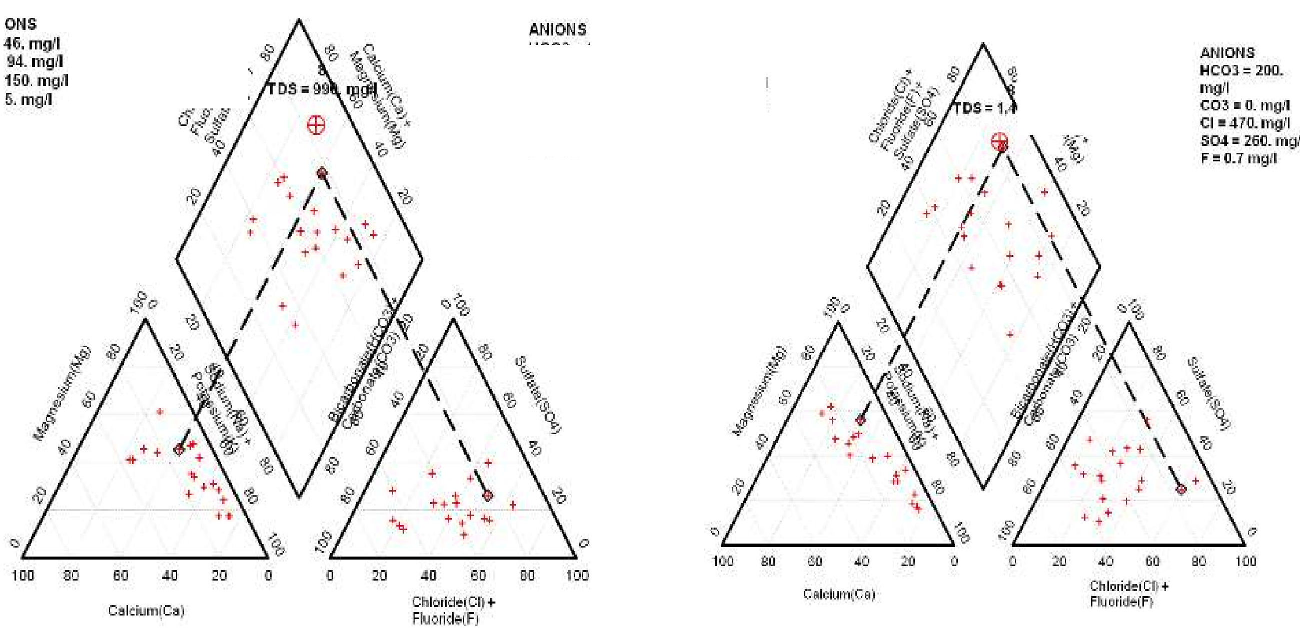

Fig. 2. Pre-Monsoon and post-monsoon season Piper diagram

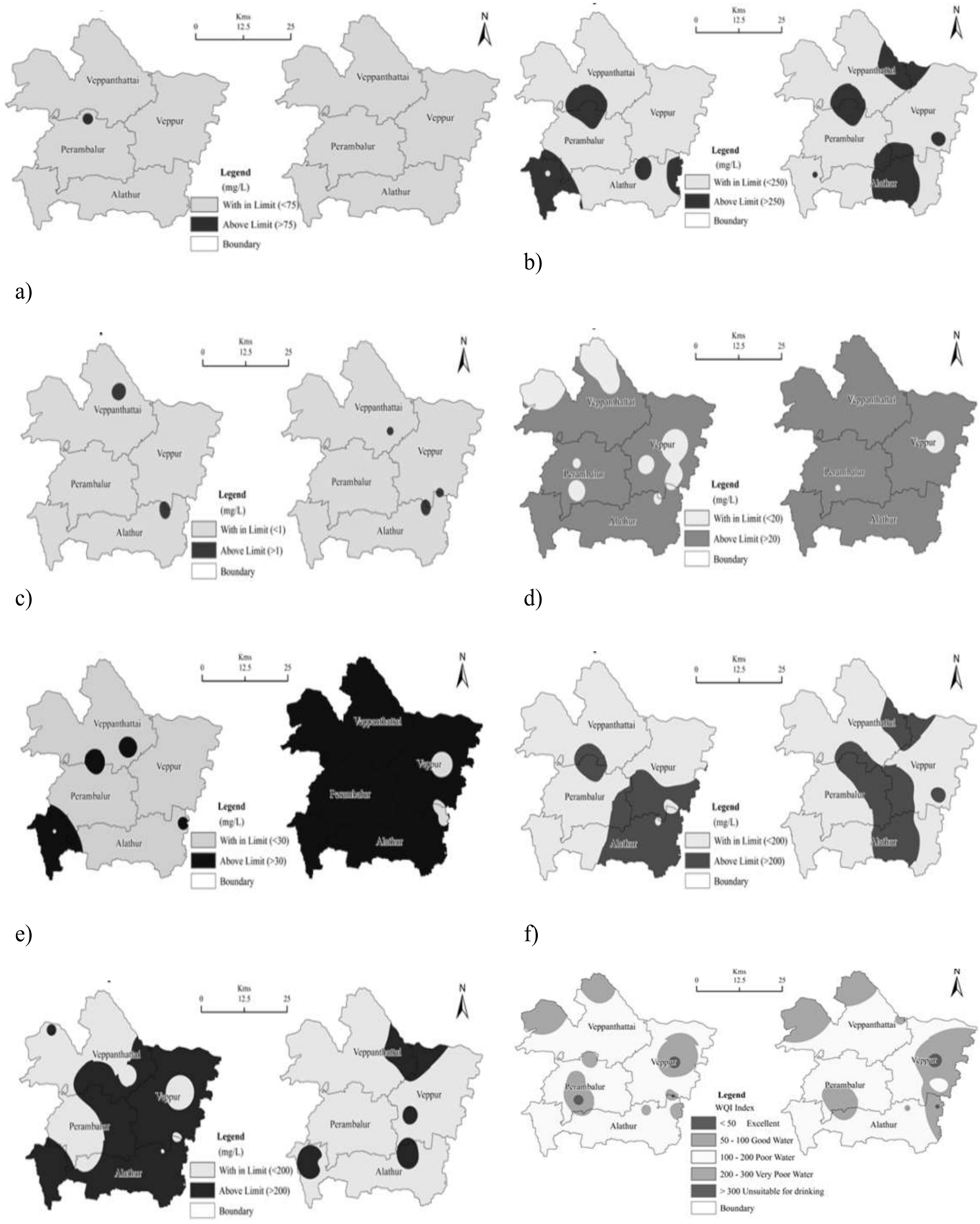

Fig. 2. Spatial distribution map of water quality parameters a) Calcium, b) Chloride, c) Fluoride, d) Potassium e) Magnesium f) Sodium g) Sulfate h) WQI

monsoon) and 84 percent (post-monsoon). The excess amount of potassium is present in the groundwater is due to the high use of potassium fertilizer in the agriculture field leads to percolates into the groundwater (Augustine and Anitha Pius 2018).

Magnesium: The mean values of magnesium for pre-monsoon was 73 mg L^{-1} and in post-monsoon 58 mg L^{-1} (Fig. 3e). The magnesium values are range from 24.3 to 167.67 mg L^{-1} for pre-monsoon and 21.8 to 98.42 mg L^{-1} for the post-monsoon season. Magnesium value indicates that 84 percent of samples are above the desirable limit in both monsoon seasons during the study period. The spatial map shows that except for small patch in the northern and eastern parts all other areas are beyond the limit prescribed.

Sodium: Sodium value during the pre-monsoon season varied from 12 to 621 mg L^{-1} with a mean of 183.58 mg $L^{-1}$and in post-monsoon season 24 to 495 mg L^{-1} with mean value of 166.32 mg L^{-1} (Fig. 3f). The 32 percent of groundwater samples are above the desirable limit during the study period. Excess intake of sodium content in water to humans causes hypertension, kidney and nervous disorders (Subba Rao et al 2012).

pH: During 2018, the pH ranged from 8.1 to 8.6 and 7.7 to 8.3 in pre and post-monsoon season respectively. Among the samples, 89 percent of samples observed in pre and 100 percent in post-monsoon season are under the desirable limit for the period of study. The permissible level of pH in groundwater is 6.5-8.5 (WHO 2011). Only two samples in pre-monsoon are exceeded the desirable limit found in the villages of Periyar in Vepanthattai taluk and Kilmattur village of Kunnam taluk.

Sulfate: The sulfate in the pre-monsoon period varied from 24 to 864 mg L^{-1} with a mean of 254.58 mg L^{-1} and for the post-monsoon season, the values are 29 to 600 mgL^{-1} with a mean value of 156 mg L^{-1}. In the pre-monsoon period, 9 wells are under the desirable range, which is shown in the northwestern part and 10 wells have exceeded the desirable range, which is noted in the southeastern and northeastern part of the area (Fig. 3g). During the post-monsoon season, 15 (78.95%) wells were in the south-western and south-eastern part of the area indicate the desirable range, while the 4 wells such as the villages of ChittaliNakkaselam, Kottarai of Kunnam taluk and Peraiyur village of Veppanthattai taluk were above the desirable range.

Total dissolved solids: The TDS values present in the groundwater ranged from 226 to 2697 mg L^{-1} (pre monsoon) and 276 to 1925 mg L^{-1} (post-monsoon season). Only 3 (16%) wells are in the desirable range found in Perambalur and Kunnam villages, the remaining 16 (84%) wells were above the desirable range and spatially distributed almost the entire study area. But during post-monsoon season, 5 (26%) wells are under the desirable range and 14 (74%) wells fall above the desirable limit during the study period. Selvam et al (2013) studied that the excess presence of TDS is due to salts having a high connection with the subsurface lithology and much time in contact with the aquifer body.

Table 3. Domestic water quality index-Perambalur District-2018

WQI classification	Categories	Pre-monsoon (sq.km)	Post-monsoon (sq.km)
< 50	Excellent	17.36	14.711
50 - 100	Good water	359.10	532.69
100 - 200	Poor water	1345.00	1203.42
200 - 300	Very poor water	36.54	7.4
> 300	Unfit for drinking	-	-

Total hardness: The TH ranged from 150 to 840 mg L^{-1} with a mean of 405.7 mg L^{-1} in the pre and post-monsoon period total hardness value between 125 and 510 mgL^{-1} and an average of 325.79 mg L^{-1}. About 3 villages namely Kilumattur, Peraiyur and Vellore are in the desirable range and 16 wells (84.21%) are above the desirable during the pre-monsoon period. During post-monsoon, 4 wells are within the desired range and the remaining 16 wells (84.21%) which are widely found in the district exceed the desirable limit.

Water quality index: Water quality indexes were categorized as excellent, good, poor, very poor and unfit for drinking. WQI values in the district indicate that 1382 sq.km of the study area falls under the poor quality of drinking water during pre-monsoon season mainly distributed in the entire district except in the northwestern part. But in the post-monsoon season, 1211 sq.km is under poor quality mostly spread in the central part of Perambalur (Table 3). Poor and very poor water is dominantly present in the study period over the study area (Mohamed Ibraheem et al 2014). Only 376 and 547 sq.km are under good water for drinking purposes (Fig. 3h).

CONCLUSION

Domestic groundwater quality index was identified using Bureau of Indian Standards (IBS) considering ten chemical parameters such as TDS, Ca^{2+}, Mg^{2+}, Na^{+}, K^{+}, Cl, SO^{2}_{4}, F, pH and total hardness. The major factor for governing the groundwater chemistry in the Perambalur district is due to silicate weathering. The dominant cations namely Na^{+} and K^{+} are present in this area. The chemical ions are presented in the order of Na^{+}-K^{+}-Cl-SO^{2}_{4}> Na^{+}-K^{+}-HCO_3> Ca^{2+}-Mg^{2+}-HCO^{3}> Ca^{2+}-Mg^{2+}-Cl^{-}-SO^{2}_{4} indicates alkali exceeds alkaline earth and weak acids exceed strong acids in both pre-monsoon and post-monsoon seasons. The majority of groundwater samples contain chemical parameters such as total hardness, TDS, SO^2_4 and Mg^{2+} are exceed the permissible limit as prescribed by BIS. WQI portrays that majority of index values fall under drinking waterquality character poorly. It is necessary to advise the people about water purification while taking groundwater for drinking purposes in the Perambalur district.

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Morphometric Analysis of Bhesra Kalan Micro-watershed using Remote Sensing and GIS Technique

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Abstract: The present study has been carried out to analyse morphometric characteristics of Bhesra Kalan micro-watershed of Udaipur (Rajasthan) by using remote sensing and GIS technique. The area of the micro-watershed is 1060 ha. Bhuvan DEM data of 30 m spatial resolution and topographical maps have been utilised to analyse stream network and determine geomorphological parameters (linear, areal and relief aspects) using in the GIS environment. The drainage network of the research area came out to be dendritic and the 4th order stream observed as trunk order. The bifurcation ratio (3.24) indicates an undistorted drainage network and low structural disturbance in area. Form factor (0.227), elongation ratio (0.538) and circulatory ratio (0.276) shows elongated shape of watershed. Drainage density (2.626 km km^{-2}) implies permeable sub-surface material with sparse vegetation, mountainousrelief and coarse drainage. The value of constant of channel maintenance (0.381 km^{2}km^{-1}) shows steep slope, high surface runoff and low permeability in the watershed. The low value of relief ratio (0.052) characterises less resistant rocks in area. The ruggedness number (0.922) indicates the steep slope of the watershed. The findings of this study provide complete information about the watershed's geomorphological characteristics, which may help in watershed planning and management and explore groundwater potential.

Keywords: Morphometric characteristics, Micro-watershed, Remote sensing, GIS, Watershed planning

Morphometric analysis of streams is a vital factor for watershed characterisation (Chandniha and Kansal 2017). It is a quantitative method of defining drainage features and conveys key data about the watershed's topography, runoff, hydrogeological attributes of rock layers and geological conditions (Umrikar 2017). Geomorphic assessment of watershed is generally utilised for developing regional hydrological models to solve various watershed related problems when there is the unavailability of accessible database (Gajbhiye et al 2014). The viable management of watershed resources should be necessary objective for future strategic planning and management (Gautam and Awasthi 2020). The physical and hydrological conditions and morphometric parameters decide the reaction of a specific watershed to various hydrological processes and their behaviour (Bansode and Ajabe 2018). Geomorphic analysis of a watershed can be well understood by its drainage pattern, aerial and relief aspects, and slope of the region (Nag and Chakraborty 2003). The different geomorphological parameters including linear aspects (stream order, stream number, stream length, bifurcation ratio), areal aspects (form factor, basin shape factor, circulatory ratio, elongation ratio, drainage density, stream frequency) and relief aspects (maximum relief, relative relief, relief ratio, ruggedness number) need to be measured for morphometric analysis of watershed (Shaikh and Birajdar 2015). The geomorphological analysis of watershed using traditional methods is labour intensive, inconvenient and time-consuming (Bera et al 2018). Remote sensing and GIS (Geographical Information System) are widely acknowledged as effective geospatial tools for creating drainage maps and determining the morphometric characteristics ofwatersheds (Singhand Urmila 2012). There are several researchers and scientists who performed morphometric analysis of watershed using remote sensing and GIS (Dhabale et al 2014, Asode et al 2016, Kumar et al 2017, Rai et al 2017, Savita et al 2017, Asfaw and Workineh 2019, Siddi Raju et al 2020 and Singh et al 2020). In the present research, an attempt is made to understand the morphometric characteristics of the Bhesra Kalan micro-watershed of Udaipur (Rajasthan) using remote sensing and GIS.

MATERIAL AND METHODS

Study area: Bhesra Kalan micro-water lies in Girwa Tehsil of Udaipur district of Rajasthan, India and covers 1060 ha area and lies between 24°37'33'' N to 24°39'48'' N latitude and 73°45'20'' E to 73°48'28'' Elongitude. The watershed area covered under toposheet no. G43T14 (Fig. 1). The mean annual rainfall of the area is 662 mm. The watershed falls in the agro-climatic zone- IVA of Rajasthan, i.e. Sub-humid southern plains of Aravalli hills. The study area comprises moderately dissected hills and valleys, low dissected hills and valleys, pediment pediplain complex, water bodies and others. The maximum and minimum elevations above sea level are 865 m and 511 m, respectively.

Data and Software used: The data and software used to evaluate the geomorphological characteristics are represented in Table 1.

Morphometric analysis: Morphometric analysis is the systematic representation of watershed's geometry and its stream channel system to determine(I) Linear aspects of drainage network (stream order, stream number, bifurcation ratio, stream length, stream length ratio) (II) Areal aspects of watershed (form factor, basin shape factor, circulatory ratio, elongation ratio, drainage density, stream frequency, constant of channel maintenance) and (III) Relief aspects of channel network (maximum relief, relative relief, relief ratio, ruggedness number). The geomorphological parameters can be determined using DEM data as a base layer and by applying suitable operations given in the ArcMap toolbar.

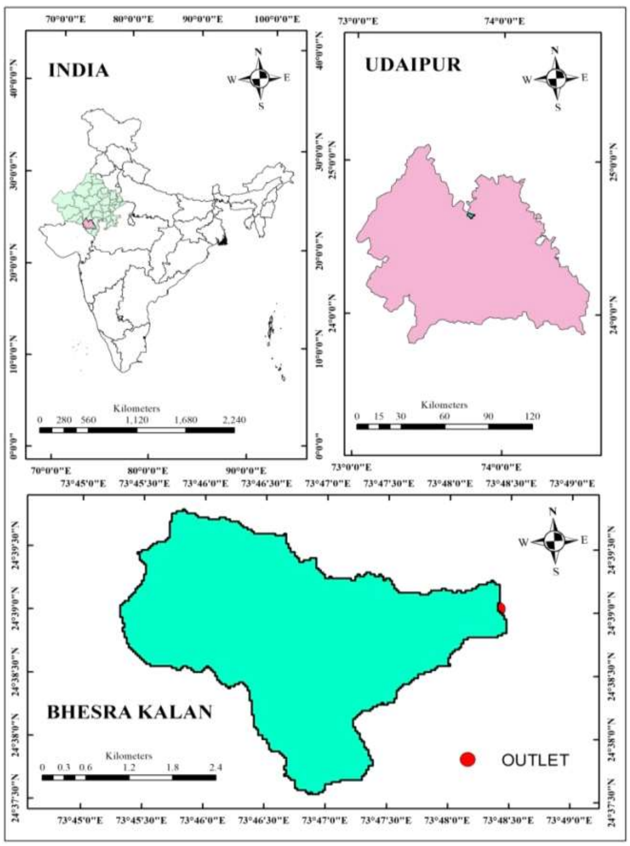

Fig. 1. Study area

Determination geomorphological characteristics: The geomorphological parameters can be determined by using DEM data as a base layer and by applying suitable operations given in the ArcMap toolbar as tools > spatial analyst tools > hydrology. The flowchart as shown in Figure 2 shows the procedures to obtain different morphometric aspects of watershed.

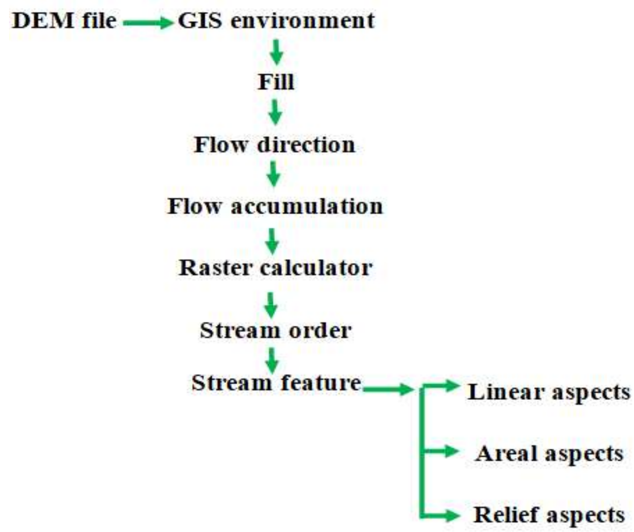

Fig. 2. Flowchart of procedure of determining geomorphological parameters

RESULTS AND DISCUSSION

After delineating the watershed, a drainage mapwas generated by applying operations from the hydrology tool available in the software toolbar (Fig. 3). The output drainage map of the study area hasdifferent stream orders (Fig. 4). Based on the measurements from the digitized drainage patterns and watershed boundary, the values of different geomorphological parameters of the watershed were calculated according to the formulas mentioned in (Table 2). The evaluated values of geomorphological characteristics are shown in Table 3.

Stream analysis: Stream analysis consists of grouping

Table 1. Software and data acquisition

Software used	Use	
ArcGIS 10.1	To delineate and determine geomorphological characteristics of the area under research.	
Data acquisition	Description	Source
Maps	Toposheet (1:50,000 scale)	Survey of India (SOI)
Remote sensing data	DEM (Digital Elevation Model)	bhuvan.nrsc.gov.in

stream segments in different orders (1st to 4th order), measuring stream lengths (14.147 km, 7.293 km, 6.191 km and 0.212 km), calculating cumulative stream length (27.843 km) and calculating mean stream lengths (0.488 km, 0.810 km, 3.096 km and 0.212 km).

Relationship between stream number/cumulative stream length and stream order/stream number: The correlation coefficient for the straight-line fit between the logarithm of stream number (ordinate) and stream order (abscissa) for the study area comes out to be 0.98, which is quite satisfactory (Fig. 5). The same kind of graph was plotted between the logarithm of cumulative stream length (ordinate) and stream order (abscissa) for verifying Horton's law (Fig. 6). It came out to be a straight line of fit with a satisfactory correlation coefficient of 0.86, which was entirely satisfactory.

Linear aspects of drainage network: The linear aspects include stream order, stream number, stream length, bifurcation ratio and stream length ratio. The study revealed that the watershed is of 4th order type with a dendrite drainage pattern (Singh 2005, Singh et al 2019). The stream numbers for the stream order 1st, 2nd, 3rd and 4th were 29, 9, 2 and 1, respectively and their corresponding stream length was

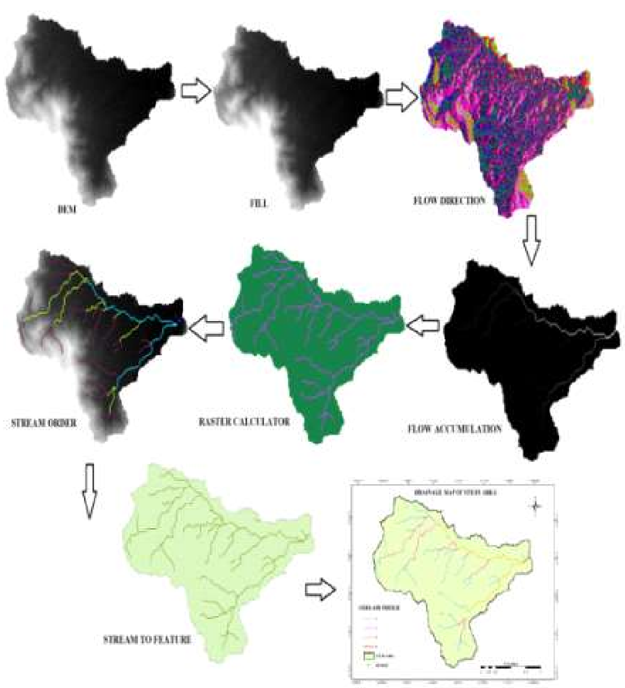

Fig. 3. Procedure of generating drainage map

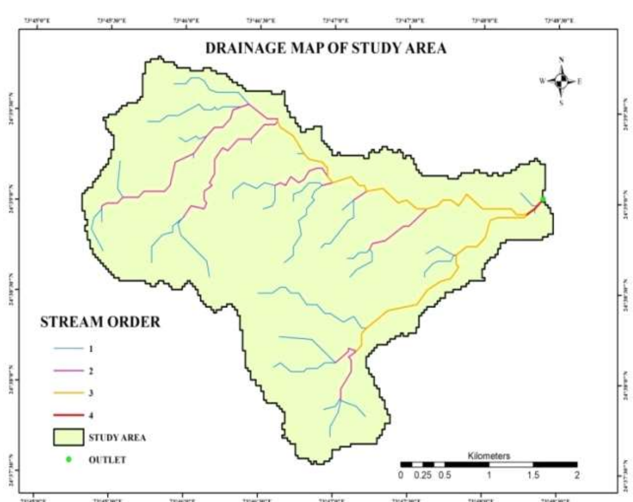

Fig. 4. Drainage map of the study area

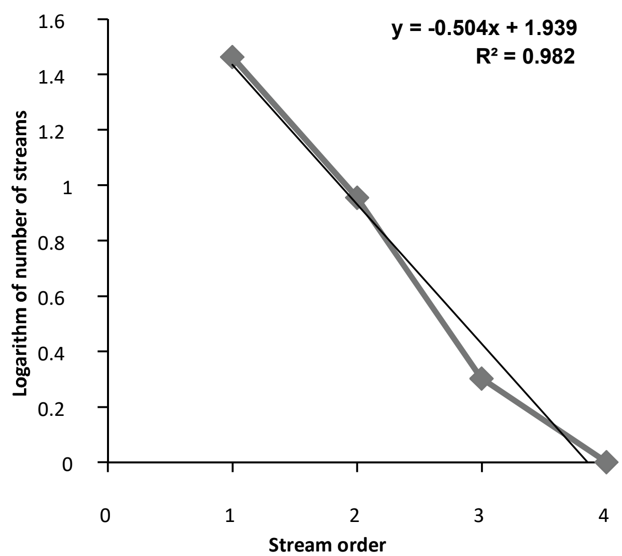

Fig. 5. Regression of logarithm of stream number and stream order

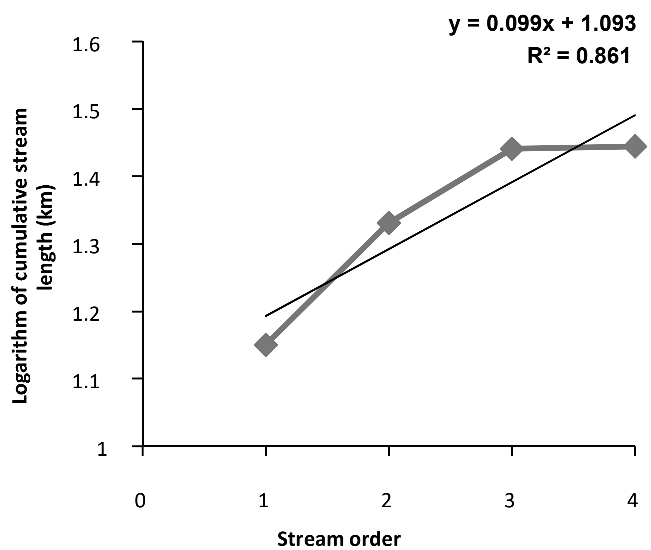

Fig. 6. Regression of logarithm of cumulative stream length and stream order

14.147, 7.293, 6.191 and 0.212 km, respectively. The bifurcation ratio (R_b) for the Bhesra Kalan micro-watershed was in the range of 2.00 to 4.50 with an average of 3.24 and this low value shows that the watershed is less affected by the structural disturbance and the drainage pattern has not been distorted (Nag and Chakraborty 2003). The elongated basins have low R_b, while the circular basins have higher R_b values, which show that the area under study is elongated. The average value of stream length ratio (R_L) for the watershed evaluated as 1.850. R_L value between the successive stream orders of the watershed varies cause of differences in slope and topographic conditions (Singh 2005). The stream length ratio has an important relationship with the basin's surface flow discharge and erosional stage (Dahiphale 2014).

Areal aspects of watershed: The areal aspects include form factor, basin shape factor, circulatory ratio, elongation ratio, drainage density, stream frequency and constant of channel maintenance. The form factor value estimated as 0.227 indicates the shape of the watershed to be elongated and hence, a flat peak flow for a longer duration can be obtained in the watershed. Flood flow of elongated basins is much easier to manage in comparison to circular basins. The

Table 2. Calculation of geomorphological parameters.

Morphometric parameter	Formula	Reference
Stream order and stream number	Hierarchical order	Strahler (1964)
Bifurcation ratio	$R_b = N_u/N_{u+1}$	Schumm (1956)
Mean stream length	$\bar{L}_u = \bar{L}_u/N_u$	Strahler (1964)
Stream length ratio	$R_L = \bar{L}_u/\bar{L}_u\text{-}1$	Horton (1945)
Form factor	$R_f = A/L^2_b$	Horton (1945)
Basin shape factor	$B_s = L^2_b/A$	Horton (1945)
Circulatory ratio	$R_c = 4\pi A/P^2$	Miller (1953)
Elongation ratio	$R_e = 2\sqrt{(A/\pi)}/L_b$	Schumm (1956)
Drainage density	$D_d = \Sigma L_u/A$	Horton (1932)
Stream frequency	$Fs = \Sigma N_u/A$	Horton (1932)
Constant of channel maintenance	$C = 1/D_d$	Schumm (1956)
Maximum watershed relief	$H = Z - z$	Strahler (1957)
Relative relief	$R_R = (H/P) * 100$	Melton (1957)
Relief ratio	$R_r = H/L_b$	Schumm (1956)
Ruggedness number	$R_N = H * D_d$	Strahler (1958)
Time of concentration	$TC = 0.0195\ L^{0.77}\ S^{-0.385}$	

Where, N_u= total no. of streams of order u, N_{u+1}= total number of streams of next higher order, Lu= length of stream of order u, $\bar{L}u$ = mean stream length of order u, $\bar{L}u_{-1}$ = stream length of its next lower order, A= area of watershed, L_b= maximum basin length, P= perimeter of watershed, $\sum L_u$= total length of streams of all orders, $\sum N_u$= total number of streams of all orders, D_d= drainage density, Z= maximum watershed relief, z= minimum watershed relief, H= maximum watershed relief, L= Length of channel reach, S= Average slope of the channel reach

Table 3. Evaluated morphometric parameters of watershed

Parameters	Calculated value
Linear aspects	
Area	10.60 km^2
Perimeter	21.95 km
No. of stream order (N_u)	
I	29
II	9
III	2
IV	1
Stream length (L_u)	
I	14.147 km
II	7.293 km
III	6.191 km
IV	0.212 km
Bifurcation ratio (R_b)	
R_{b1}	3.22
R_{b2}	4.50
R_{b3}	2.00
Average	3.24
Average stream length	
I	0.488 km
II	0.810 km
III	3.096 km
IV	0.212 km
Stream length ratio (R_L)	
R_{L1}	1.661
R_{L2}	3.820
R_{L3}	0.068
Average	1.850
Areal aspects	
Form factor (R_f)	0.227
Basin shape factor (B_s)	4.397
Circulatory ratio (R_c)	0.276
Elongation ratio (R_e)	0.538
Drainage density (D_d)	2.626 $kmkm^{-2}$
Stream frequency (F_s)	3.867 km^{-2}
Constant of channel maintenance (C)	0.381 km^2km^{-1}
Relief aspects	
Maximum watershed relief (H)	354 m
Relative relief (R_R)	1.612%
Relief ratio (R_r)	0.052
Ruggedness number (R_N)	0.922
Time of concentration (T_c)	63.32 min

calculated value of basin shape factor for the study area was 4.397, showing the elongated watershed. The runoff discharge in an elongated basin is less efficient than a circular basin (Singh et al 2021).

The circulatory ratio (R_c) value ranges from 0 to 1, in which ratio value approaching 1 shows circular shape while value approaching 0 shows elongated watershed. The ratio is more influenced by the stream length and stream frequency than slope and drainage pattern. The value of Rc for the watershed came out to be 0.276, which refers to the elongated shape of the watershed. The elongation ratio (R_e), according to its values, is categorised as circular (0.9-1.0), oval (0.8-0.9), less elongated (0.5-0.7) and more elongated (<0.5) by Strahler (1964). Strahler (1968) showed that the R_e value when approaches to 1 indicated very low relief and when value is in the range of 0.5 to 0.8, the area has strong relief and steep ground slope. The value of R_e estimated as 0.538 enable the watershed to fall in a less elongated category with strong relief and steep slope.

Drainage density is a measure of how well or poorly a watershed is drained by stream channels. A low drainage density value indicates a relatively low density of streams and thus slow response (Srivalli and Singh 2017). The low drainage density (D_d = 2.626 kmkm^{-2}) indicated that the area had permeable sub surface material with sparse vegetation, mountainous relief and coarse drainage (generally shows when value is less than 5.0).The value of stream frequency (F_s = 3.867 km^{-1}) showed that the watershed had moderately resistant sub-surface material with low infiltration and moderate runoff. The value of constant of channel maintenance (C) came out to be 0.381 km^{2}km^{-1}, which was quite low indicated area having steep slope, high surface runoff and low permeability.

Relief aspects of channel network: The relief aspects include maximum watershed relief, relief ratio, relative relief and ruggedness number. The maximum watershed relief was 354 m. The relative relief is the ratio of maximum watershed relief to the perimeter of the watershed (1.612 %).The relief ratio is estimated as 0.052. The low value of relief ratio is the characteristic feature of less resistant rocks of the area (Singh et al 2021). Ruggedness number (R_N) is a dimensionless term indicating structural complexity of the terrain. It is a measure of surface unevenness (Selvan et al 2011, Singh et al 2018). The R_N value of 0.922 for the study area show the steep slope of watershed. The time of concentration for the present study area computed as 63.32 min, which shows some barriers in the flow path and runoff takes less time in reaching the outlet from the remotest point. The morphometric analysis of the study area shows that the watershed is of elongated shape with a steep slope.

CONCLUSIONS:

The morphometric analysis of Bhesra Kalan micro-watershed was carried out to determine the watershed's linear, areal and relief aspects using Arc GIS 10.1 software. The drainage pattern of the watershed was observed as dendritic with 4th order stream as trunk order. The linear relationship between the logarithm of stream number and stream order and logarithm of cumulative stream length and stream order verified their conformity with Horton's laws (1945) with a satisfactory correlation coefficient. The low value of the bifurcation ratio showed less structural disturbance and undistorted drainage pattern in the study area. The form factor value reflected a flat peak flow for longer duration in the watershed. A comparatively higher elongation ratio than the circulatory ratio implied elongated shape of the watershed. A low drainage density indicated that the area had permeable subsurface material with sparse vegetation. The maximum watershed relief was 354 m. The relief ratio and ruggedness number showed the availability of less resistant rocks and steep slopes in the watershed. The present morphometric analysis of the study area indicates the elongated shape of the watershed with steep slopes. This study may assist the local policymakers and authorities for sustainable watershed management as well as augmenting the groundwater potential in the sub-humid to semi-arid regions.

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Applications of Geospatial Technologies in Land Capability Classification of a Macro Watershed

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Abstract: This study deals with the estimation of the land capability and generation of different classes on Chevella watershed area, Ranga Reddy dist., Telangana state. The land capability was estimated with the land capability classification technique where the land is classified into 8 classes based on the characteristics associated with each of the class on certain parameters that affect the soil and the water as well, which are the two most important factors of the cultivation. The classes of land capability are broadly classified into 2 i.e., cultivable and non-cultivable. Based on the land capability, the land resource development Plan was generated which give the in-site of the crops and the precautions that need to be grown in the region which was compared to 3 classes. This land is suitable for occasional cultivation in rotation with hay or pasture, or orchards protected by permanent cover crops. Special precautions suggested in accordance to IS Code for conservation of rainfall to utilize for irrigation, conversion of land to pasture or grazing lands the regions.

Keywords: Land capabilitym, Macro watershed, Capability, Cultivation, Mobile mapping, GIS platform

The soil and water conservation method are all recommended based on the capability of the land and enlists the natural limitations of the soil and water. The land capability is important to estimate because of the increasing growth of the population (Singh 2000). As its increase will lead to more pressure on the land thus, making the optimum utilization of the land (Gangopadhyay et al 2010). Therefore, being present at the field or the location at which the capability is to be estimated becomes time consuming and tedious process (Mohan et al 2007). To estimate the Land capability potential index, one needs to integrate hydrology, hydraulics, land-surface elevations, and soil permeability (Singer 2020). The index integrates the above-mentioned fundamental factors that determine suitability of land for different kinds of utilization and provide a useful mechanism to guide land-management decisions (Jacobson et al 2007). In order to get better results at a finer resolution the technique used by Tideman (2007), Solanki and Bishnoi (1995) the Land capability is categorized into 8 classes and estimating the capability will be used. These 8 classes are broadly classified into 2 and each one of them is assigned a specific colour (Kumar et al 2019). LUCC is made on the capability of land for agricultural production on permanent basis, under specified management practices to sustain the productivity (Prince et al 2009). According to this definition two considerations are made in suggesting LUCC, one is agricultural production from land and the other is negative weightage are considered as natural hazards (Sujatha et al 2019). The present study is carried out for determining the procedure for automatic generation of the land capability maps from the various thematic maps and collateral information. Therefore, to achieve the desired land capability map, the study has been carried out with objectives to know the land capability classification alongside the slope, erosion, and depth of Chevella macro watershed area and creating land capability classification model to show the land capable for cultivation and to prepare land resource development plan of the area based on land capability.

MATERIAL AND METHODS

Study area: The study was conducted on a Macro watershed, Chevella Block, Ranga Reddy District Telangana state. The area lies in between 17.3067°N Latitude and 78.1353°E Longitude (Fig. 1). The macro watershed has area of about 5836 hectares, the inhabited villages are 36. This macro watershed has 525 cultivators, 210 agricultural labourers, 15 household industry workers and 100 other workers (Census 2011). The major crops that are cultivated in this region are cotton & green gram, vegetables, red gram. This region has gone through a change in the type of crops that are grown due to the change in weather conditions of the regions. The terrain is undulating. These undulations are barren with some shrubs here and there on them. The groundwater level is very low at 200 to 500 feet whereas the wells are dry from the past 2 years. Moreover, the fluoride content in the soil has also increased over the period. This village is also a part of Integrated Watershed Management Project - IWMP launched by the Telangana Government for the restoration of all the check dams and streams that are present in the region. Under this mission the water of all the identified check dams will be used for irrigation in the area surrounding it.

Land capability classification map: Land capability classification map was made considering the basic 4 parameters and other local limitations that effects the land capability were also considered and based on the combination of the characteristics of each parameter the respective land capability class was given. The division of the parameters are denoted with a particular symbol which represents a specific characteristic (Table 1).

Classification of land capability: Each of these classes has specific characteristics associated with them and there are four factors that are considered for the estimation of Land capability each with a defined symbol. They are mainly slope, soil texture, erosion and soil depth. The first step of capability classification is the estimation of mapping units and to the grouping of one or more than one individual soil mapping units which have same potentials. The equation of mapping units is given by:

(Soil series – texture of soil – soil depth) / (Land slope – erosion)

Mapping units are needed as the units and the values for each of the factors is considered in the estimation of land capability is different and cannot be considered without normalizing the data of the factors.

Soil depth: Soil depth influences the crop that is grown, crop yield and the amount of soil water. The data for soil depth was obtained from the field with the help of the local people through Participatory Rural Appraisal (PRA) for different point locations and then this point data was interpolated for the complete area. The depth of the soil was classified according to the land capability class where it ranges from more than 90 cm to less than 7.5 cm (Table 2).

Soil texture: The data for the soil texture was obtained from the Mandal Agricultural office from the soil health cards for the region which were then checked with through PRA and the soil texture map for the region was generated. The texture of the soil was classified based on the land capability class (Table 3).

Slope: To find the slope of the area used the contours at the interval of 5 m to generate the DEM i.e., Digital Elevation Model and then the slope of the study area was estimated. The slope of the area was also classified based on the specific characteristics associated with each land capability class (Table 4).

Erosion: The information of the erosion was collected on the field with the help of local people through PRA and the official who were working in the area. The degree of erosion was also classified based on the land capability classification class (Table 5). First, watershed shape file was collected and then later in QGIS grids/centroids points were created before going to the field. Collection of data in PRA (Public Rural

Table 1. Land capability class

Broad class	Class	Colour
Land fit for cultivation	I	Light colour
	II	Yellow
	III	Red
	IV	Blue
Land Not suitable for cultivation	V	Dark green
	VI	Orange
	VII	Brown
	VIII	Purple

Table 2. Soil depth class after E.M Tide man, 1996

Soil depth (cm)	Class symbols	Description	Land capability class
>90	d5	Very deep	I
45 – 90	d4	Deep	II
22.5 - 45	d3	Moderately deep	III
7.5 – 22.5	d2	shallow	IV
< 7.5	d1	Very shallow	VI, VII

Table 3. Soil texture

Texture class	Symbol
Land capability class I	
Sandy loam	Sl
Clay loam sandy	L
Clay loam silt	Cl
Silty loam	SCL
Clay loam	Si sil sicl
Land capability class II	
Silty clay	Sic
Sandy clay	Sc
Clay	C
Land capability class III	
Loamy sand Clay	ls c
Land capability class IV	
Sand	s

Appraisal) with help of ODK was done. Interpolation and IDW was done using QGIS. Raster layers of texture, depth and erosion were created and then the SRTM – DEM was downloaded from Bhuvan website on which slope and all raster files were converted into vector and finally smooth layering was done in GRSS 7.2.2. That smooth vector layers were classified as per the land capability class wise and prepared layout for map of each layer therefore, the final class of Land Capability Class was made. For intersection we used formula of map unit:

Mapping unit: soil texture – soil depth / Land slope – soil erosion

Software: ArcGIS, Earth Explorer, QGIS (Quantum GIS), GRASS 7.2.2 (Geographic Resource Analysis Support System) ODK (Open Data Kit).

Table 4. Slope class

Slope class	Slope range (%)	Description	Land capability class
A	0 -1	Nearly Level	I
B	0 -3	Very Gently sloping	II
C, D	3 - 5 5 - 10	Gently sloping Moderately sloping	III
E, F	10 -15 15 -25	Strongly sloping Moderately steep to steep	IV
G	25 -33	Steep	VI
H	33 -50	Very steep	VII
I	Over 50	Very very steep	VIII

Table 5. Erosion class

Erosion class symbol	Description (degree of erosion)	Land capability class
E1	Up to 25% A horizon is lost	I
E2	Up to 25% A horizon is lost	II
E3	50 -75% A horizon is lost	III
E4	A horizon is lost and B horizon is exposed	IV
E5	25-75% B horizon is lost	V
E6	25-75% B horizon is lost	VI

All the above-mentioned factors were considered and the mapping units of each of the class were estimated based on the following notation:

Texture of soil – soil depth / Land slope: Based on the mapping units the land was classified into different Land Capability Classes with reference to the Table 6. The capability class will be the highest number allotted to any of the parameters and the other local limitation will suffix the roman Land Capability Class no. Thus, the Capability of the land of the macro watershed region was estimated. The Land capability class no. V has the similar characteristics as that of land capability class I except for a few limitations of stoniness and wetness. The classes V and above have no mention about the soil texture as these classes fall under the non-cultivable land category.

RESULTS AND DISCUSSION

Land capability classification map: The soil depth of the region ranged from 0 to 121.9 centimeters as the region has undulating terrain. There was no soil on the hillocks with highest depth recorded near the areas surrounding the reservoirs. Soil depth modifies the rooting system of plants which reflects on crop growth and yield the amount of soil water. The soil depth of the region was classified into 4 Land Capability Classes based on the classification criteria mentioned above in the methodology. The color representing each of the class is the standard color assigned to them as mentioned in the literature review. The 4-soil depth land capability classes that were present in the region were I, II, III, and IV (Table 7). Class I is area covered with 214.46 Kms and its shows in the Class I with more than 90%, class II shows with 45 to 90%, Class III with 22.5 to 45 and Class IV with 22.5 to 7.5% (Fig. 2).

Soil texture: Soil textures are of great importance in the land use capability classification as it influences the water holding capacity, permeability, drainage, runoff etc**.** This region has only two different types of soil texture i.e., sandy clay loam

Table 6. Land capability parameters

Land capability classification	Soil depth	Soil texture	Slope range	Degree of erosion
I	>90	Sandy loam clay loam silty clay	0-1	Up A horizon is lost to 25%
II	45-90	Silty clay sandy clay clay	1-3	Up to A horizon is lost o 25%
III	22.5-45	Loam sand clay	3-5 5-10	50 -75% A horizon is lost
IV	7.5-22.5	Sand	10-15 15-25	A horizon is lost and B horizon is exposed
V	< 7.5	-	25-28	25-70% B Horizon Lost
VI	< 7.5	-	25-33	25 – 75% B horizon is lost
VII	< 7.5	-	33-50	25 – 75% B horizon is lost

and clay loam. Most of the area is covered with sand clay loam and the areas near the reservoirs have the clay loam (Table 8, Fig. 3).

Slope: This region has an undulating terrain because of which there is the variation in the soil depth. In the same way there is a lot of variation in the slope of the region of the watershed area. The slope of the region ranges from 0 to 40% with highest near the hillocks and minimum in the central region of the village. Soil and water losses from an area of the watershed are influenced by length and degree of slope. These factors influence the land capability classification. Accordingly various modified slope classes, arranges and description with suggested capability classes. The slope of the region was classified into 5 Land Capability Classes based on the classification criteria mentioned above in the methodology (Table 9, Fig. 4).

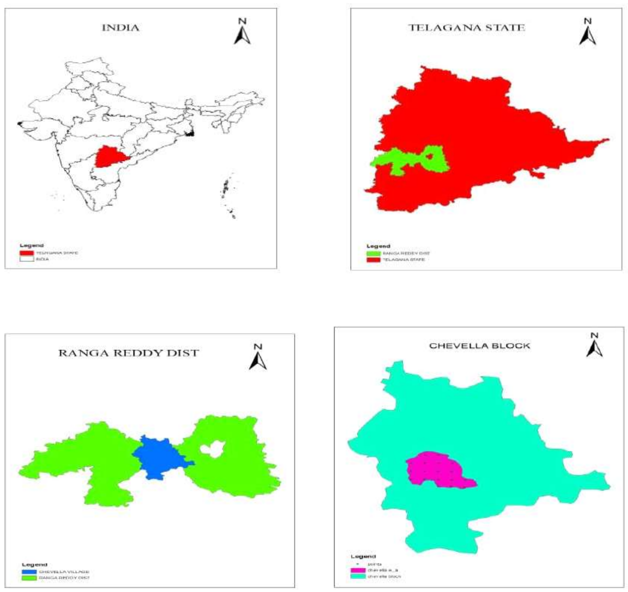

Fig. 1. Location map of study area

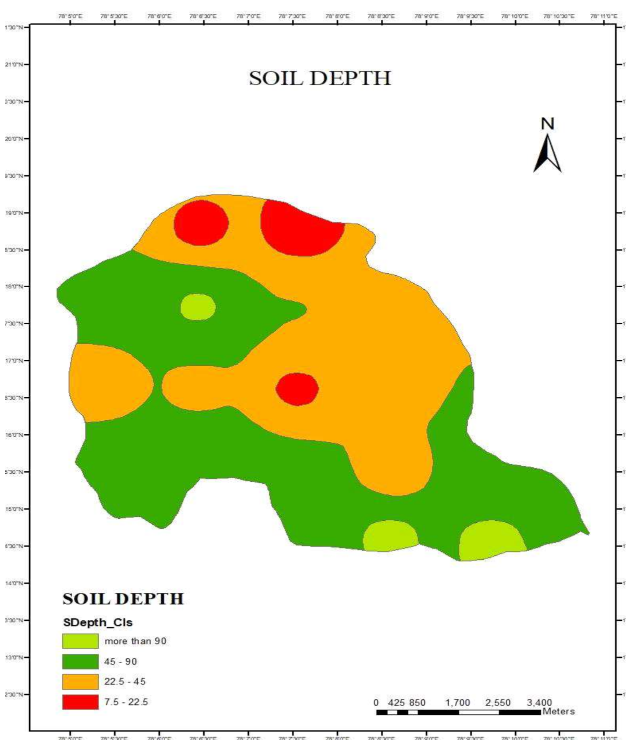

Fig. 2. Soil depth

Erosion: The erosion was estimated by visual interpretation of the region. But to decide, the other parameters like the slope and terrain conditions were decided after deciding the values based on above three parameters and it was shown as a suffix to each class. Based on the other above estimated parameters the mapping units were derived which is based on the equation mentioned in the methodology and the parameter with the highest Land Capability Class value is allotted to that region. Assessment of soil erosion is made by ocular estimate which to some extent depends on the experience and personal judgment. While it is easy to pinpoint the menace of erosion in case of a very specific situation (Fig. 5).

Land capability class: Based on the above estimated parameters the mapping units were derived which is based on the equation mentioned in the methodology and the parameters with the highest Land Capability Class value is allotted to that region (Table 11, Fig. 6).

Land capability mapping units: The study that was conducted gave the information about various conditions and

Table 7. Area under each soil depth class

Soil depth (cm)	Land capability class	Area (ha)
More than 90	I	214.46
45-90	II	3465.98
22.5 to 45	III	268884
7.5 to 22.5	IV	314.24

Table 8. Area under each soil texture class

Soil texture	Land capability class	Area (ha)
Sandy clay loam	I	5127.96
Loamy sand, clay	II	89.67
Silty clay, sandy clay	III	205.01

Table 9. Area under each slope class

Slope (I %)	Land capability class	Area (ha)
0-1	I	2473.97
1-3	II	2473.97
3-10	III	3835.63
10-25	IV	9.18
25-33	VI	4.32

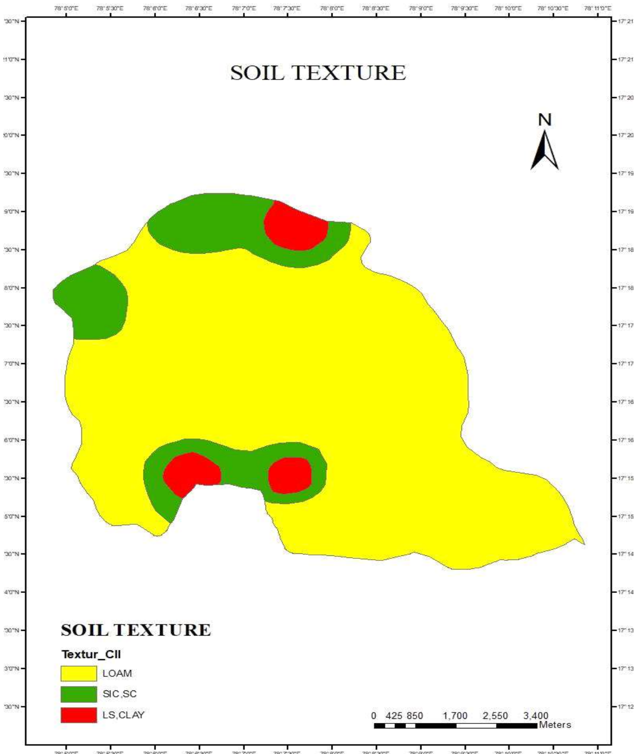

Fig. 3. Soil texture of Chevella block

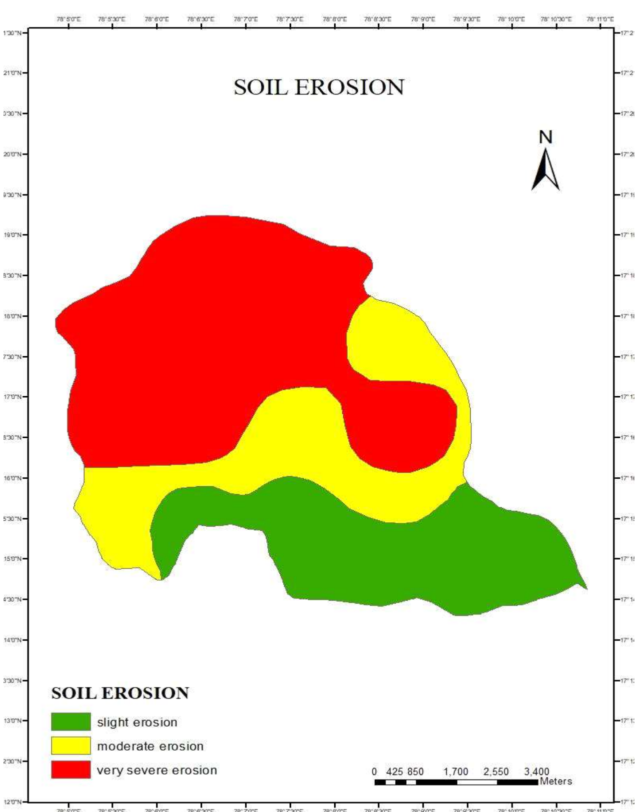

Fig. 5. Soil erosion of Chevella block

Table 10. Area under each erosion class

Land capability class	Area (ha)
Slight erosion	1671.26
Moderate erosion	1564.02
Severe erosion	3083.51
Very severe erosion	129.60

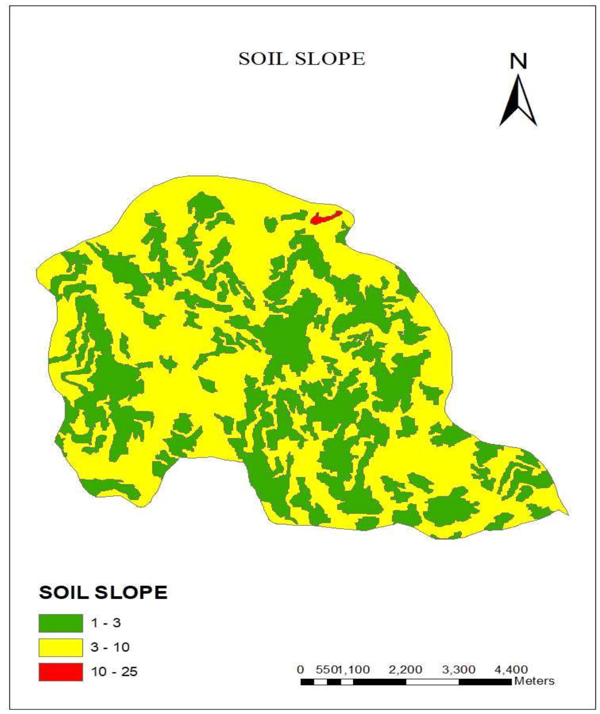

Fig. 4. Soil slope of Chevella block

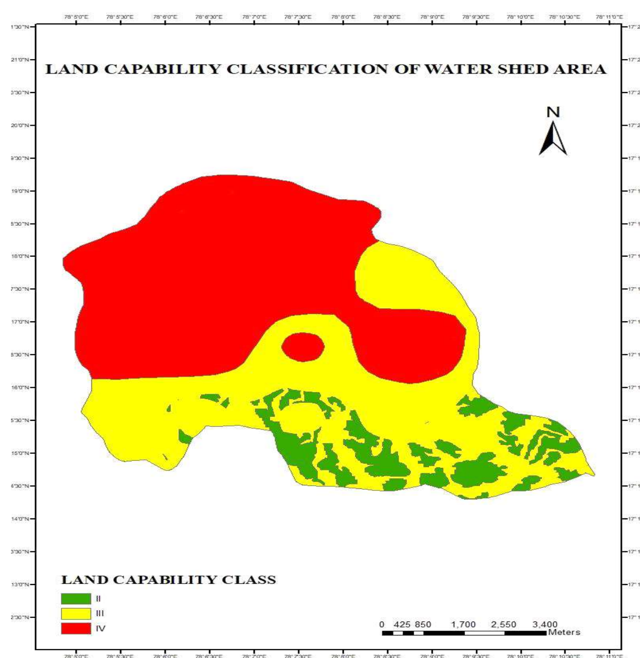

Fig. 6. Land capability classification of watershed area of Chevella block

the kind of problems associated with the agricultural practices that are prevailing in the village. The observations are collected as required under item of the mapping units are built as below:

$$\text{Mapping units: } \frac{\text{Soil series-texture of top soil -effective soil depth}}{\text{Land slope-erosion hazard}}$$

These mapping units are derived following rating and delineated on survey map for land capability classification. Boundaries are marked to separate areas belonging to different mapping units.

$$\text{Mapping units: } \frac{\text{KT} - \text{c} - \text{d5}}{\text{B} \quad \text{e1}}$$

KT – soil series, c – clay (texture) , d5 – soil depth more than 90cm , B – 1-3% land slope, e1 – sheet erosion

This study had certain elements or techniques that were included in the study for the better results and approach towards the work. They are as follows:

Table 11. Area under each land capability class

Land capability class	Area (ha)
II	596.13558
III	2510.41632
IV	3014.92911

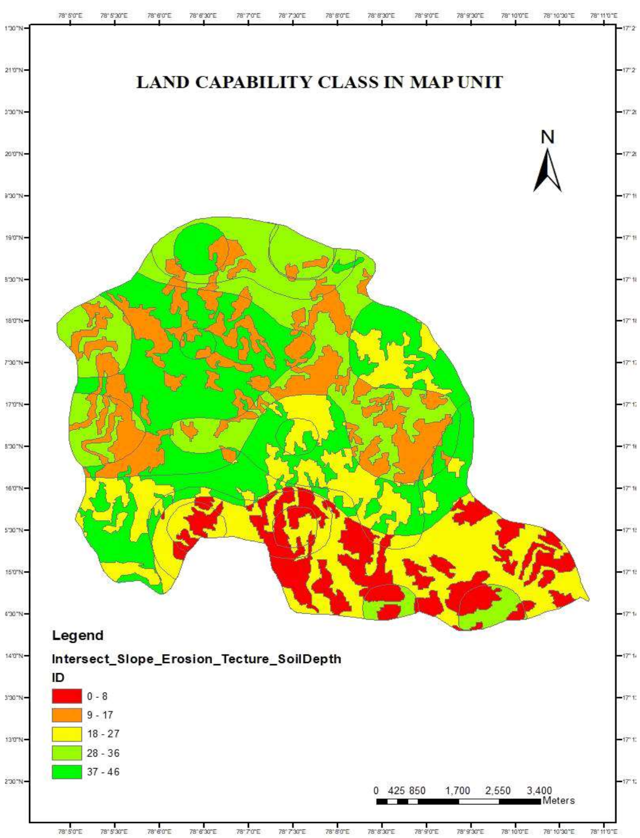

Fig. 7. Land capability class in map unit of Chevella Block

1. The information that was gathered at the village level for few parameters were done through PRA i.e., Public Rural Appraisal. It acted as a major tool for information at this micro level. The information that was obtained had fair better results than the interpolation techniques. As 100% area sampling cannot be done as there is limitation of samples and interpolation techniques fail in some cases because the soil and earth pattern changes abruptly. So, the PRA techniques was chosen to incorporate the public opinion and for mapping the area more appropriately.
2. This study if conducted at village level and done with proper techniques and analysis then it could be a very important tool for policy making and research purposes.
3. Data availability and time constrain for the collection of data lead to the consideration of only broad parameters and the other sub parameters could not be considered in detail.
4. Study done with more intensity, public interaction and actual analysis at sufficient grid distance could give perfect results.
5. Dissemination of the information: the information that has been collected or estimated at different level does not reach the grass root level but through the Web service all the information can be accessed at the ground level and this village has a computer center with a technician to assist the village from the government.
6. Frequent updating of the information at the village level would increase the efficiency of the process for future use and to maintain the land capability.
7. For better and enhanced study, the numerical weightage which gives precision to land class could be used specially in the Indian subcontinent.
8. Accuracy assessment: the accuracy assessment was not carried out for this study as the study area was remotely located and the revisit to the area in this time span was not feasible.

CONCLUSION

The results of this study clearly exhibit that due to many reasons that are prevailing in the environment the land is used more than its capability i.e., out of the total area 5836 hectares is over utilized. Thus, leading to increase in pressure on the land and with the increasing population growth the pressure would increase on them making land capability study more important. The 416 hectares of land if treated properly like the selection of crop and special attention at the time of seeding is given then this amount of land is good for agriculture. Whereas if the proper management of water, erosion, offset is taken care then 4643 hectares of land could be put to best use without damaging the land. This in turn help us in conservation of the soil and water. Thus, this technique is mainly used for the soil and water conservation as the parameters that are considered are mainly of the condition of the soil which is very important for agricultural practices. In the study area the projects like Integrated Watershed Management Programme (IWMP) have benefited the cultivable land in a great extent. They are not only conserving the water, but the fertility of the surrounding land increased by the transportation of the soil from the dried-up lake. The intersection of scientific knowledge with the public knowledge at the village level proved to be of good importance.

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Utility of Fishes as Bio-indicators for Tracing Metal Pollution in the Cochin Backwaters, Kerala, India

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Abstract: Trace metal (Fe, Ni, Zn, Cu, Pb, Cd and Cr) concentrations in water and tissues (flesh, gills and liver) of two fishes, *Etroplus suratensis* and *Arius arius* from the Cochin backwaters were investigated during February 2017 to January 2018. Trace metals were analysed using an Atomic Absorption Spectrophotometer (AAS). The omnivorous species, *E. suratensis* showed a higher concentration of trace metals in tissues than the carnivorous species, *A. arius*. Bioaccumulation of metals in fish tissues showed higher levels in the liver, which was followed by gill and flesh maybe due to the different physiological roles of these organs in fish metabolism. Bioaccumulation factors (BAF) of metals calculated for the species, *E. suratensis* follows an order Fe > Zn > Ni > Cu > Cr > Pb > Cd whereas that for the species, *A. arius* follows an another order Fe > Zn > Cr > Cu > Ni > Pb > Cd. Comparatively higher BAF values in organs of fishes indicate the increased concentration of the soluble metal in the medium in which the fishes inhabit. Metal selectivity index (MSI) and tissue selectivity index (TSI) are better tool for explaining bioaccumulation of trace metals in fishes. The results of the present study suggest the potential use of fishes, *E. suratensis* and *A. arius* as bioindicators for tracing metal pollution in the estuarine environment of Cochin.

Keywords: Trace metal, Bio-indicators, Fishes, Metal selectivity index, Tissue selectivity index, Cochin backwaters

Monitoring and analysis of trace metals in the environmental compartments of aquatic systems are necessary for pollution assessment and control (Elzwayie et al 2017). For a meaningful assessment of environmental impacts of metal pollution, measurement of metal concentrations in selected aquatic species of the resident biota in an ecosystem is necessary. Fishes are considered one of the most significant bio-indicators in aquatic systems to estimate metal pollution (Authman 2008, Al-Kahtani 2009). As fishes are located at the top of the aquatic food chains, the accumulated metals in their various tissues may pass to human beings through consumption of fish which may cause chronic or acute diseases (Al-Yousuf et al 2000). Hence, it is necessary to estimate the bioaccumulation of trace metals in fishes for monitoring water pollution and assessing potential risks associated with consuming the contaminated fish concerning human health (Ural et al 2012). The bioaccumulation of toxic metals in fishes has been a matter of public health concern since fish forms a part of the diet for a majority of the human population. The bioaccumulation of toxic contaminants in fish is caused by its uptake from ambient medium and through its diet (George et al 2012). Many factors depend on the retention of trace metals in the fish's body, such as the speciation of the metal concerned, the physiological mechanism for regulation, homeostasis and detoxification of the metal. Depending on the structure and function, the degree of accumulation of trace metals in fish tissues may vary. Generally, metabolically active tissues like gills, liver and kidneys have a higher accumulation of trace metals than the other tissues like muscles and skin (Hazrat et al 2019). The mechanism by which trace metal accumulates in tissues of different fish species appears to be a complex biochemical phenomenon that was not fully explored (George et al 2021). The accumulation of trace metals in fish tissues partly depends on metal concentrations in water and the duration of exposure. Moreover, environmental factors such as water temperature, oxygen concentration, pH, hardness, salinity, alkalinity and dissolved organic carbon play a significant role in the metal accumulation and toxicity to fish. The present study aims to evaluate and quantify the bioaccumulation of trace metals (Fe, Ni, Zn, Cu, Pb, Cd and Cr) in tissues (flesh, liver and gills) of two species of fishes, *Etroplus suratensis* and *Arius arius* collected from the Cochin Back waters.

MATERIAL AND METHODS

Study area: The Cochin backwaters, extending between (Lat. 9º 30´-10º 10´ N and Long.76º15´-76º 25´E) are located at the northern part of the Vembanad Lake which forms a complex network of the shallow brackish water body. This backwater system is subjected to inputs of various organic as well as inorganic contaminants from its neighbouring hinterlands. The estuary was polluted by trace metals loaded from industrial, agricultural and municipal sources (Jayasooryan 2015, George et al 2016, Lallu 2017). The main source of metal pollution to the central part of the estuary seems to be due to the processing of metal-containing minerals (ores) at the FACT plant, paints and pigments that are used at the shipyard and ports (George et al 2016). The southern part of the estuary is subjected to metal pollution due to land runoff from Kuttanad agricultural fields that make use of excessive fertilizers and pesticides. Three seasonal conditions viz. pre-monsoon (PrM), monsoon (M) and post-monsoon (PoM) were prevailing in the study region. For this study five stations were selected from central to the southern part of Cochin backwaters based on the geographic features, anthropogenic activities and the inflow of pollutants from the different sources (Fig. 1).

Sample collection: A bimonthly water and fish samples were collected from Cochin backwaters during February 2017 to January 2018. This work was conducted in Zoology Research Centre, St. Stephens College, Pathanapuram, India. Water samples for the analysis of dissolved trace metals were collected using a pre-sterilized plastic bucket and were stored in plastic bottles that are pre-sterilized with 1N HCl. Water samples taken in plastic bottles were fixed with 1ml of 70% HNO_3 and were preserved at about 4°C in a

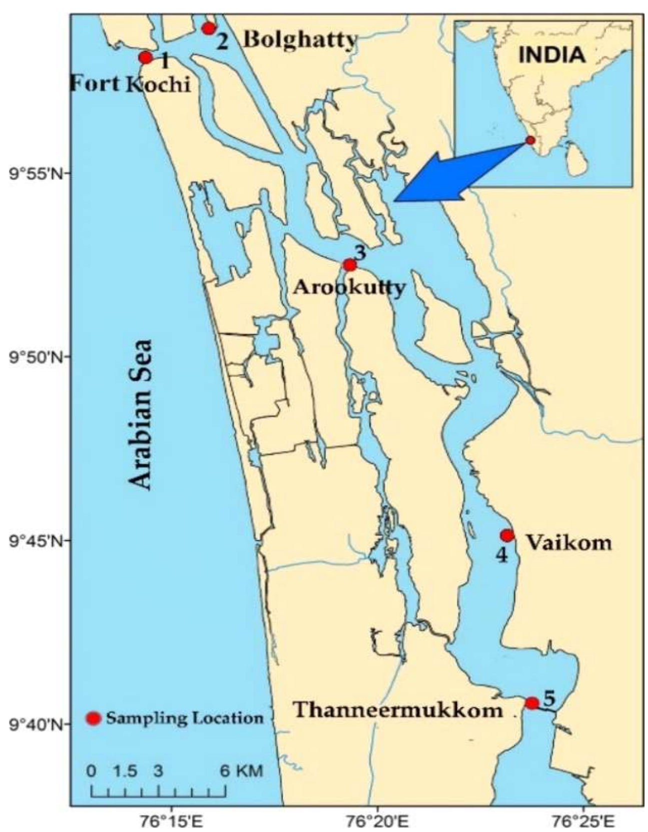

Fig. 1. Sampling locations

refrigerator till analysis in a Graphite Furnace AAS. Two species of fishes, *E. suratensis* (locally called Karimeen) and *Arius arius* (Koori) in the Cochin backwaters were collected directly from the local fishermen. The selected species are economically important and abundant in the study area. Eighty samples of fishes (40 samples of *E. suratensis* and 40 samples of *A. arius*) were collected from the sampling area. Immediately after the collection, fish samples were washed thoroughly with distilled water to remove mud or other fouling substances and were put in a clean polythene bag. They were preserved in iceboxes packed with ice in order to maintain the freshness and were transported to the laboratory. In the laboratory, fish samples were weighed and recorded for their total length. The flesh, liver and gills of the fish samples were dissected and washed thoroughly with distilled water. The organs were dried in an oven at 65 °C. The dried samples were powdered using mortar and pestle and were stored in a vacuum desiccator.

Trace metal analysis: The aliquots of about 300 mg were digested for 3h at 80°C with 3ml conc. HNO_3 (65% Merck, Suprapure) in Teflon beakers. Additional nitric acid was added if the samples were charred and 1ml of conc. $HClO_4$ (Merck Suprapure) was added to make the solution clear and evaporated to near dryness. The digests were cooled and diluted to 25ml with deionised water and were kept in plastic vials. Trace metals were analysed using an Atomic Absorption Spectrophotometer (AAS) Perkin Elmer India Pvt. Ltd. (Model: Pinaacle 900H). All metal concentrations in tissues of fish species were reported in ppm, dry weight.

Bioaccumulation factors (BAF) or Concentration factors were calculated for each metal as the ratio between the metal concentrations in the organism's body to its concentration in the ambient medium. Bioaccumulation factors (BAF) were used in assessment models as they provide pollution scale-independent parameter (Karlsson et al 2002).

$$\text{BAF} = \frac{\text{The metal concentration in organism's body}}{\text{Metal concentration in the ambient medium (Water)}}$$

Metal Selectivity Index (MSI) was calculated as the percentage of absolute concentration of a particular metal in tissue to the total concentration of all metals in that tissue (Nair et al 2006). MSI gives the affinity of a particular metal to a particular organ or tissue and is used as a reliable index for risk assessment of that particular metal.

$$\text{MSI} = \frac{\text{Absolute concentration of a metal in a tissue}}{\text{Total concentration of all metals in that tissue}} \times 100$$

Tissue selectivity index (TSI*)* is the percentage of the ratio between the absolute concentration of a metal in tissue and the total concentration of that metal in all the tissues (Nair et al 2006).

$$TSI = \frac{\text{Absolute concentration of a metal in a tissue}}{\text{Total concentration of all metals in that tissue}} \times 100$$

RESULTS AND DISCUSSION

Trace metal concentrations in water: The concentrations of Fe, Ni, Zn, Cu, Pb, Cd and Cr in water ranged from 0.051 to 0.284 mg L^{-1}, 0.008 to 0.112 mg L^{-1}, 0.012 to 0.341 mg L^{-1}, 0.009 to 0.126 mg L^{-1}, 0.013 to 0.199 mg L^{-1}, 0.002 to 0.095 mg $L^{-1}$and 0.018 to 0.124 mg L^{-1} respectively. The mean concentration of trace metals in water (mg L^{-1}) follows a decreasing order: Fe > Zn > Pb > Cr > Cu > Ni > Cd (Table 1). The increased concentration of trace metals in the water might be due to the large quantities of solid wastes mixed with the wastes of factories, market and industrial wastes that either discharge directly into the water bodies or dumped in open land fill which are directed to the water bodies through the rainwater runoff (Elamin et al 2021). In Cochin backwaters, the dissolved phase is the most sensitive compartment to every change in hydrographical conditions of the water column due to its large surface area and shallow depth (1.5- 6 m) (Anu et al 2014).

Hence, seasonally the concentration of dissolved metals in the water column may vary due to variations in the magnitude of freshwater discharges from rivers, discharge of industrial effluents and domestic sewage, and leakage of pesticide and fertilizer residues from agricultural fields. Thus, the increased concentrations of metals in the water column due to anthropogenic activities act as a significant source to the increased metal levels in fishes of the Cochin backwaters (Hannibal et al 2006, George et al 2012).

Table 1. Trace metal concentration in water (mg L^{-1}) from the Cochin backwaters

Trace metals	Mean ± SD
Fe	0.284 ± 0.267
Ni	0.049 ± 0.025
Zn	0.093 ± 0.091
Cu	0.064 ± 0.033
Pb	0.079 ± 0.044
Cd	0.038 ± 0.025
Cr	0.066 ± 0.029

Trace metal concentrations in fishes: The trace metal concentrations (in ppm, dry weight) in flesh, gill and liver tissues of fishes, *E. suratensis* and *A. arius* were presented in (Table 2). Marked variations were found in the concentrations of trace metals in flesh, gill and liver of *E. suratensis* and *A. arius* that collected from the Cochin backwaters. In general, the studied fish species showed a higher concentration of metals in the liver with few exceptions and the lowest concentrations of metals were found in the flesh.

The average concentrations of Fe, Ni, Zn, Cu, Pb, Cd and Cr in *E. suratensis* were 290.39, 23.52, 84.85, 11.24, 8.33, 4.00 and 34.76 respectively in flesh, 820.89, 40.67, 252.94, 51.17, 28.29, 7.33 and 50.50 respectively in liver, 712.45, 45.75, 210.05, 24.50, 17.04, 7.86 and 46.10 respectively in gills (Table 2). The average concentrations of Fe, Ni, Zn, Cu, Pb, Cd and Cr in flesh of *A. arius* were 266.01, 21.20, 62.98, 9.37, 8.80, 3.51 and 19.02 respectively in flesh, 719.95, 31.00, 196.89. 45.24, 15.69, 6.76 and 47.45 respectively in liver and 610.06, 29.76, 166.03, 17.86, 19.30, 6.86 and 40.35 respectively in gills (Table 2). The average concentration of trace metals accumulated in *E. suratensis* follows an order: Fe > Zn > Cr > Ni > Cu > Pb > Cd for flesh, Fe > Zn > Cu > Cr > Ni > Pb > Cd for gill, and Fe > Zn > Cr > Ni > Cu > Pb > Cd for liver, respectively. In *A. arius* the trace metals accumulated follows an order: Fe > Zn > Ni > Cr > Cu > Pb > Cd for flesh, Fe > Zn > Cr > Ni > Cu > Pb > Cd for gill and Fe > Zn > Cr > Cu > Ni > Pb > Cd for liver, respectively (Table 2). Trace metal bioaccumulation in fish depends on the trophic level, size, food and feeding habits (Sankar et al 2006, George et al 2012, 2021). Dietary preferences, foraging behaviours and food web structure also influence metal bioaccumulation in fishes (Geldiay and Balik 2000). The concentration of trace metals detected in fish organs of *E. suratensis* and *A. arius* indicates different bioaccumulation

Table 2. Trace metal concentration in fishes (ppm) of the Cochin backwaters

Trace metals	*E. suratensis*			*A. arius*		
	Flesh	Liver	Gills	Flesh	Liver	Gills
Fe	290.39 ± 103.57	820.89 ± 345.66	712.45 ± 249.58	266.01 ±118.97	719.95 ± 188.80	610.06 ± 200.06
Ni	23.52 ± 9.15	40.67 ± 16.95	45.75 ± 14.12	21.20 ± 7.60	31.00 ± 11.25	29.76 ± 8.45
Zn	84.85 ± 43.97	252.94 ± 106.62	210.05 ± 91.85	62.98 ± 23.22	196.89± 68.42	166.03 ± 51.62
Cu	11.24 ± 7.25	51.17 ± 25.53	24.50 ± 15.31	9.37 ± 5.87	45.24 ± 21.20	17.86 ± 9.84
Pb	8.33 ± 5.00	28.29 ± 24.28	17.04 ±13.13	9.67 ± 4.35	15.69 ± 8.18	19.30 ± 9.44
Cd	4.00 ± 1.61	7.33 ± 4.34	7.86 ± 4.69	3.51 ± 1.52	6.69 ± 3.83	6.86 ± 3.64
Cr	34.76 ± 20.08	50.50 ± 20.84	46.10 ± 22.33	19.02 ± 9.32	47.45 ± 18.55	40.18 ± 20.81

potentials (Mahesh et al 2012). The interspecies variability in metal accumulation can be explained by species-specific differences in bioaccumulation dynamics.

In general, the concentration of trace metals was higher in the omnivorous species, *E. suratensis* when compared to the carnivorous species, *A. arius.* The concentration of Fe, Zn, Cu and Cd in organs of *E. suratensis* follow an order liver > gill > flesh while the Ni, Pb and Cr follow another order gills > liver > flesh. Similarly in *A. arius*, the Fe, Zn, Cu Pb, Cd and Cr concentration in the organs follow an order liver > gill > flesh, while, the Ni follow another order gills > liver > flesh. The omnivorous fish species, *E. suratensis,* showed higher concentrations of metals when compared to the carnivorous fish species, *A. arius.* This may be due to the feeding of *E. suratensis,* in both benthic and pelagic zones of the backwaters. *E. suratensis,* is a bentho-pelagic species and hence can feed on both benthic and pelagic food chains which enhances its trace metal accumulation behaviour when compared to the benthic species, *A. arius* (Yousafzai et al 2012, Siraj et al 2014, Obasohan 2008).

Bioaccumulation factor (BAF): The degree to which bioaccumulation occurs can be expressed as bioaccumulation factor and is evaluated in relation to the concentration of the soluble metal in the medium (water) in which the fishes inhabit. The concentration factor of the elements in the species *E. suratensis* and *A. arius* are in the order: Fe > Zn > Ni > Cu > Cr > Pb > Cd and Fe > Zn > Cr > Cu > Ni > Pb > Cd respectively. Of the fishes examined, *E. suratensis* showed a higher range of bioaccumulation factors for all the metals in the liver (Table 3). The bioaccumulation factor of elements in liver of the species *E. suratensis* and *A. arius* follows the order: Fe > Zn > Ni > Cu > Cr > Pb > Cd and Fe > Zn > Cr > Cu > Ni > Pb > Cd, respectively. In general, the higher values of BAF found in plankton followed by zoobenthos, predator fish and herbivorous fishes which is mainly depending up on the organism placed in the food chain, their feeding behaviour, hydrology and age of the organism (Culioli et al 2009, Tao et al 2012, Pantelica et al 2012). In the present study comparatively higher BAF values were observed in organs of studied fishes (Table 3), indicate the increased concentration of the soluble metal in the medium (water) in which the fishes inhabit. Many other studies reported the highest BAF in the fish organs and the tissues as Fe and Zn followed by Cu, Pb Cd and As (Uluturhan and Kucuksezgin 2007, Ayotunde et al 2012, Nwani et al 2010, Farombi et al 2007). Most metals showed a decreasing BAF in higher chains of food web, from phytoplankton to zooplankton, then fish (Tiphaine et al 2019). The BAFs of many elements in a given type of organism are much lower in marine waters compared to the freshwater environments, whereas the opposite is true for some elements.

Metal selectivity index (MSI) and Tissue selectivity index (TSI): Metal selectivity index (MSI) measures the affinity of a species to accumulate a particular metal in that tissue or organ of the body and is calculated for all the metals. MSI values (%) for different organs of fishes (Table 4). In *E. suratensis,* MSI values follows an order: Fe > Zn > Cr > Ni > Cu > Pb > Cd in flesh and gills but in liver it follows another order: Fe > Zn > Cr > Ni > Cu > Pb > Cd. In *A. arius,* MSI values were in the order: Fe > Zn > Ni > Cr > Cu > Pb > Cd in flesh, Fe > Zn > Cr > Cu > Ni > Pb > Cd in liver and Fe > Zn > Cr > Ni > Cu > Pb > Cd in gills. In both fishes, Fe and Cd showed the highest and lowest MSI values, respectively. The relative tissue occupying capacity of metal in a particular tissue is known as Tissue Selectivity Index (TSI). The tissue selectivity of trace metals in fishes is determined by the bioavailability of metals in the environmental matrix, feeding behaviour and metabolic activities. The TSI values (%) for different organs of fishes are given in (Table 5). In *E. suratensis*, the TSI values for the metals Fe, Zn, Cu, Pb and Cr follow an order: liver > gill > flesh whereas for the metals Ni and Cd it follows another order: gills > liver > flesh. In *A. arius* the TSI values for the metals Fe, Ni, Zn, Cu and Cr follow an order liver > gill > flesh whereas for the metals Pb and Cd it follows another order: gills > liver > flesh.

Table 3. Bioaccumulation factors for trace metals in fishes from Cochin backwaters

Trace metals	*E. suratensis*			*A. arius*		
	Flesh	Liver	Gills	Flesh	Liver	Gills
Fe	1014.74	2868.57	2489.64	929.56	2515.83	2131.83
Ni	478.43	827.13	930.41	431.14	630.60	605.24
Zn	908.80	2709.12	2249.69	674.56	2108.74	1778.30
Cu	174.66	795.04	380.56	145.52	702.91	277.51
Pb	105.88	359.73	216.67	111.92	199.58	245.50
Cd	105.64	193.87	207.69	92.75	178.59	181.30
Cr	526.74	765.10	698.53	288.23	718.95	611.43

Table 4. Metal selectivity index (%) of fishes collected from Cochin backwaters

Fishes	Organ	Fe	Ni	Zn	Cu	Pb	Cd	Cr
E. suratensis	Flesh	63.53	5.15	18.56	2.46	1.82	0.87	7.61
	Liver	65.58	3.25	20.21	4.09	2.26	0.59	4.03
	Gills	66.98	4.30	19.75	2.30	1.60	0.74	4.33
A. arius	Flesh	68.05	5.42	16.11	2.40	2.25	0.90	4.87
	Liver	67.73	2.92	18.52	4.26	1.48	0.64	4.46
	Gills	68.53	3.34	18.65	2.01	2.17	0.77	4.53

Table 5. Tissue selectivity index (%) off fishes collected from the Cochin backwaters

Fishes	Organ	Fe	Ni	Zn	Cu	Pb	Cd	Cr
E. suratensis	Flesh	15.92	21.40	15.49	12.94	15.52	20.83	26.46
	Liver	45.01	36.99	46.17	58.88	52.73	38.22	38.44
	Gills	39.07	41.61	38.34	28.18	31.76	40.95	35.10
A. *arius*	Flesh	16.67	25.86	14.79	12.92	20.09	20.49	17.81
	Liver	45.11	37.83	46.23	62.43	35.83	39.46	44.42
	Gills	38.22	36.31	38.98	24.65	44.08	40.05	37.77

The TSI reveal that the accumulation of trace metals in the flesh of fishes was lowest when compared to the gill and liver. This is maybe due to the different physiological roles of these organs in fish metabolism (Merciai et al 2014). When compared to muscle, the gill and liver in fishes serve for respiration and metabolism and are considered as target organs for trace metal contaminant accumulation (Nair et al 2006). This is associated to the fact that food and water are the main routes of contaminant assimilation as it is directly linked with the metabolism and respiration (Reddy et al 2007). Trace elements assimilated from food that contaminated with wastewater effluents are ingested in fish body and are transported through the blood and gets incorporated in various tissues at variable degrees (Kojadinovic et al 2007, George et al 2021). When compared to the liver and gill, the low concentration of metals in the muscle of fish species may be the low metabolic activity and/or low levels of metal-binding proteins in the muscle. Unlike other tissues, the liver accumulates high concentrations of metals, irrespectively of the uptake route and is considered as an indicator of water pollution by trace metals since their concentrations accumulated in this organ are often proportional to those present in the aquatic environment. Consequently, the high level of metals accumulation in the fish liver followed by gill and muscle highlights an environmental indication of water pollution due to the persistent exposure of trace metals loaded from the industrial effluent discharges, agricultural run-off and domestic sewage inputs (George et al 2012, Robin et al 2012). Hence metal concentrations in organs of fishes could be used as an index to estimate the level of pollution in aquatic ecosystems (Karadede-Akin and Unlu 2007).

CONCLUSION

The accumulation of trace metals in fish tissues varied among species. The omnivorous species, *E. suratensis* accumulated a higher concentration of trace metals in fish tissues than the carnivorous species, *A. arius*. The liver and gill of fishes showed higher concentrations of metals when compared to the flesh tissue due to higher metabolic activity of the liver and gill when compared to muscle. Bioaccumulation of trace metals in aquatic life, especially fishes have possible detrimental effects and direct toxic effect on human life and hence have environmental concern worldwide.

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Aquatic Plant Diversity of Ponds in Thrissur District, Kerala, India

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Abstract: The analysis of aquatic plant diversity was conducted in twenty ponds of Thrissur district, Kerala, during April 2014 to March 2016. During the period of study, 41 macrophytes were identified which comes under 35 genera belonging to 24 families including Pteridophytes. 46.3% of total plant species that were recorded fall into the category of marshy, followed by 19.5% submerged hydrophytes, 12.2% emergent hydrophytes, 12.2% free floating hydrophytes and 9.8% attached floating hydrophytes. The diverse plant family is Poaceae followed by Hydrocharitaceae, Onagraceae and Asteraceae.

Keywords: Aquatic plants, Macrophytes, Thrissur, Pteridophytes, Poaceae, Hydrocharitaceae, Onagraceae, Asteraceae

The macrophytes play a vital role in healthy aquatic ecosystems and serve as primary producers of oxygen through photosynthesis. These plants supply a wide variety of nesting habitats for aquatic organisms. They provide a substrate for epiphytic algae and shelter for many invertebrates, aid in nutrient cycling to and from the sediments and help to stabilize river and stream banks. The macroscopic flora includes the aquatic Angiosperms (flowering plants) and Pteridophytes (ferns). The macrophytes constitutes a diverse assemblage of taxonomic groups and are classified into four categories based on their habit of growth namely free floating, attached floating, submerged and emergent (Kumar 2015). Majority of the ponds in India are shallow and perennial freshwater bodies. Algae in deep waters dominate the aquatic biota and macrophytes dominate in the shallow waters. The macrophytes are the major contributors of pond productivity. The aquatic macro-vegetation plays an important role in maintaining ecological balance (Bhagyaleena and Gopalan 2012).The eutrophic water bodies are characterized by the presence of aquatic plants (Bronmark and Hansson 2017). The increased number of macro vegetation indicates the eutrophic condition of the reservoirs (Reju et al 2015). The macrophytes produce additional amount of nutrients and that pollute the water after their death (Tewari and Mittal 2020). The water quality of the freshwater bodies is rapidly declining (Nandal et al 2020).The aquatic plants in the freshwater habitats of India were reported by Cook (1996). The baseline data on biodiversity is essential for the conservation and management strategies of wetland and aquatic habitats (Ravi et al 2020). In Kerala the systematic reports regarding the freshwater ecology, limnology and conservation biology of ponds was insufficient.

MATERIAL AND METHODS

The present work was conducted in twenty ponds (P_1 – P_{20}) of Thrissur district, Kerala, during April 2014 to March 2016 (Table 1). The twigs of plants were collected periodically with flowers and fruits. The habit, morphology and floristic characters are recorded during the time of collection. The plants collected were identified with the help of floras (Manilal and Sivarajan 1982, Gamble and Fischer 1915 – 1936, Sreekumar and Nair 1991).

RESULTS AND DISCUSSION

During the period of study, 41 macrophytes were identified which comes under 35 genera belonging to 24 families including Pteridophytes (Table 2 and Plate 1). The 46.3% of total plant species that were recorded fall into the category of marshy land, followed by 19.5% submerged hydrophytes, 12.2% emergent hydrophytes, 12.2% free floating hydrophytes and 9.8% attached floating hydrophytes (Fig. 1). The diverse family is Poaceae followed by Hydrocharitaceae, Onagraceae and Asteraceae (Table 2). The free floating hydrophytes found in the ponds of Thrissur district are *Eichhornia crassipes* (Mart.) Solms, *Lemna perpusilla* Torrey, *Pistia stratiotes* L., *Azolla pinnata* R. Br. and *Salvinia molesta* D. Mitch. The rooted plants with floating leaves are *Nymphaea nouchali* Burm. f., *Nymphaea rubra* Roxb. *ex* Salisb., *Nymphoides hydrophylla* (Lour.) O. Ktze. and *Nymphoides indica* (L.) O. Ktze. The prominent growth of the floating plants will not allow light to pass through the water and the growth of the microphytes are inhibited. The rooted submerged plants found in the ponds are *Ottelia alismoides* (L.) Pers., *Utricularia aurea* Lour., *Cabomba caroliniana* Gray., *Hydrilla verticillata* (L. f.) Royle, *Ceratophyllum*

Table 1. GPS locations of the ponds studied

Pond No.	Name of the pond	GPS location
P_1	Pond at Christ College campus, Irinjalakuda	10°21'23.4"N 76°12'44.1"E
P_2	Njourikulam, Irinjalakuda	10°20'53.1"N 76°12'48.3"E
P_3	Andanikulam, Irinjalakuda	10°18'56.2"N 76°13'12.5"E
P_4	Marathampully pond, Irinjalakuda	10°20'29.8"N 76°12'55.0"E
P_5	Pallikulam, Thrissur	10°31'17.5"N 76°13'20.4"E
P_6	Ayyanpadi pond, Edamuttam	10°22'32.7"N 76°08'10.3"E
P_7	Pond at Edamuttam	10°22'29.1"N 76°07'33.1"E
P_8	Kothakulam pond, Valapad	10°23'40.7"N 76°06'58.5"E
P_9	Kuttankulam, Irinjalakuda	10°20'48.3"N 76°12'10.0"E
P_{10}	Temple pond, Kodungallur	10°13'38.0"N 76°11'52.2"E
P_{11}	Temple pond, Guruvayur	10°35'44.3"N 76°02'21.3"E
P_{12}	Vadakkechira temple pond, Thrissur	10°31'46.1"N 76°12'57.9"E
P_{13}	Pond at Kaduppassery, Velukkara Panchayath	10°18'59.8"N 76°15'15.5"E
P_{14}	Oomenkulam, Irinjalakuda	10°20'26.5"N 76°13'06.9"E
P_{15}	Velathikulam, Muriyad Panchayath	10°21'07.4"N 76°13'49.2"E
P_{16}	Ayyappankavu kulam, Cheloor, Irinjalakuda	10°20'22.6"N 76°11'40.2"E
P_{17}	Kottamkulam, Thalikulam	10°26'07.7"N 76°05'49.1"E
P_{18}	Narayanamangalam temple pond, Palakkal	10°28'12.1"N 76°13'14.4"E
P_{19}	Pallikulam, Koratty	10°16'10.3"N 76°20'39.9"E
P_{20}	Mudichira, Muriyad Panchayath	10°21'12.3"N 76°14'00.6"E

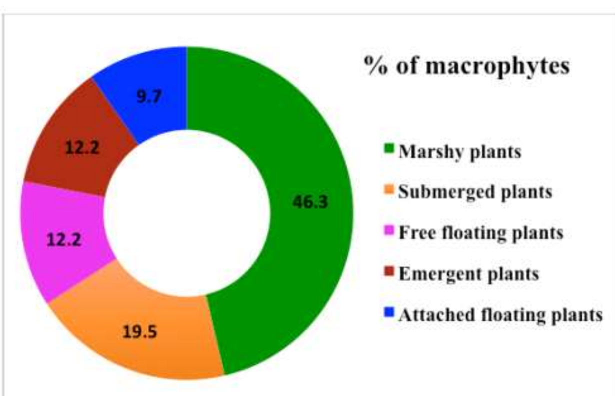

Fig. 1. Distribution of macrophytes in the ponds of Thrissur district

Plate 1. 1. *Alternanthera philoxeroides* (Mart.) Grisb.; **2.** *Cabomba caroliniana* Gray.; **3.** *Ceratophyllum demersum* L.; **4.** *Eclipta prostrata* L.; **5.** *Eichhornia crassipes* (Mart.) Solms.; **6.** *Ipomoea aquatica* Forssk.; **7.** *Hydrilla verticillata* (L. f.) Royle; **8.** *Lemna perpusilla* Torrey; **9.** *Limnocharis flava* (L.) Buch.; **10.** *Limnophila aquatica* (Roxb.) Alston; **11.** *Ludwigia adscendens* (L.) Hara.; **12.** *Monochoria vaginalis* (Burm. f.) Presl; **13.** *Ottelia alismoides* (L.) Pers.; **14.** *Nymphaea nouchali* Burm. f.; **15.** *Nymphaea rubra* Roxb. *ex* Salisb.; **16.** *Pistia stratiotes* L.; **17.** *Vallisneria natans* (Lour.) Hara; **18.** *Nymphoides indica* (L.) O. Ktze.; **19.** *Nymphoides hydrophylla* (Lour.) O. Ktze.; **20.** *Utricularia aurea* Lour.; **21.** *Ceratopteris thalictroides* (L.) Brongn.; **22.** *Azolla pinnata* R. Br.; **23.** *Salvinia molesta* D. Mitch.; **24.** *Marsilea minuta* L.

demersum L., *Najas graminea* Del. and *Najas indica* (Willd.) Cham. The *Cyperus pilosus* Vahl., *Cyperus compressus* L. and *Eragrostis unioloides* (Retz.) Nees *ex* Steud were found to be dominant during dry season of the year in the marshy areas of the ponds.

The macrophytes have capacity to improve the water quality by absorbing nutrients, with their effective root system. At the same time death and decay of the macrophytes increases nutrient concentration and it leads to the eutrophication. *Eichhornia crassipes* (Mart.) Solms and

Table 2. Distribution of macrophytes in the ponds of Thrissur district, Kerala

Name of species	Family name	Habit	Pond No:
Alternanthera philoxeroides (Mart.) Grisb.	Amaranthaceae	M	P_{13}, P_{14}
Cabomba caroliniana Gray.	Cabombaceae	S	P_{13}
Ceratophyllum demersum L.	Ceratophyllaceae	S	P_1
Colocasia esculenta (L.) Schott	Araceae	E	P_{13}, P_{20}
Cyperus compressus L.	Cyperaceae	M	P_1, P_2, P_3, P_{13}, P_{15}, P_{16}, P_{17}, P_{20}
Cyperus pilosus Vahl.	Cyperaceae	M	P_1, P_{15}, P_{17}, P_{20}
Echinochloa colona (L.) Link.	Poaceae	M	P_2
Eclipta prostrata (L.) L.	Asteraceae	M	P_1, P_{13}, P_{20}
Eichhornia crassipes (Mart.) Solms.	Pontederiaceae	FF	P_6, P_{13}
Eragrostis unioloides (Retz.) Nees *ex* Steud	Poaceae	M	P_4, P_{13}, P_{15}, P_{20}
Hydrilla verticillata (L. f.) Royle	Hydrocharitaceae	S	P_1, P_2, P_6, P_{13}, P_{14}, P_{18}
Hygrophila schulli (Buch - Ham) M.R. & S.M. Almeida	Acanthaceae	E	P_2, P_6, P_{13}, P_{20}
Hygroryza aristata (Retz.) Nees ex Wight & Arn.	Poaceae	E	P_{13}, P_{15}
Ipomoea aquatica Forssk.	Convolvulaceae	M	P_6, P_{13}
Lemna perpusilla Torrey	Lemnaceae	FF	P_7, P_{15}
Limnocharis flava (L.) Buch.	Alismataceae	E	P_6, P_{13}
Limnophila aquatica (Roxb.) Alston	Scrophulariaceae	E	P_{13}
Ludwigia adscendens (L.) Hara.	Onagraceae	M	P_2
Ludwigia hyssopifolia (G. Don) Exell	Onagraceae	M	P_{13}, P_{15}
Ludwigia perennis L.	Onagraceae	M	P_2, P_4, P_6, P_{12}, P_{13}, P_{15}
Monochoria vaginalis (Burm. F.) Presl	Pontederiaceae	M	P_1, P_2, P_4
Najas graminea Del.	Najadaceae	S	P_1
Najas indica (Willd.) Cham.	Najadaceae	S	P_1
Nymphaea nouchali Burm. F.	Nympaeaceae	AF	P_2, P_8, P_{10}, P_{11}, P_{14}
Nymphaea rubra Roxb. *Ex* Salisb.	Nympaeaceae	AF	P_5, P_6
Nymphoides hydrophylla (Lour.) O. Ktze.	Menyanthaceae	AF	P_2
Nymphoides indica (L.) O. Ktze.	Menyanthaceae	AF	P_2
Ottelia alismoides (L.) Pers.	Hydrocharitaceae	S	P_6
Panicum repens L.	Poaceae	M	P_2, P_3, P_9, P_{13}, P_{14}, P_{15}, P_{16}, P_{20}
Paspalum scrobiculatum L.	Poaceae	M	P_{13}, P_{20}
Pistia stratiotes L.	Araceae	FF	P_{17}
Persicaria barbata (L.) Hara var. *barbata* Joseph	Polygonaceae	M	P_{13}
Sacciolepis interrupta (Willd.) Stapf.	Poaceae	M	P_9
Spilanthes ciliata HBK	Asteraceae	M	P_{13}
Utricularia aurea Lour.	Lentibulariaceae	S	P_1, P_{13}
Vallisneria natans (Lour.) Hara	Hydrocharitaceae	S	P_{13}
Wedelia chinensis (Osbeck) Merr	Asteraceae	M	P_{13}
Azolla pinnata R. Br.	Azollaceae	FF	P_{13}
Ceratopteris thalictroides (L.) Brongn.	Parkeriaceae	M	P_4, P_6,, P_{13}, P_{14}, P_{15}, P_{17}, P_{20}
Marsilea minuta L.	Marsileaceae	M	P_4, P_6, P_{13}, P_{20}
Salvinia molesta D. Mitch.	Salviniaceae	FF	P_1, P_2, P_4, P_{12}, P_{13}, P_{19}

AF – Attached floating; E – Emergent; FF – Free floating; M – Marshy; S – Submerged

Hydrilla verticillata (L.f.) Royle are capable in improving water quality by reducing nutrient concentration. The macrophytes such as *Hydrilla*, *Ceratophyllum* and *Eichhornia* grown in ponds have the ability to maintain water quality (Pradeep and Dwivedi 2016). Some Pteridophytes such as *Azolla pinnata* R. Br., *Ceratopteris thalictroides* (L.) Brongn., *Marsilea minuta* L. and *Salvinia molesta* D. Mitch. were also found abundant in the perrennial ponds studied (Table 2). Aquatic macrophytes act as microhabitat for the fauna of wetlands due to the diversity of growth forms which outcomes in a greater niche modification (Malaiya 2015). It is very important to conserve the natural ecosystems that are deteriorating at an alarming rate otherwise the remnants will significantly lose their ability to sustain the present biological diversity (Gupta et al 2020).

CONCLUSION

This assessment on the macrophytes in the perennial ponds of Thrissur district, Kerala is a comprehensive floristic analysis of the aquatic flora. During the investigation 41 macrophytes were reported which comes under 35 genera belonging to 24 families including Pteridophytes. This report will be useful for analyzing the biodiversity of the macrophytes in the ponds of Kerala. The ponds promote abundance and high richness of aquatic plants and enhance regional biodiversity. The aquatic macro-vegetation plays a significant role in maintaining ecological balance by nutrient recycling. The ponds that are not periodically cleaned showed more diversity of macrophytes.

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Studies on Gonad Histology and Length at First Maturity of the Rainbow Trout *Oncorhynchus mykiss* Walbaum, 1792 (Salmoniformes: Salmonidae) from Kashmir

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Abstract: The present study was conducted on gonad histology and length at first maturity of the rainbow trout *Oncorhynchus mykiss* Walbaum 1792. The length at first maturity recorded was at 28.7cm. Histological snaps of immature phase revealed the ovigerous lamellae containing oogonial nests. Early maturing phase showed vascularisation and initiation of yolk formation with the ovaries start occupying the space within abdominal cavity. The oocytes show increase in yolk deposition in the form of globules and appearance of zona pellucida membrane with ooplasmic content was the highlight of the advance maturing phase. Considerable percentage of vittellogenic oocytes were observed within the advance maturing phase. The spawning phase revealed developed ovaries that reflected maturation of oocytes justified by increase in their size, volume, weight and entire abdominal cavity was filled with mature ovaries surrounded by thinnest tunica albuginea and zona pellucida. The presence of the late maturing oocytes and post ovulatory follicles was seen in late maturing phase with conspicuous blood vessels. The histology of spent phase revealed ruptured post-ovulatory follicles and showed irregular folds of zona pellucida and post-ovulatory follicles. During this phase atretic oocytes were also observed that is highlighting the atresia incase of trout fishes.

Keywords: Histology, *O. mykiss,* Trout farms, Kashmir, Coldwater

Histology, the study of the microanatomy of specific tissues, has been successfully employed as a diagnostic tool within medical and veterinary science since the first cellular investigations were carried out in the mid-nineteenth century (Virchow 1858). Since then, considerable developments have taken place in all aspects of cellular biology with the result that today many novel and sophisticated histological techniques, only recently devised for the mammalian histologist are now available to the fish histopathologist. Before any satisfactory histological sections can be produced from biological material, strict attention has to be paid to its preparation. The very rapid rate of autolysis of fish tissues compared to that of homeotherms means that they must be handled rapidly to prevent degenerative changes within the specimen making ultimate diagnosis either unreliable or impossible.

Histological studies are used to predict many biological phenomena such as fish reproduction for invention of new and effective methods to increase the efficiency of broodstock, increasing fish production. Histological studies determine the peak period of spawning & exploitation of fish, and biological characteristics and life cycle of a species and provide precise information on gonadal development of a species. A histological study is a prime tool for conserving and protecting fisheries in terms of detecting pathogens, pollutants, and catching the correct stage of spawning to provide protection to broodstock. Diverse anthropogenic activities discharge numerous pollutants into the environment, posing a threat to whole biodiversity, including aquatic life (Dhara et al 2021). Two important sectors of fisheries contribute to the food security and nutrition safety of the growing population, namely inland and offshore fisheries (Mishra et al 2021). In order to avoid overexploitation of fishes, it is extremely important to harvest fish at the right age. This can be tracked using various measures like the Lm, or length at first maturity, which basically provides us with information regarding the length at which the fish is ripe. Providing safety to mature stock of fishes is important to avoid the catching and harvesting of spawners hence providing the fish a chance to reproduce at least once in life time.

MATERIAL AND METHODS

The study was based on 90 samples of *O. mykiss,* in the length range of 220 to 350 mm and weight of 85 to 505.5gm, collected from three state owned trout fish farms, namely, Achabal Trout Fish Farm, District Anantnag (33.73ºN latitutde and 75.24ºE longitutude); Dachigam Trout Fish Farm, District Srinagar (34.8ºN latitutde and 74.79ºE longitutde) and Mammar Trout Fish Farm, District Ganderbal

(34.21ºN latitutde and 74.77ºE longitutde. The samples were collected at random every month between August 2015 to January 2016 from the three sites and length at first maturity and gonadal development was observed during the study.

Length at 1st maturity: The length, at which about 50% of the fish were mature, was taken as the Length at first maturity (L_m).) The length at first maturity was determined in the spawning season. When their maturity was in stages one and two, they were considered as immature, and those which were in stages three to eight, were considered as mature (Farmer et al 2005). The relation between length and maturity in length classes was demonstrated by plotting (cumulative frequency) of such mature fish in each length group against respective length group (10 mm class intervals).

Gonadal development: Maturity stages were recognized as the basis of color and size of ovary as well as the space it occupied in the abdominal cavity. The diameter of the ova was also taken into consideration which recognizing the different maturity stages. The different developmental stages for the female fish were determined by using the International Council for Exploration of Seas (ICES) scale given by Wood (1930). For histological studies, the preserved ovaries were cut into 1-2 mm size and washed overnight under gentle flow of tap water. The washed tissues were dehydrated with series of concentration of ethyl alcohol (30, 50, 70 and 100%) and cleared in Xylene A.R. (Himedia). These tissues were embedded into paraffin, following impregnation techniques and sections of 5μ thickness made by using microtome, and stained with Haematoxylin and Eosin 2%. Microphotographs of the prepared slides were taken using Olympus (CX31). These photographs were utilized for further study and analysis.

RESULTS AND DISCUSSION

Length at first maturity: The length at first maturity (L_m) was recorded at 28.7 cm Alp et al (2003) recorded the length at first maturity in male and female brown trout as17.4cm and 17.8cm Arsalan and Aras (2007) also recorded length as 14.0and 17.3cm in male and female brown trout. The length at maturity was suggested as the minimum size that should be allowed to be caught in commercial fishing, as it will allow the fish to gain considerable biomass and spawn at least once in its life (Mahmoud, 2009). The onset of maturity differs considerably interspecifically as well as intra-specifically. Information on the size of maturation is essential for avoiding over exploitation of immature juveniles and ensuring the spawning of individual fish at least once in life (Thakran 2014). Hussain (2014) also reported mean length at first maturity (L_m)in males to be 178.14mm and in females to be 167.32mm in *S. niger*. The differences in L_m values in same or different specimens of fishes are mainly due to environmental condition and sampling procedures (Shah 2012). Shah et al (2009) also reported that male rainbow trout attained full maturity after 2 years while female rainbow trouts attained maturity after 3 years in Kashmir.

Fig. 1. Specimen of *O. mykiss* (Walbuam 1792)

Gonadal development: The ovarian cycle of *O.mykiss* showed considerable changes of growth, maturation and degeneration during the different stages. The ovary was enveloped by a thin peritoneal membrane, ovary wall being thin at early stage but with the advancement in maturity it became thick. The three layers that cover ovary are thin squamous epithelium, a thicker tunica albuginea and innermost. The connective tissue, muscle fibres and blood capillaries forms tunica albuginea and with the development of stages during maturation it becomes thinner. The finger like projection or folds formed in germinal vesicles called as ovigerous lamellae contained clusters of germ cells are formed in it. The oogonium arose from the germinal vesicle. On the basis of gross histological examination and changes occurring in ovary and gonadosomatic index, the ovarian cycle of *O. mykiss* was divided into following six stages:

Stage I: Immature phase: This phase extends from August to September and gonads appear thin thread like structures, translucent or slightly whitish in colour, occupying a very small portion of the abdominal cavity with inconspicuous vascularisation. Examination shows ovigerous lamellae containing oogonial nests (OoN) and immature oocytes. Major portion of oocycte was occupied by the nucleus (ON).

Stage II: Early maturing phase: This phase extends from September to October with increase in size and volume of ovaries, opaque with yellow texture occupying about one-half of the abdominal cavity. Vascularisation increases, oocytes are visible to the naked eye and beginning of yolk formation in oocytes with scattered yolk droplets (YD) is shown. Peripheral yolk vesicles are observed in oocytes along with a number of late maturing oocytes (LmO). The ovaries contain both maturing and developing immature oocytes (ImO). Maturing oocytes (MO) were recognized by their oval shape and medium size.

Stage III: Advanced maturing phase: This phase extends from October to November shows considerable increase in size, volume and weight of the ovaries which occupy more than three-fourth of the abdominal cavity as oocytes are large, slightly orange in colour due to distinct blood capillaries. Histologically, the oocytes show increase in yolk deposition in the form of globules (YG) and are covered by a zona pellucida/vitelline membrane (ZP/VM) with ooplasmic content (OC) as well. A considerable percentage of vittellogenic oocytes (VO) are observed.

Stage IV: Mature/spawning phase: This phase extends from the month of November to December with fully mature ovaries occupying almost the entire abdominal cavity of the fish and showed further increase in size, volume and weight with increase in oocyte diameter also. The ovaries are fully opaque with orange or yellow tinge and oocytes show full yolk globule (YG) deposition which are also visible to the naked eye. During the phase the fish is ready to expel eggs, if slight pressure is applied to the abdominal area of the fish. The Tunica albuginea becomes very thin as well as zona pellucid (ZP).

Stage V: Late maturingphase: This phase extends from December to January with further increase in size, volume and weight of ovary, fish displays a conspicuously swollen abdomen. Colour of the ovaries acquires a reddish tinge due to increase blood supply of blood. The phase shows late growth of late maturing oocytes (LmO) and post ovulatory follicles. The oocytes attain their maximum size and are covered by zona pellucida (ZP) and zona radiate.

Stage VI: Spent phase: The phase starts from the month of January to February. This phase shows ruptured post-ovulatory follicles (POF) because of which ovaries become shrunken, flaccid, transparent and reduced in size, volume and weight with pale colour. The ovaries show irregular folds of zona pellucida (ZP/VM) and post-ovulatory follicles. Some unexpelled oocytes (UO) can also be observed in the ovaries. During this phase atretic oocytes (AO) were also observed with ooplasmic content (OC).During the present study, the immature ovaries were obtained in August and September and mature ovaries were obtained in November and December while the spent ovaries were found in January, indicating a single reproductive cycle in a year. The ovaries during the spawning phase are filled with yolk laden oocytes (type-IV oocytes) which became so large that interfollicular space was obliterated and septa were stretched to their fullest capacity. Very few immature oocytes were also visible along the peripheral region of the ovary. Towards end of this phase the ovary decreased in weight not only due to ovulation or discharge of the eggs, but also due to degeneration of oocytes which is referred to as atresia (Gadekar 2014), while late maturing phase showed few post-ovulatory follicles and maturing oocytes covered by zona pellucida/vetilline memberane. During spent phase, degeneration of oocytes has been seen with irregular folds of zona pellucida and post-ovulatory follicles, gonad size reduces and gonads become flaccid leading to atresia. During spent phase degeneration of oocytes has been seen with irregular folds of zona pellucida and post ovulatory follicles and gonad size reduces and become flaccid leading to atresia.The histological examination of ovaries of *O. mykiss* at three sites during the study provides information about the maturity of fish. During the study six different

Table 1. Length-wise percentage distribution of maturity stages in *O. mykiss* (Female)

Length group (mm) ll	No. of females examined	Maturity stages					
		I	II	III	IV	V	VI
220-230	2		100				
231-240	1			100			
241-250	1	100					
251-260	1			100			
261-270	6			33.34	50	16.66	
271-280	15		6.68	33.33	33.33	13.33	13.33
281-290	10			40	40	10	0
291-300	15			26.66	40	20	13.34
301-310	9			22.22	33.34	22.22	22.22
311-320	6				50	16.66	33.34
321-330	7			14.29	57.14	28.57	
331-340	1				100		
341-350	1					100	

stages, immature, early maturing, advance mature, mature, late mature and spent stage were found in *O. mykiss* at three sites. Sharma and Bhat (2015) reported four distinct reproductive phases viz. resting or spent stage, maturation stage, mature stage and regression stage in *O. mykiss* of Kashmir.Five developmental stages for golden mahseer have been reported in Bhimtal and Sattal lakes by Shahi et al(2014), five stages of oocytes in Indian major carp *Labeo rohita* by Gadekar (2014), seven stages in females in *Labeo dyocheilus* byVerma (2013), six stages of gonad maturation in*Auchenoglanis occidentalis* by Shinkafi and Ipinjolu (2012), six stages in*Xenentodon cancila* byScuba and Mehta (2012), six main stages in female fishes in *Barbus luteus* and *Varicorhinuus trutta* by Rahemo and Al-Shatter (2012). Qadri et al (2019) studied in river Jhelum Kashmir and described maturity phases of reproductive development with about five maturity stages namely Immature phase, Preparatory phase, Maturing phase, Ripe/spawning phase and Spent phase *Schizothorax curvifrons*.

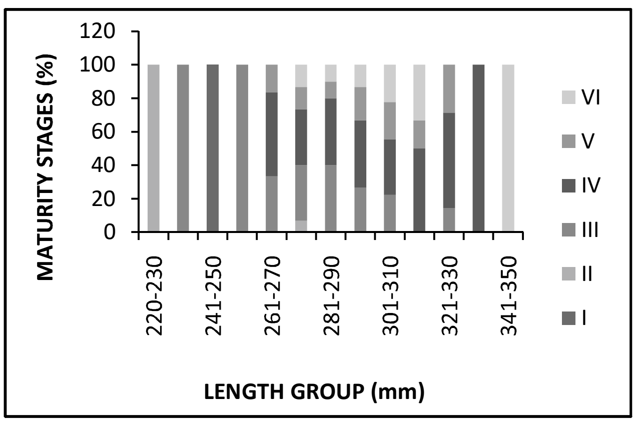

Fig. 2. Percentage distribution of maturity stages in different length groups of *O. mykiss* (Female)

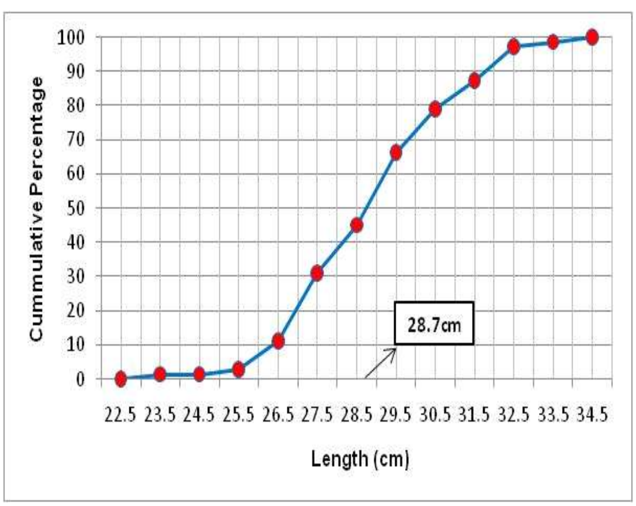

Fig. 3. Length at first maturity in *O. mykiss* (Female)

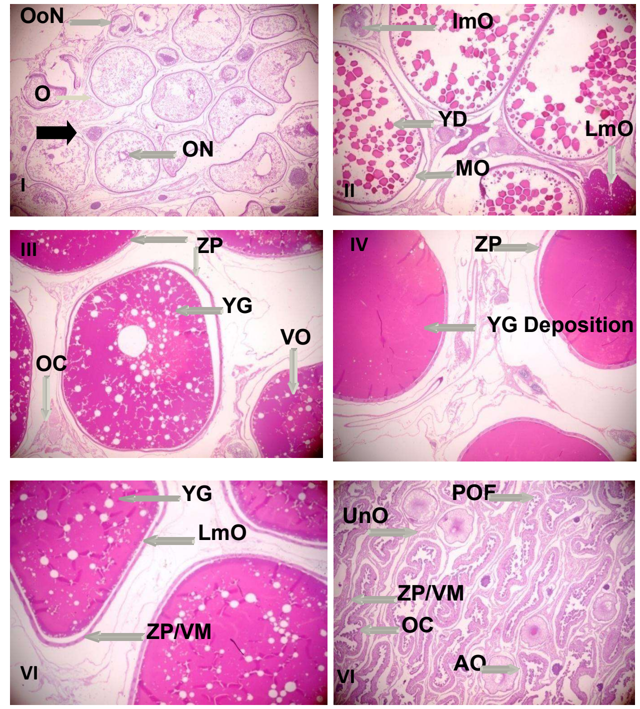

Fig. 3. Egg developmetal stages. **I –VI**: Ovaries of rainbow trout collected from three state owned farms in Kashmir from developmental period to degeneration period. I: Immature phase showing oogonial nests **(OoN)**, oocyte nucleus **(ON)** with considerable oogoniums **(O)**.II: Early Maturing phase captured immature oocytes **(ImO)** with scattered yolk droplets **(YD)** and consistent development of maturing oocytes **(MO)** and peripheral oocytes vesicle contained late maturing oocytes **(LmO)**. III: Advance Maturing phase with considerable growth of vitellogenic oocytes **(VO)** along with appearance of zona pellucida **(ZP)** and showed yolk deposition by formation of globules **(YG)** with ooplasmic content **(OC)**. IV: Mature/Spawning phase showed full yolk deposition with thinner zona pellucida (ZP). V: Late Maturing phase showed yolk globules (YG) and zona pellucida (ZP) of late maturing oocyte (LmO). VI: Spent phase, a snap shot of ruptured post ovulatory follicle **(POF)**, unexpelled ova **(UO)**, and ooplasmic content **(OC)** with irregular folds of zona pellucida (ZP)/vitelline memberane **(VM)** and atretic oocytes **(AO)** aboutr evealing atresia

CONCLUSION

Histological analysis of gonads revealed species has good intensity of oogenesis. The post ovulatory follicles were seen in late maturing phase. The atresia in trout fishes can be seen within spent phase as observed in this research. The length at first maturity recorded was at 28.7cm. The reproductive potential of these female trout generally increases with size but decrease in large, old fish.

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Study of Freshwater Prawn Diversity from Different Rivers of Jammu, India

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Abstract: Diversity of freshwater prawns and biological indices were studied from June, 2019 to May, 2020 in five rivers of Jammu region of J&K. In total, five species of prawns belonging to *Macrobrachium* and *Caridina* genus were recorded. Out of the five species, *Macrobrachium dayanum* was dominant species present in all the surveyed water bodies whereas *M. lamarrei* was only in two water bodies. The different diversity indices showed significant differences. The highest and lowest values of Shanon-Weiner index, Margalef richness index and Pielou eveness index (%) were 1.39 (Chadwal stream) and 0.67 (Sai stream), 0.79 (Chadwal stream) and 0.30 (Sai stream), 0.97 (Sai stream) and 0.80 (Chadwal stream). Sai stream showed least diversity and abundance of species compared to other study sites, which is also revealed by the results of cluster analysis that showed this site to be significantly different indicating it to be the least suitable habitat.

Keywords: Diversity indices, Prawn diversity, *Macrobrachium*, *Caridina*, Shanon-Weiner index, Margalef richness index, Pielou eveness

Conservation of aquatic biodiversity especially freshwater diversity is one of the important matters of concern as it is exhausting at an accelerated rate due to various factors like human activity, loss of habitat, over harvesting, increasing pollution levels, competition from exotic species and other biotic and abiotic components. Freshwater is essential for life and yet it comprises of only 3% of total water present on earth (Souilmi and Tahraoui 2021). Freshwater ecosystem includes lakes, rivers, wetlands and these harbour remarkable life diversity and serve as home to 10% of total species (Strayer and Dudgeon 2010). Decapoda is the most significant order that includes enormous diversity of freshwater crustaceans. Among decapoda crustaceans, caridean shrimp and prawns represent second largest group after Brachyura (Davis et al 2018) and about 800 species living in fresh water have been described from this infraorder (De Grave et al 2015). Freshwater prawns form economically important group as most of them are harvested from the wild or cultured for food as well as aquarium trade. Overall diversity of freshwater prawns is rapidly declining or under risk category mainly due to competition from invasive species, change in climate and commercial developmental projects (De Grave et al 2015). Freshwater prawns play a crucial role in the recycling of nutrients, structuring and functioning of the ecosystem (Snyder, 2016) and form one of the most dominant biomass rich group in the river ecosystem (Greathouse and Pringle 2006). Being keystone species in the river ecosystem, they actively participate in sustaining the food web by transferring nutrients and energy from decay matter and producers to higher trophic levels and also play an important role as scavengers (Camara et al 2009). Quality of water and anthropogenic pollution can be determined by presence of species and their abundance (Sharma and Chowdhary 2012, Susilo et al 2020).

Jammu region is bestowed with large number of perennial rivers which form part of Indus river system. The most important rivers that flow in the Jammu region are Ravi and Chenab that harbour abundant fishery resources. Since freshwater fauna especially prawn resources are at risk of being carried away from their respective habitats (Ranganu and Marippan 2011), therefore it is necessary to have a reliable data based on surveys and identification of prawns from natural habitats. These records are prerequisite for further biological studies related to cultural aspects and protection of the fauna.

MATERIAL AND METHODS

Sampling sites, duration and method: The present research was carried out in five rivers (Fig. 1). Gho Manhasa River (Site 1), Chakrali River (Site 2), Chadwal River (Site 3), Sai River (Site 4) and Nagri river (Site 5). Gho Manhasa, Chakrali and Sai rivers form the tributaries of Chenab whereas Chadwal and Nagri form the tributaries of Ravi. Gho Manhasa, Chakrali and Sai rivers lie in district Jammu with an elevation of 300, 302 and 333mrespectively whereas Chadwal and Nagri rivers lie in Kathua district with an elevation of 379m and 318m respectively. Bottoms of Gho Manhasa and Chakrali rivers comprise mostly of cobbles, Sai and Nagri rivers is mostly sandy whereas the Chadwal river had mostly sandy bottoms with few large stones at the marginal area around the river. Plenty of aquatic vegetation is found along the margins of Gho Manhasa, Chakraliand Nagri rivers, moderate vegetation was observed in the marginal area of Chadwal along with floating macrophytes in the middle of the river and Sai River had scanty vegetation. The study was conducted for a period of one year i.e., from June, 2019 to May, 2020. Sampling was done early in the morning between 7 to 9 am with the help of cast net having mesh size 5mm×5mm. The collected samples were counted on the spot and were brought to the Department of Zoology, University of Jammu in ice cooled boxes.

Identification of the specimens: The identification of the prawn specimens was done following Paul (1991), Cai and Ng (2002), Sharma and Subba (2005) and Thomas (2011). The prawns belonging to genus *Macrobrachium* were larger in size whereas those belonging to genus *Caridina* were smaller in size, therefore they were studied under stereomicroscope. Shape of the rostrum, number of teeth present on dorsal and ventral side of rostrum, characteristics of second pereiopod, shape of telson and arrangement of spines on dorsal and distal end of telson form important features for identification.

Diversity analysis

Relative abundance of prawn species were determined by the following formula

$$\text{R.A.} = \frac{\text{Number of specimens of a species}}{\text{Total number of specimens of all the species}} \times 100$$

Diversity index among different sites was calculated using Shanon Weiner index

$$H = -\Sigma\left(\frac{ni}{N}\right)\log 2\left(\frac{ni}{N}\right)$$

Where, ni is the total count of all the specimens of a species, total count of all the specimens of all the species.

Species richness was calculated using Margalef index

M= S-1/ ln N, where N is the total number of specimen, S is the number of species.

Evenness was calculated using Pielou index

J= H/ ln S, where H is the Shannon Weiner diversity index, S is the total number of species in the sample

Statistical analysis and Hierarchical cluster analysis was performed using PAST software (Version 4.03) and Microsoft Excel 2016.

RESULTS AND DISCUSSION

Morphological identification of the specimen showed the presence of five species of prawn from the five water bodies of Jammu region. All the specimens were identified upto the species level except one species which was identified only upto the genus level and named as *Caridina* spp. The species belong to two genera i.e., *Macrobrachium* and *Caridina* and the species include *Macrobrachium dayanum, Macrobrachium kistnense, Macrobrachium lamarrei, Caridina babaulti, Caridina* spp. (Fig.1).

Macrobrachium dayanum: The rostrum of this species is elongated reaching upto or beyond the length of the antennal scale. It may be curved or slightly curved upwards. Chela of second pereiopod is longer than the carpus, which is moderately longer than merus. Two pairs of spines are present on the dorsal surface of the telson. Uropod consists of accessory spine on the telson.

Macrobrachium kistnense: The length of the rostrum is short rarely reaching the length of antennal scale. The rostrum is deep and straight. Merus of second pereiopod is shorter than the carpus and ischium is shorter than chela, merus and carpus. Distal half of the telson bears two pairs of spines. Uropod does not have accessory spine.

Macrobrachium lamarrei: Length of the rostrum is long, reaching past the antennal scale. Distal end of rostrum is slender and turned upwards. The most important feature of this species is the wide edentulous gap between first two and third dorsal teeth. Chela of second pereiopod is shorter than merus but carpus is longer than merus. Telson possesses two pairs of dorsal spines and uropod does not have accessory spine.

Caridina babaulti: This species is recently discovered in this region. Rostrum of this species is long, reaching the third antennular segment of antennular peduncle. Distal end of the rostrum is straight with slight bend in the upward direction. Ischium of second pereiopod is half in length as merus and merus is almost equal to carpus. Distal end of telson has

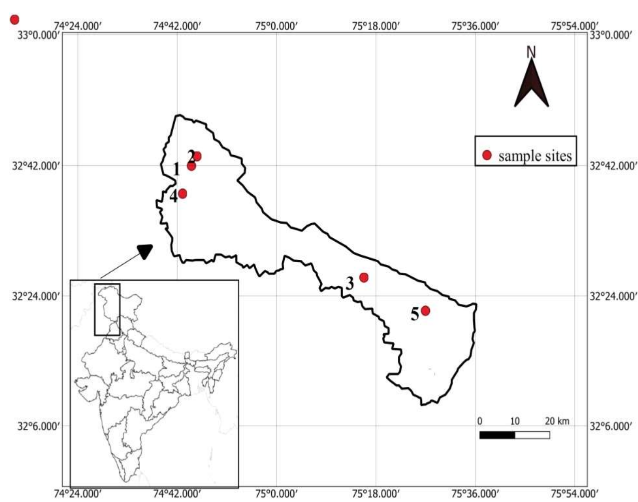


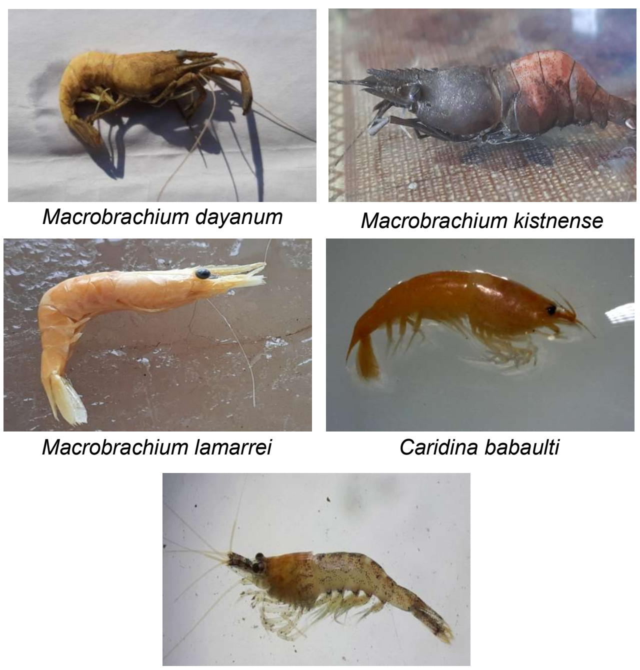
Fig. 1. Map showing different sampling sites

convex shape and 5-6 pairs of teeth are present on dorsal surface

Relative abundance of species at different sites: Among all the species, *M. dayanum* occurred at all the stations showing its cosmopolitan distribution and its highest relative abundance was at station 2 (Table 1). Station 3 showed high relative abundance of *M. kistnense*and*M. lamarrei* showed its high abundance at site 4. *C. babaulti* was found at station 3 and 5. Earlier only three species were recorded from five sites, *Caridina* species has been recently recorded from the study sites.

Cluster analysis between stations: Hierarchal cluster analysis using Euclidean distance method was performed to reveal the similarity between stations based on abundance and presence/ absence of the species (Fig. 3). Site 1 and 2 are closely associated in first cluster whereas site 3 and 5 forms part of first cluster with slight distance. Site 4 is totally distinct than the other sites and forms second cluster.

Diversity indices: Shanon- Weiner diversity index indicated the highest diversity at station 3 and lowest diversity at station 4 (Table 2). Margalef richness index was highest at station 3 whereas low values were found to be at station 4. Species evenness is described as the relative abundance of individuals of each species present in a community. Species evenness found no significant variations among stations and all the values were well within the range between 0.75< E<1



Macrobrachium dayanum *Macrobrachium kistnense*

Macrobrachium lamarrei *Caridina babaulti*

Caridina spp.

Fig. 2. Photographs of different species

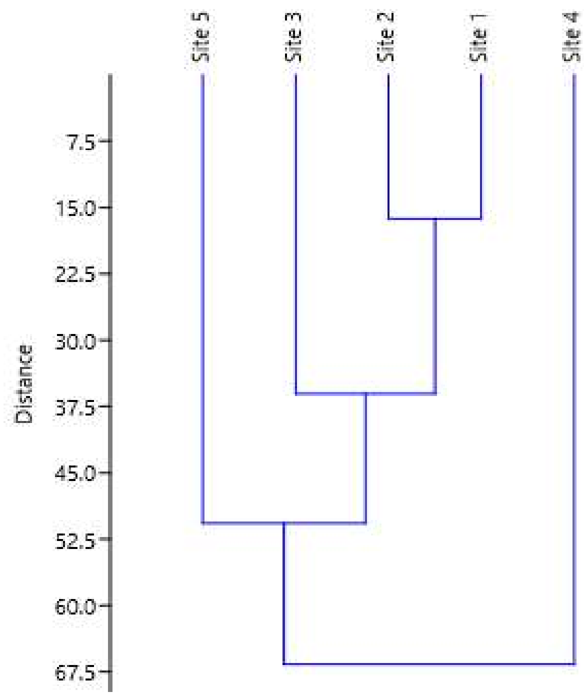


Fig. 3. Dendrogram of the sampling sites based on presence and abundance of the species

Table 1. Relative abundance of species at different sites

Species	Site 1	Site 2	Site 3	Site 4	Site 5
M. dayanum	50	38	69	11	78
M. kistnense	25	16	38	0	65
M. lamarrei	0	0	18	17	0
C. babaulti	18	12	17	0	29
C. spp.	17	15	12	0	19

Table 2. Diversity indices at different sites

Index	Site 1	Site 2	Site 3	Site 4	Site5
Shannon Weiner index	1.28	1.27	1.39	0.67	1.24
Margalef index	0.63	0.68	0.79	0.30	0.57
Pielou index	0.89	0.89	0.80	0.97	0.87

which represents stable community (Kreb 1989). Diversity indices showed that site 3 followed by site 1 and 2 are most preferred habitats as it shows highest number and diversity of prawn species. It may be due to abundant food resources present in these sites like benthic organisms, algae and planktons. Prawns feed on benthic organisms and are detritivores (Sharma and Subba 2005), therefore there is significant positive correlation between its abundance and food resources as indicated by Bakhtiyar (2008). These streams have abundant aquatic vegetation, which may have provided the species with ample space, so no significant competition among species occurred. Low diversity and low rate of abundance of species was observed at site 4, indicating loss of its suitability for sustaining life due to destruction of natural habitats, increased level of pollution and over exploitation of the species. *Macrobrachium siwalikense* was earlier reported from station 4 (Nipoon 2015) but during the present survey, no specimens of *M. siwalikense* were found revealing that the population of this species must have wiped out. Jewel et al. (2018) observed similar reasons for declined diversity and low abundance in one of the studied habitats.

CONCLUSION

The results of the present study will serve as baseline information regarding fresh water prawn diversity in Jammu region. Diversity and abundance of prawn species is affected by the anthropogenic factors that has significant effect on them. The study suggests that site 4 needs appropriate management and conservation strategies to prevent the further loss of populations from this site.

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Zooplankton Diversity and Water Quality Assessment of Lentic Waters of Jammu, India

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Abstract: An attempt was made to study the abiotic parameters of three water bodies of Jammu region along with their impact on distribution and presence of zooplankton. The total of 49 organisms belonging to five groups of zooplankton viz Protozoa, Rotifera, Cladocera, Copepoda and Ostracoda were identified. Of the three stations, ostracods were recorded from station 1 only. Phylum Rotifera was observed to be dominant in all the three stations. Many pollution indicator species like *Brachionus calyciflorus, Brachionus angularis, Keratella tropica, Polyarthra vulgaris, Filinia longiseta, Moina brachiata, and Chydorus sphaericus* were recorded from Station 1. Both biotic and abiotic components indicate that station 1 is progressing towards eutrophication.

Keywords: Physico-chemical parameters, Zooplankton, Trophic status, Eutrophication, Pollution indicator

Water provides habitat to millions of aquatic organisms and of these, zooplankton form the most dynamic component. These are free swimming organisms in freshwaters represented mostly by five major groups viz Protozoa, Rotifera, Cladocera, Copepoda and Ostracoda. They have significant role in aquatic food web as they transfer energy from primary producers to secondary consumers and act as efficient live feed for fish larvae. The qualitative and quantitative studies of zooplankton help in assessing the pollution level and trophic status of any water body (Thakur et al 2013). Physico-chemical parameters of a water body are used as key factors to determine the trophic status of water bodies and their influence determines zooplanktonic existence as abiotic and biotic components are co-related in any aquatic system. The biotic components represented by zooplankton can be used as a bio tool for trophic status estimation as they react rapidly to changing ecological conditions and thus can be helpful in determining the utility level of water so present. The present work aimed to study the impact of abiotic factor on biotic components of three different water bodies of Jammu region with special emphasis on their trophic status estimation and water quality assessment.

MATERIAL AND METHODS

Study area: Jammu region is blessed with various lentic and lotic water sources. For the present study, three lentic water bodies were selected which are located at different regions of Jammu. Station 1 is a wetland situated at Gharana village (R.S. Pura) at a latitude of 32°32´26´´N and longitude of 74°41´24´´E. This is a world famous wetland being breeding site of Siberian birds. Station 2 is a temple pond situated at Deeli village of Jammu district located at 32°40´38´´N latitude and 74°54´22´´E longitude. Being a sacred pond, it has religious importance. Station 3, also a temple pond situated at Bishnah village of Jammu district located at a latitude of 32.62°N and longitude of 74.87°E topographically being different from previous two as it is surrounded by agricultural fields.

Sample collection: The investigation was carried out during (March 2019-February 2020). Water sample was collected during morning hours for analysing various abiotic and biotic components. For collection of zooplankton, 50 litres of pond water was filtered through plankton net of mesh size 40µm and the filtrate was concentrated to 20 ml followed by preservation in 4% formalin. Further taxonomic analysis was done in laboratory by observing the sample under compound microscope. For quantitative analysis of zooplankton, drop count method (Adoni 1985) was used. The abiotic parameters were analysed following APHA (1985) and identification of zooplankton was done following Kudo (1966), Pennak (1978), Adoni (1985), Michael & Sharma (1988), Edmondson (1992) and Altaff (2004).

RESULTS AND DISCUSSION

Abiotic parameters: The fCO_2 level at Station 1 was higher as compared to the other two stations (Table 1). The probable reason for this can be the thick mat of floating *Eichhornia* sp. which reduces light penetration thereby reducing photosynthesis inside water resulting in increased fCO_2 level here. Relatively high BOD was obtained from this station. BOD is directly related to the amount of organic matter decomposed and its high value indicates presence of enormous amount of organic matter in this water body. High values of chloride at this station is also an indicator of eutrophy. The bicarbonates, calcium, magnesium and total hardness were high due to low water levels of this wetland. Station 2 had average values for all these abiotic parameters except for high values of phosphates which can be due to anthropogenic activities. In station 3 dissolved oxygen, carbonates, and pH were comparatively higher than the other two stations. High DO level of this station is an indicator of its relatively clearer status.

Biotic parameters: The total of 49 zooplankton species were recorded of which 4 species belonged to phylum Protozoa, 31 species to phylum Rotifera, 9 to Cladocera, 3 to Copepoda and 2 species belonged to phylum Ostracoda. Ostracods showed their presence at station 1 only. Muddy bottom of this station seems to be a supportive condition for their existence. Station wise qualitative analysis showed species diversity in the order Station 1(34)> Station 3(29)> Station 2(28) (Table 2, Fig. 1).The hierarchy of dominance of zooplankton present at the three stations is described below:

Station 1: Rotifera(53%) > Cladocera(26%) > Protozoa(9%) > Copepoda (6%) = Ostracoda (6%) (Fig. 2).

Station 2: Rotifera (75%)> Cladocera (11%) = Protozoa (11%)> Copepoda(3%) (Fig. 3).

Station 3: Rotifera (72%) > Cladocera (14%) > Protozoa (7%) = Copepoda (7%) (Fig. 4)

The phylum Rotifera dominated all the three stations (Fig. 1-4). Among rotifers, family Brachionidae was most abundant. Kour et al (2021), also observed the dominance of family Brachionidae among all zooplankton groups. Comparatively less number of copepods were recorded from all the study sites.

Correlation analysis: Station 1 had the highest species richness (Table 2) which may be due to the high organic load in this water body which supports a wide variety of life forms here. Correlation analysis of this water body revealed positive as well as negative correlation between biotic and abiotic parameters (Table 3). Among zooplankton, Protozoa and Rotifera showed significant positive correlation. Further both groups showed significant positive correlation with chloride and fCO_2 and a significant negative correlation with calcium. Cladocerans were positively co-related with bicarbonates and nitrates and negatively co-related with temperature. Copepods showed negative correlation with sulphates. The positive correlation of ostracods with magnesium and total hardness was also observed. Apart

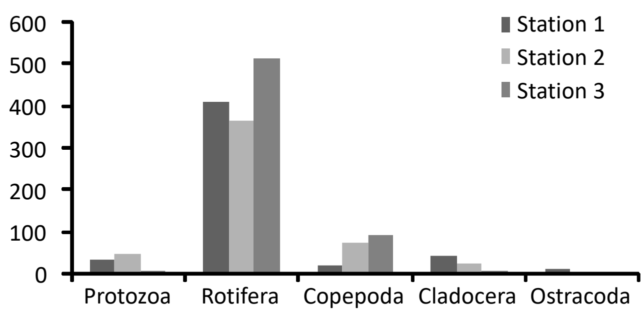

Fig. 1. Comparative abundance of zooplankton at three stations

Table 1. Annual mean values of physico-chemical parameters of the water bodies (Average±SD)

Abiotic parameters	Station 1	Station 2	Station 3
Air temperature (°C)	21.8±10.47	24.5±12.58	20.62±10.87
Water temperature (°C)	22..3±9.56	23.2±10.43	19.5±8.54
pH	7.2±1.23	7.4±0.298	8.27±0.63
DO (mg l^{-1})	3.84±0.32	2.02±0.48	7.92±7.13
fCO_2 (mg l^{-1})	27.28±26.13	10.7±1.78	15.84±4.89
Carbonates (mg l^{-1})	7.2±3.6	-	15.6±7.8
Bicarbonates (mg l^{-1})	640.09±589.07	158.6±15.23	306.22±244.57
Chloride (mg l^{-1})	47.7±27.56	23.7±6.19	25.64±7.98
Calcium (mg l^{-1})	34.47±13.28	33±14.66	22.07±6.25
Magnesium (mg l^{-1})	26.9±8.70	24.5±14.84	24.5±5.37
Total hardness (mg l^{-1})	225.5±37.46	183.5±25.21	183.5±17.35
BOD (mg l^{-1})	2.7±1.02	2.02±0.48	2.02±0.911
Phosphate (mg l^{-1})	0.286±0.044	0.314±0.264	0.112±0.0658
Sulphate (mg l^{-1})	0.002±0.0003	0.0019±0.0003	0.0017±0.0003
Nitrate (mg l^{-1})	0.578±0.0039	0.576±0.0036	0.5819±0.0068

Table 2. Organisms recorded from the three stations

Family	Zooplankton species	St. 1	St. 2	St. 3
Phylum Protozoa				
Centropyxidae	*Centropyxis aculeata* (Ehrenberg) Stein	+	++	+
Vorticellidae	*Vorticella* sp.	++	+	+
Epistylidae	*Epistylis* sp.	+++	+	++
Difflugiidae	*Difflugia accuminata* (Ehrenberg 1838)	-	+	-
Phylum Rotifera				
Family Brachionidae	*Brachionus calyciflorus* (Pallas 1766)	+++	+	+
	B. falcatus (Zachariad 1898)	-	++	+++
	B. caudatus (Barrois and Daday 1894)	-	++	+
	B. bidentata (Anderson 1889)	-	-	+
	B. quadridentatus(Hermann 1783)	++	+	+
	B. forficula (Wierzejski 1891)	+	+	+
	B. rubens (Ehrenberg.1838)	+	+	+
	B. angularis (Gosse 1851)	++	+	-
	B. budapestinensis (Daday 1885)	-	+	-
	Keratella tropica (Apstein 1907)	++	+	+
	Keratella quadrata (O.F.Muller 1786)	-	-	+
	Platyias patulus(O.F.Muller 1786)	+	+	+
	P. quadricornis (Wiszniewski 1954)	+	-	-
	Anuraeopsis fissa (Gosse 1851)	-	+	+
Family Euchlanidae	*Euchlanis dilatata* (Myers)	++	-	-
Family Synchaetidae	*Polyarthra vulgaris* (Carlin 1943)	+	+	+
Family Asplanchnidae	*Asplanchna brightwelli* (Gosse 1850)	++	+	+
Family Testudinellidae	*Testudinella patina* (Hermann 1783)	++	-	-
Family Mytillinidae	*Mytilina ventralis* (Ehrenberg 1832)	+	-	-
Family Epiphanidae	*Epiphanes brachionus*(Ehrenberg 1837)	+	-	-
	E. clavulata (Ehrenberg 1831)	-	+	-
Family Lecanidae	*Lecane leontina* (Turner 1892)	+	+	+
	L. curvicornis (Murray 1913)	+	++	+
	Monostyla bulla (Gosse 1851)	+	-	+
	M. decipiens (Murray 1913)	-	-	+
Family Lepadellidae	*Lepadella ovalis* (O.F. Muller 1786)	+	-	-
Family Trichocercidae	*Trichocerca similis* (Wierzejski 1893)	-	+	+
Family Notommatidae	*Cephalodella gibba*(Ehrenberg 1832)	+	+	+
Family Philodinidae	*Philodina* sp.	+	+	+
Family Filinidae	*Filinia longiseta* (Ehrenberg 1834)	++	+	+
Family Hexarthridae	*Hexarthra mira* (Hudson 1871)	-	+	-
Phylum Arthropoda				
Subphylum Crustacea				
Order Cladocera				
Family Chydoridae	*Alona* sp.	+	+	+
	Chydorus sphaericus (Muller 1785)	++	+	+
	Pleuroxus sp. (Baird 1843)	+	-	-
Family Moinidae	*Moina brachiata* (Jurine 1820)	+++	+	+
Family Macrothricidae	*Macrothrix rosea* (Jurine 1820)	+	-	+
Family Daphniidae	*Ceriodaphnia* sp. (Dana 1853)	+	-	-
	Scapholeberis kingi (Sars 1903)	+	-	-
	Simocepahalus vetulus (Schodler 1858)	+	-	-
Family Sididae	*Diaphanosoma* sp.	+	-	-
Subclass Copepoda				
Family Cyclopidae	*Mesocyclops leuckarti* (Claus 1857)	+	+	+
	Cryptocyclops bicolor (Sars 1863)	-	-	+
	Eucyclops agilis (Koch 1838)	+	-	-
Phylum Ostracoda				
Family Cyprididae	*Stenocypris* sp.	++	-	-
	Cypris sp.	+	-	-

Table 3. Correlation between biotic and abiotic parameters of Station 1

	Correlations																			
	AT	WT	pH	DO	fCO2	CAR	BICAR	CHL	CAL	MAG	TH	BOD	PHOS	SUL	NIT	PROTOZOA	ROTIFERA	CLADOCERA	COPEPODA	OSTRACODA
AT	1																			
WT	.987*	1																		
pH	.962*	.951*	1																	
DO	-0.824	-0.879	-0.688	1																
fCO2	0.269	0.274	0.521	0.138	1															
CAR	0.453	0.531	0.242	-0.870	-0.549	1														
BICAR	-.999**	-.989*	-0.948	0.852	-0.225	-0.499	1													
CHL	0.163	0.239	0.397	0.016	0.901	-0.309	-0.135	1												
CAL	-0.278	-0.309	-0.524	-0.055	-.987*	0.443	0.239	-.957*	1											
MAG	-0.141	-0.260	0.037	0.675	0.550	-0.922	0.189	0.188	-0.412	1										
TH	-0.380	-0.522	-0.428	0.597	-0.348	-0.489	0.393	-0.668	0.492	0.591	1									
BOD	0.570	0.696	0.567	-0.782	0.244	0.647	-0.587	0.524	-0.380	-0.659	-.966*	1								
PHOS	.975*	.973*	.996**	-0.748	0.469	0.325	-.966*	0.375	-0.483	-0.051	-0.476	0.622	1							
SUL	0.350	0.302	0.579	0.176	0.943	-0.632	-0.301	0.706	-0.880	0.737	-0.075	0.022	0.512	1						
NIT	-0.767	-0.664	-0.652	0.520	0.110	-0.269	0.765	0.401	-0.187	-0.122	-0.283	0.044	-0.645	-0.154	1					
PROTOZOA	0.156	0.226	0.395	0.045	0.917	-0.346	-0.126	.999**	-.966*	0.230	-0.636	0.491	0.370	0.732	0.392	1				
ROTIFERA	0.342	0.378	0.578	-0.022	.977*	-0.376	-0.306	.957*	-.997**	0.360	-0.539	0.441	0.542	0.867	0.148	.964*	1			
CLADOCERA	-0.827	-0.773	-0.658	0.773	0.270	-0.601	0.843	0.419	-0.292	0.247	-0.023	-0.233	-0.683	0.087	0.931	0.425	0.233	1		
COPEPODA	-0.508	-0.416	-0.671	-0.064	-0.764	0.537	0.463	-0.423	0.666	-0.766	-0.142	0.110	-0.603	-0.931	0.487	-0.452	-0.662	0.219	1	
OSTRACODA	0.076	-0.085	0.111	0.401	0.128	-0.595	-0.043	-0.310	0.034	0.830	0.824	-0.755	0.041	0.440	-0.568	-0.271	-0.065	-0.236	-0.670	1

*. Correlation is significant at the 0.05 level (2-tailed).
**. Correlation is significant at the 0.01 level (2-tailed).

from this, bicarbonates showed a significant negative correlation with temperature and pH. A significant positive correlation was observed between phosphates, temperature and pH and a significant negative correlation between phosphates and bicarbonates was observed. Chloride and fCO_2 were positively correlated and both showed a significant negative correlation with calcium.

Station 2 bears the highest anthropogenic influence which is supported by less abundance of copepods in this station. In this station, a positive correlation was observed between Ostracoda and Cladocera. Ostracoda showed positive correlation with DO, BOD, magnesium and total hardness. Rotifera showed positive correlation with temperature. Cladocera, DO and BOD were positively co-related and a negative correlation was observed between Cladocera and fCO_2. Chloride showed a significant positive correlation with phosphates and a significant negative correlation with sulphates. DO, BOD, magnesium and total hardness were positively co-related (Table 4)

In Station 3, cladocerans and protozoans were positively co-related. Protozoans also showed a significant positive correlation with chloride. Rotifers showed positive correlation with pH. A significant negative correlation between cladocerans and magnesium and a positive correlation between cladocerans and chloride was observed. Copepods showed a significant negative correlation with carbonates, bicarbonates and total hardness and positive correlation with temperature and fCO_2. Among abiotic parameters, a significant positive correlation was observed between carbonates, bicarbonates and total hardness. Magnesium showed negative correlation with temperature and chloride (Table 5).

Zooplankton as bioindicators: The potentiality of zooplankton as pollution indicators and their role in trophic status estimation of water bodies has long been considered by many workers (Parmar et al 2016, Ferdous and Muktadir 2009, Ramchandra et al 2006). Many pollution indicator rotifer species such as *Brachionus calyciflorus, B. angularis, Keratella tropica, Filinia longiseta, Polyarthra vulgaris, Euchlanis dilatata, Testudunella patina, Asplanchna brighwelli, Cephalodella gibba* were numerically abundant at station 1 (Table 2). Abundance of these pollution tolerant species in organically rich water bodies was also recorded by Thakur et al (2013) and Murkute and Chavan (2016).

Rotifers such as *Brachionus falcatus, Anuraeopsis fissa and Trichocerca* sp. showed their presence at station 2 and 3 and were completely absent from Station 1. These rotifers commonly dwell in oligotrophic waters (Arora 1966). Their

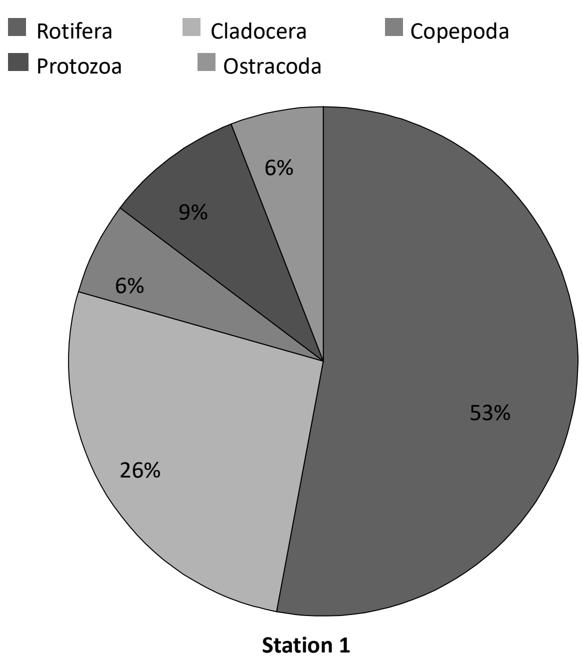

Fig. 2. Percent contribution of zooplankton at station 1

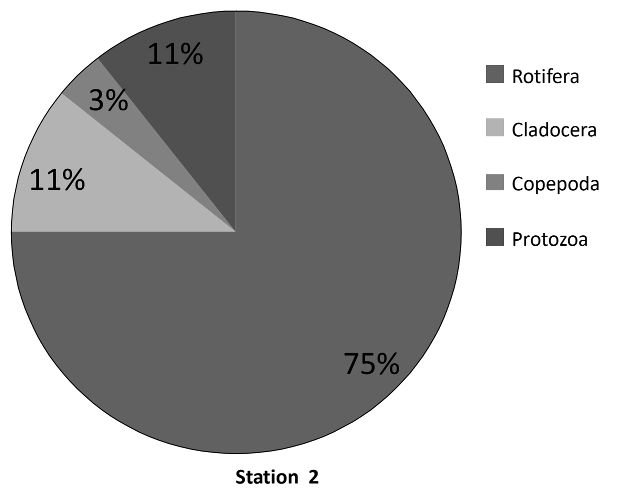

Fig. 3. Percentage composition of zooplankton at station 2

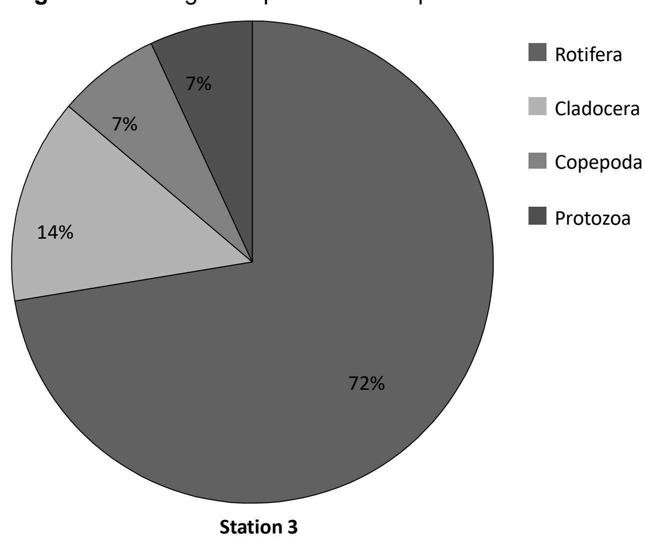

Fig. 4. Percentage composition of zooplankton at station 3

Table 4. Correlation between biotic and abiotic parameters of Station 2

	Correlations																		
	AT	WT	pH	DO	fCO2	BICAR	CHL	CAL	MAG	TH	BOD	PHOS	SUL	NIT	PROTOZOA	ROTIFERA	CLADOCERA	COPEPODA	OSTRACODA
AT	1																		
WT	.996**	1																	
pH	0.067	0.131	1																
DO	0.849	0.874	0.573	1															
fCO2	-0.486	-0.470	-0.471	-0.719	1														
BICAR	0.007	0.020	0.765	0.469	-0.825	1													
CHL	0.717	0.740	-0.149	0.438	0.242	-0.575	1												
CAL	-0.607	-0.666	-0.802	-0.887	0.462	-0.445	-0.434	1											
MAG	0.637	0.691	0.803	0.924	-0.560	0.517	0.382	-.993**	1										
TH	0.667	0.710	0.786	.957*	-0.689	0.607	0.298	-.960*	.986*	1									
BOD	0.849	0.874	0.573	1.000**	-0.719	0.469	0.438	-0.887	0.924	.957*	1								
PHOS	0.582	0.597	-0.336	0.225	0.426	-0.747	.974*	-0.228	0.166	0.073	0.225	1							
SUL	-0.868	-0.871	0.212	-0.554	-0.010	0.468	-.954*	0.413	-0.394	-0.357	-0.554	-0.907	1						
NIT	0.335	0.411	0.875	0.685	-0.238	0.402	0.337	-0.944	0.909	0.838	0.685	0.160	-0.224	1					
PROTOZOA	0.100	0.155	-0.010	-0.027	0.710	-0.652	0.740	-0.270	0.162	0.003	-0.027	0.782	-0.505	0.414	1				
ROTIFERA	0.917	0.947	0.269	0.851	-0.281	-0.052	0.844	-0.791	0.781	0.749	0.851	0.701	-0.881	0.620	0.426	1			
CLADOCERA	0.796	0.787	0.403	0.908	-0.914	0.592	0.171	-0.640	0.719	0.816	0.908	-0.025	-0.391	0.370	-0.418	0.635	1		
COPEPODA	-0.654	-0.625	0.645	-0.166	-0.219	0.723	-0.813	-0.060	0.074	0.092	-0.166	-0.864	0.884	0.247	-0.386	-0.562	-0.126	1	
OSTRACODA	0.662	0.687	0.726	0.948	-0.855	0.726	0.135	-0.854	0.908	.965*	0.948	-0.093	-0.262	0.683	-0.252	0.645	0.919	0.133	1

**. Correlation is significant at the 0.01 level (2-tailed).

*. Correlation is significant at the 0.05 level (2-tailed).

Table 5. Correlation between biotic and abiotic parameters of Station 3

	Correlations																		
	AT	WT	pH	DO	fCO2	CAR	BICAR	CHL	CAL	MAG	TH	BOD	PHOS	SUL	NIT	PROTOZOA	ROTIFERA	CLADOCERA	COPEPODA
AT	1																		
WT	.989*	1																	
pH	-0.045	-0.046	1																
DO	-0.263	-0.293	.951*	1															
fCO2	0.548	0.476	0.680	0.616	1														
CAR	-0.866	-0.819	-0.391	-0.232	-0.893	1													
BICAR	-0.850	-0.789	-0.353	-0.221	-0.901	.994**	1												
CHL	0.696	0.772	0.393	0.091	0.420	-0.638	-0.554	1											
CAL	0.263	0.391	-0.376	-0.606	-0.515	0.156	0.234	0.545	1										
MAG	-0.880	-0.939	-0.031	0.268	-0.320	0.672	0.609	-0.914	-0.626	1									
TH	-0.885	-0.845	-0.378	-0.205	-0.872	.999**	.988*	-0.675	0.103	0.711	1								
BOD	0.068	0.196	0.447	0.212	-0.046	-0.026	0.080	0.754	0.649	-0.510	-0.066	1							
PHOS	0.017	-0.035	-0.930	-0.799	-0.481	0.292	0.221	-0.596	0.016	0.223	0.299	-0.744	1						
SUL	-0.605	-0.597	-0.768	-0.590	-0.894	0.867	0.827	-0.758	0.134	0.587	0.869	-0.397	0.729	1					
NIT	-0.163	-0.027	-0.327	-0.473	-0.743	0.522	0.597	0.281	0.908	-0.269	0.475	0.664	-0.031	0.369	1				
PROTOZOA	0.580	0.677	0.370	0.066	0.277	-0.492	-0.397	.984*	0.644	-0.873	-0.533	0.851	-0.620	-0.665	0.432	1			
ROTIFERA	0.181	0.166	.971*	0.891	0.826	-0.598	-0.566	0.497	-0.380	-0.191	-0.586	0.384	-0.880	-0.890	-0.431	0.438	1		
CLADOCERA	0.758	0.844	0.045	-0.266	0.179	-0.525	-0.447	0.936	0.749	-.977*	-0.571	0.663	-0.298	-0.519	0.451	0.932	0.163	1	
COPEPODA	0.870	0.824	0.388	0.227	0.889	-1.000**	-.994**	0.644	-0.147	-0.679	-.999**	0.032	-0.293	-0.868	-0.514	0.499	0.596	0.533	1

*. Correlation is significant at the 0.05 level (2-tailed).

**. Correlation is significant at the 0.01 level (2-tailed).

presence at Station 2 and Station 3 indicate comparatively less organic matter in these water bodies. Apart from rotifers, cladocerans also act as bioindicator of health of the aquatic system. Cladocerans like *Moina brachiata, Chydorus sphaericus, Ceriodaphnia* sp., *Alona* sp., *Diaphanosoma* sp. were commonly observed at Station 1. These cladoceran species are considered as good indicators of eutrophic conditions by many workers (Ferdous and Muktadir 2009, Singh et al 2013) and their presence at Station 1 further authenticate the eutrophic nature of this water body. Protozoans such as *Epistylis* sp. and *Vorticella* sp. indicate presence of high amount of organic matter in any water body. Both these species were recorded from Station 1 in considerable number. Their abundance in a water body is an indicator of high trophic status (Singh et al 2013). Copepods,in general, flourish well in relatively stable environments and indicate good health of water body. In the present case, copepods were less abundant than other groups in all sites. Considering this data, Station 1 was found to have more organic load as compared to other two stations as this water body had many pollution tolerant and bioindicator species (Table 2). This station is tending fast towards eutrophism as evident by both biotic and abiotic parameter.

CONCLUSION

A well-marked correlation among biotic and abiotic components of water systems was observed. The three stations, situated at distant places of Jammu region, showed a total of 49 zooplankton species belonging to 5 groups. Various pollution indicator species like *Brachionus calyciflorus, B. angularis, Keratella tropica, Polyarthra vulgaris, Filinia longiseta, Moina brachiata, and Chydorus sphaericus* were reported. Ostracods being the only group showing selectivity for soft bottom and thus were present only at Station 1. Overall analysis of zooplankton revealed station 1 to be most inclined towards eutrophication as compared to the other two stations due to abundance of indicator species and this was also supported by abiotic data.

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Bio-monitoring of Western Ghats Stream using Aquatic insects

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Abstract**:** In this study health of the Kallar stream and its tributaries originating from Western Ghats in Kerala using aquatic insects as indicators was assessed. Two-year sampling of aquatic insects was done on a monthly basis from five different sites. Insects were collected and identified using the methodology of Rapid Bio-assessment Protocol. A total of 29372 individuals belonging to 9 orders and 61 families of aquatic insects were collected and identified from the selected study sites. Highest number of aquatic insect was obtained in the site 5 (7531) and the lowest number was observed in site 3 (4571). All richness measures were maximum in site 5 and the minimum in site 3. In addition to that the biotic indices like Family Biotic Index (FBI), Biological Monitoring Working Party (BMWP) Score and Average Score per Taxon (ASPT) also show that water quality of site 5 is free from organic pollution compared to the other sites.

Keywords: Aquatic insects, Biomonitoring, Family Biotic Index, Indicators, Kallar stream

Aquatic insects have been used as bio-indicators and are amongst the most frequently used groups in biological assessment of water quality worldwide (Bunn et al 2010, Chon et al 2013, Kamal and Kumar 2021). They play important ecological roles in keeping freshwater ecosystems functioning properly (Choudhary and Janak 2015). Aquatic insects may have considered model organisms in analyzing the structure and function of the freshwater ecosystem because of their high abundance, high birth rate with short generation time, large biomass and rapid colonization of freshwater habitats (Solanki and Shukla 2015, Pandian et al 2019). Rapid bio-assessment approaches are meant to provide an initial screening of water bodies for further investigations (Mandaville 2002). Family level identification is useful for one-time assessment of water quality in a specific area, or in the ranking of sites for additional study. Variations in the diversity of aquatic insects may be attributed to the degree of anthropogenic interference in the ecological balance of fresh water bodies, where anthropogenic activities of humans associated with a reduction in diversity of aquatic insect communities (Popoola and Otalekor 2011, Wahizatul et al 2011, Abhijna et al 2012, Adu and Oyeniyi 2019). The present study is an attempt to evaluate the water quality of Kallar stream and its tributaries using aquatic insects. This data will be helpful as a yardstick to assess the water quality in the years to come.

MATERIAL AND METHODS

Study area: The study stream Kallar is a perennial river located near Ponmudi in Thiruvananthapuram district, Kerala, part of the Southern tip of Western Ghats. 'Kallar' literally means stony river. It forms the upper course of Vamanapuram River, part of Neyyar Wildlife Sanctuary. It originates from Chemmunji Mottai, a mountain peak in the Western Ghats at an elevation of 1860 m above MSL. In this study five collection sites were selected were- Darpha-Kalungu (S1- 8˚40'42se N, 77˚04'02se E), Pottanchira (S2- 8˚41'31se N, 77˚03'09se E), Kaliyikkal (S3- 8˚40'16se N, 77˚06'04se E), Meenmutti (S4- 8˚42'36se N, 77˚07'41se E) and main Kallar (S5- 8˚43'42se N, 77˚07'37se E) (Table 1, Fig. 1). From these the first four sites are the tributaries of Kallar stream and the fifth one is the main stream. The sites are chosen based on their location relative to habitat availability, land use pattern and human intervention. At each sampling locality, a stretch of 100 m area was chosen for collection of samples.

The aquatic insect sampling was done for two years (January 2012- December 2013) based on the methodology of Rapid Bio-assessment Protocol (Barbour et al 1999). Aquatic insects were collected by using kick net ($1 m^2$ area, mesh size 200 μm) and D-frame net (mesh size 50 μm). The organisms trapped within the net were collected without any damage using fine forceps and brush and preserved in 70% alcohol. In the laboratory, the immature insects were sorted, identified and counted. Family level identifications were made by using available references (Mc Cafferty and Provonsha 1981, Morse et al 1984, Yule and Sen 2004, Subramanian and Sivaramakrishnan 2007). All the taxa encountered during the study were assigned a habit (mode of existence) and functional feeding categories with the help of published references (Resh and Rosenberg 1984, Pringle et al 1988, Merrit and Cummins 1996). Benthic metrics like richness measures (taxa), composition measures (%), feeding measures (%) and habit measures were calculated for each site (Barbour et al 1999). In addition to that the biotic indices like Family Biotic Index (FBI), Biological Monitoring Working Party (BMWP) Score and Average Score Per Taxon (ASPT) values were also measured.

Family biotic index (FBI): The biotic index was originally developed by Hilsenhoff (1982) to provide a single 'tolerance value' which is the average of the tolerance values of all species within the benthic arthropod community. The biotic index was subsequently modified to the family-level with tolerance values ranging from 0 (very intolerant) to 10 (highly tolerant) based on their tolerance to organic pollution, creating the Family Biotic Index (FBI) (Hilsenhoff 1988). FBI was further developed by the State of New York to include other macroinvertebrates for the use of the U.S. EPA Rapid Bio-assessment Protocol II (Plafkin et al 1989, Bode 1991). FBI was calculated as:

$FBI = n_i t_i$

N

Where, n_i= number of organisms in each family

$t_{i=}$ tolerance value of that family

N = total number of insects

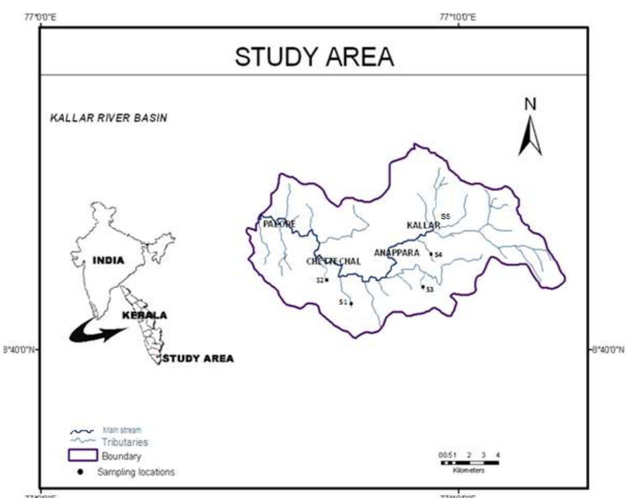

Fig. 1. Location site

Biological monitoring working party score (BMWP): The biological monitoring working party score (BMWP) provides single values, at the family level, representative of the organisms' tolerance to pollution. The greater their tolerances towards pollution, the lower the BMWP score. To reflect conditions within North America, Mackie (2001) has modified this index. BMWP was calculated by adding the

Table 2. Evaluation of water quality using the family-level biotic index

FBI	Water quality	Degree of organic pollution
0.00-3.75	Excellent	Organic pollution unlikely
3.76-4.25	Very good	Possible slight organic pollution
4.26-5.00	Good	Some organic pollution probable
5.01-5.75	Fair	Fairly substantial pollution likely
5.76-6.50	Fairly poor	Substantial pollution likely
6.51-7.25	Poor	Very substantial pollution likely
7.26-10.00	Very poor	Severe organic pollution likely

Table 3. Evaluation of water quality using the average score per taxon (ASPT)

ASPT value	Water quality assessment
>6	Clean water
5-6	Doubtful quality
4-5	Probable moderate pollution
<4	Probable severe pollution

Table 1. Characteristics of Kallar stream and its tributaries

Characteristics	Site 1	Site 2	Site 3	Site 4	Site 5
Name of site	Darpha-Kalungu	Pottanchira	Kaliyikkal	Meenmutty	Main Kallar
Latitude	8˚40'42se N	8˚41'31se N	8˚40'16se N	8˚42'36se N	8˚43'42se N
Longitude	77˚04'02se E	77˚03'09se E	77˚06'04se E	77˚07'41se E	77˚07'37se E
Altitude(m)	111	105	116	156	227
Subsystem	Perennial	Perennial	Perennial	Perennial	Perennial
Vegetation	Trees and grass	Trees and grass	Trees and grass	Trees and grass	Trees and grass
Land use	Plantations	Plantations	Residential	Forest	Forest
Canopy	Open	Open	Open	Shaded	Shaded
Turbidity	Clear	Clear	Clear	Clear	Clear
Human settlement	Present	Present	Present	Present	Absent

Table 4. Aquatic insects collected from the study sites

Family	Site 1	Site 2	Site 3	Site 4	Site 5	Tolerance values	BMWP score value
Ephemeroptera							
Leptophlebiidae	932	1028	380	631	461	2	10
Ephemeridae	24	24	17	14	29	4	10
Potamanthidae	9	0	0	0	8	4	10
Ephemerellidae	2	4	0	4	8	1	10
Tricorythidae	0	0	0	0	2	4	
Caenidae	286	207	138	37	36	7	7
Heptageniidae	25	17	7	717	1230	4	10
Baetidae	300	245	177	184	129	4	4
Plecoptera							
Perlidae	216	297	49	695	1046	1	10
TRICHOPTERA							
Hydropsychidae	850	1312	845	1360	1890	4	5
Polycentropodidae	6	21	5	97	130	6	7
Psychomyeidae	0	3	0	0	4	2	8
Xiphocentropodidae	0	2	0	0	4		
Calamoceratidae	4	2	2	1	7	3	
Odontoceridae	2	2	2	4	8	0	10
Philopotamidae	0	2	5	150	189	3	8
Stenopsychidae	0	0	0	30	58		
Brachycenridae	4	4	4	18	17	1	10
Lepidostomatidae	2	0	0	9	50	1	10
Odonata							
Gomphidae	426	1044	374	320	683	1	8
Cordullidae	70	17	137	79	8	5	8
Libellulidae	240	31	259	42	12	9	8
Macromidae	7	20	37	10	4	3	
Coenagrionidae	14	18	24	13	15	9	6
Platycnemididae	51	3	94	11	24		6
Platystictidae	14	18	24	13	42		
Protoneuridae	86	14	75	9	7		
Lestidae	13	7	14	4	12	9	8
Chlorolestidae	70	79	156	95	123		
Calopterygidae	207	110	76	84	18	5	8
Chlorocyphidae	8	7	14	9	18		
Euphaidae	99	164	180	80	234	4	
Hemiptera							
Aphelocheridae	11	8	9	73	12		10
Nepidae	34	16	11	8	0	7	5
Belostomatidae	178	4	27	0	5	9	5
Naucoridae	624	166	932	330	215	5	5
Notonectidia	3	2	0	0	0	6	5

Cont...

Table 4. Aquatic insects collected from the study sites

Family	Site 1	Site 2	Site 3	Site 4	Site 5	Tolerance values	BMWP score value
Pleidae	2	3	1	4	7	1	5
Vellidae	80	103	21	92	2	6	5
Gerridae	71	76	83	82	26	5	5
Hydrometridae	10	0	0	0	0		
Coleoptera							
Hydroscaphidae	13	5	8	5	0	7	
Dytiscidae	313	130	100	59	17	5	5
Gyrinidae	9	35	6	14	5	4	5
Amphizoidae	0	9	4	3	14	1	
Hydraenidae	75	104	37	46	11	5	
Elmidae	9	51	12	64	80	4	5
Dryopidae	2	5	8	28	45	5	5
Hydrophilidae	21	15	45	46	13	5	5
Psephinidae	7	6	21	163	281	4	
Sperchidae	2	0	5	0	0		
Scritidae	0	0	6	0	0	5	5
Megaloptera							
Corydalidae	4	2	7	87	105	0	6
Lepidoptera							
Pyralidae	4	2	2	16	20	5	
Diptera							
Tipulidae	51	64	14	78	90	3	5
Ceratopogonidae	12	38	19	26	23	6	4
Chironomidae	4	6	17	5	6	6	2
Simulidae	8	12	35	19	10	6	5
Tabanidae	17	3	30	12	4	6	3
Athericidae	13	7	14	159	24	2	6
Ephydridae	5	4	2	4	10	6	4
Total	5549	5578	4571	6143	7531		

individual scores of all families, and order Oligochaeta (Friedrich et al 1996), represented within the community.

Average score per taxon (ASPT): The average score per taxon (ASPT) represents the average tolerance score of all taxa within the community, and was calculated by dividing the BMWP by the number of families represented in the sample (Friedrich et al 1996). From this value, the water quality of each lake was assessed.

RESULTS AND DISCUSSION

Overall 29372 individuals belonging to 9 orders and 61 families of aquatic insects were collected and identified. From this, a total of 5549 individuals belonging to 54 families were collected from site 1, 5578 individuals of 54 families from site 2, 4571 individuals of 53 families from site 3, 6143 individuals of 52 families from site 4 and 7531 individuals of 61 families from site 5 (Table 4). Aquatic insects were mostly contributed by the immature stages. They were represented by the orders of Ephemeroptera, Plecoptera, Trichoptera, Odonata, Hemiptera, Coleoptera, Megaloptera, Lepidoptera and Diptera. Ephemeroptera was the most dominant order with the highest number of individuals (24.89%) followed by Trichoptera, Odonata , Hemiptera and Plecoptera.

Highest number of aquatic insects was obtained in the site 5 (7531) and the lowest number was observed in site 3 (4571) (Table 4). The aquatic insects like Ephemeroptera, Plecoptera and Trichoptera are sensitive to environmental perturbations and occur in clean and well oxygenated waters

Table 5. Benthic metrics of the aquatic insects from selected sites

Category	Metrics (Taxa)	Site 1	Site 2	Site 3	Site 4	Site 5
Richness measures	Total number	5549	5578	4571	6143	7531
	EPT	2662	3170	1631	3951	5306
	Ephemeroptera	1578	1525	719	1587	1903
	Plecoptera	216	297	49	695	1046
	Trichoptera	868	1348	863	1669	2357
Composition measures (%)	EPT	47.97	56.83	35.68	64.32	70.46
	Ephemeroptera	28.44	27.34	15.73	25.83	25.27
	Trichoptera	15.64	24.17	18.88	27.17	31.30
	Diptera	1.98	2.40	2.87	4.93	2.22
	Chironomidae	0.07	0.11	0.37	0.08	0.08
Feeding measures (%)	Collector Filters	11.84	19.36	14.87	20.63	23.56
	Scrapers	18.89	18.27	12.16	20.50	22.29
	Collector-gatherers	24.22	23.98	14.83	23.09	21.52
	Predators	44.52	37.72	57.59	34.10	30.18
	Shredders	0.53	0.67	0.55	1.68	2.44
Habit measures	Number of clingers	3133	3353	2551	4717	6069
	Clingers (%)	35.70	41.10	38.10	53.10	64.60
FBI		4.2	3.22	4.42	3.4	3.16
BMWP		255	246	238	233	261
ASPT		6.38	6.31	6.26	6.47	6.53

only. Among EPT taxa, Oder Plecoptera have long been as the most pollution intolerant of the aquatic insect orders compared to the other two groups in this category such as Ephemeroptera and Trichoptera (Ab - Hamid 2017). In our study the number of Plecoptera was found to be maximum site 5 and the minimum value was observed in site 3. The Diptera was maximum in site 4 and the minimum in site 1. Diptera can be found in a clean stream to polluted streams (Abbasi et al 2020). The Chironomidae measures indicates that highest value was in site 3 and the lowest value in site 1. Family Chironomidae belongs to order Diptera is considered to be a pollution tolerant group may be due to the presence of hemoglobin pigment that helps them to collect oxygen directly from the atmosphere (Davason and Henry 2007).

The feeding measures like collector- filterers and shredders were highest in site 5 and the lowest in site 1. The percent scrapers were maximum in site 5 and minimum in site 3. The highest value of collector- gatherers was observed in site 1 and lowest in site 3. The maximum predators were obtained in site 3 and the minimum in site 5. The clingers were found to be maximum in site 5 and minimum in site 1. Collector gatherers are more tolerant to disturbances because they exhibit generalist feeding habits, whereas shredders and scrapers are exhibited the highest level of feeding specialization because of that they are considered to be more sensitive to environmental disturbances (Min et al 2019).

Comparison of FBI throughout the study showed that the higher FBI value was at site 3 (4.54) indicating greater pollution due to the presence of highly tolerant taxa such as Libellulidae, Coenagrionidae, Lestidae and Chironomidae compared to other sites which shows less pollution. Lower FBI value was found in site 5 (3.14) and it is due to the large number of pollution intolerant taxa like Ephemerellidae, Perlidae, Odontoceridae, Brachycentridae, Lepidostomatidae and Corydalidae. In our study the value of FBI ranged between 3.16 to 4.42 that is excellent to good water quality conditions. Similar results were also observed by Marwein and Gupta (2018) in a small stream of Shillong, Meghalaya. The maximum BMWP score was reported from site 5 and minimum in Site 3. This is because in site 5 the number of pollution intolerant families was high, while in site 3 pollution tolerant families are dominant. Low index value indicates the study area was physically disturbed and which results from the low abundance of aquatic organisms (Bhandarkar and Bhandarkar 2013). In study the highest ASPT score was reported in site 5 and lowest values observed in site 3.

CONCLUSION

The biomonitoring based on aquatic insects played a significant role in assessing the environmental status of Kallar stream and its tributaries. The biotic index value of site 3 comes in the range of 4.26-5.00, water quality is good but some organic pollution is possible here. The small scale human activities in site 3 are sufficient to produce some kind of organic pollution and to change the composition of aquatic insects during the period of observation. Rare specimens of habitat sensitive organisms such as Ephemeroptera, Plecoptera and Trichoptera still minimum in site 3 and maximum numbers were present in site 5. In addition to that all the calculated benthic metrics revealed that the water quality of site 5 was good compared to the other four sites, i.e. tributaries. Routine monitoring and continuous investigations are required to keep the stream healthy in the future also. The rapid bio-assessment protocols are being applied in many countries with success and optimizing time and resources in sample methodologies. But there is lack thorough knowledge on the taxonomy and ecology of regional aquatic insects. Hence, more comprehensive investigations are needed to expand our knowledge on aquatic insect diversity, and then only and can assign tolerance value to the regional biota and to develop our own biotic index and metrics to evaluate water quality.

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Calliandra calothyrsus: A Potential Host for the Indian Lac Insect [*Kerria lacca* (Kerr.)] Cultivation in India

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Abstract: More than 400 host plants have been reported to support lac insects throughout the world but not all have been exploited for their commercial potential except some traditional hosts. In this study, potentially of four host plants *viz., Calliandra calothyrsus, Calliandra surinamensis, Dalbergia assamica* and *Malvaviscus penduliflorus* was evaluated for *kusmi* and *rangeeni* strain of *Kerria lacca* (Kerr.) during three consecutive years 2014-15, 2015-16 and 2016-17. The data on pre and post-harvest parameters *viz*., initial settlement density, mortality, fecundity, cell weight, resin weight, broodlac, broodlac ratio and total scrapedlac were recorded based on pre and post-harvest attributes of *rangeeni* (summer season (*baisakhi)* & rainy season (*katki)* crop) and *kusmi* summer season (*jethwi)* & winter season (*aghani*). *C. calothyrsus* outperformed other hosts during all the three years. In addition to this, *C. calothyrsus* is having quick growth, bushy nature and high response to coppicing make this host ideal for Lac Integrated Cropping System (LICS).

Keywords: *Calliandra calothyrsus, Kerria lacca, Rangeeni, Kusmi*

Indian lac insect, *Kerria lacca* (Kerr.) belongs to the family Tachardiidae (=Kerridae), order Hemiptera and superfamily Coccoidea is phytosuccivorous and sessile. The presence of lac insects was first reported on *Ficus religiosa* L. and *Ficus indica* L. (now *F. benghalensis*) along with *Butea monosperma* Lam (*palas*), *Ziziphus mauritiana* Lamk (*ber*) from Bihar region (Now Bihar, Jharkhand and some parts of West Bengal). More than 400 plant species are reported as a host for lac insects from different parts of the country. There are two strains of the Indian lac insect *viz., rangeeni* and *kusmi*. Each strain completes its life-cycle twice a year with varying period. Of the two strains i.e., *kusmi* and *rangeeni*, *aghani* (winter season) crop of *kusmi* strain contributes the most to the total lac production (Sharma and Ramani 1999). Lac insect strains have been generally characterized by different life-cycle and their respective host plants. Lac production and quality are dependent on the host plant and the strain of lac insect. Besides lac host plant, *K. lacca* is associated with large pest complex comprising predatory and parasitic insects which influence lac production and quality. Various parasitoids such as *Aprostocetus purperous* (Cam.), *Trachidaephagus trachidae* (How.) are responsible for majority of crop loss. Among these parasitoids, *A. purperous* alone has acquired the most dreaded pest of lac insect (Mohanasundaram et al 2016). Lac tree=*Kusum* (*Schleichera oleosa* Lour.), Indian jujube=ber (*Ziziphus mauritiana* Lamk.) and Flame of forest=*palas* (*Butea monosperma* Lam.) are major lac hosts, however these host plants have some constraints like longer gestation period to raise new plantation (5 to 10 years), longer waiting period after pruning like *kusum* (12-18 months), strain specificity *i.e.* only *kusmi* strain on *kusum* and *rangeeni* on *palas* and difficulty in lac culture operation due to a few morphological characters like thorns on *ber*. Studies have been conducted earlier on exploring the bushy host plants so that they can be integrated with the agricultural crops. One such bushy host plant, *Flemingia semialata* Roxb. (*Semialata*) has gained popularity among farmers recently. *Calliandra calothyrsus* Meisn, *Calliandra surinamensis* Benth, *Dalbergia assamica* Benth and *Malvaviscus arboreus var. penduliflorus* (DC.) Schery has been reported as a lac insect host plants (Ramani and Sharma 2010, Sharma et al 2012). Looking into the major host plants, there is a need to identify more host plants which are easy to maintain from lac cultivation aspects. The lac host plants under study are bushy in nature and quick growing in habit. Therefore, the present study was undertaken to evaluate the potentiality of these hosts for lac cultivation under Ranchi conditions.

MATERIAL AND METHODS

Evaluation was carried out in the summer and rainy seasons of *Rangeeni* strain of lac insect and summer and winter (seasons of *kusmi* strain of lac insect on four bushy hosts *viz., C. calothyrsus, C. surinamensis, D. assamica* and

M. penduliflorus during three consecutive years (2014-15 to 2016-17). Field experiments were undertaken at Institute Research Farm, ICAR- Indian Institute of Natural Resins and Gums (IINRG), Namkum, Ranchi, Jharkhand (23.19ºN latitude and 85.22ºE longitude and elevation 2076 feet). Seedlings were grown in paired row system in triangular method of planting by keeping four meter distance between plants, two meter distance between a paired row and four meter distance between two paired rows during the year 2012 (Fig. 1). Ten plants of each host were taken per season (5 for *rangeeni* lac insect and 5 for *kusmi* lac insect); in total 40 plants were used for this experiment. Required agronomic practices *viz*., weeding, earthing up, pruning, FYM and fertilizer application, pesticide application, irrigation etc. were followed for maintenance. Plants were pruned in the month of February-March for inoculation of winter season crop and in June-July for inoculating summer season crop of *kusmi* strain. Similarly, plants were pruned in the month of February-March for inoculation of rainy season crop and in April-May for inoculating summer season crop of *rangeeni* strain. Recommended packages of practices for lac cultivation were followed. Observations on biological and economic attributes of lac insect were recorded as per the standard procedure (Mohanasundaram et al 2016). Pre-harvest productivity parameters *viz*., settlement density (crawlers per sq cm), initial mortality (%), sex ratio (% male); post-harvest productivity parameters *viz*., fecundity (Nos./Female), cell weight (mg), resin weight (mg) and yield parameters *viz*., broodlac (includes both stick and lac insect cell weight) (g), rejected lac (g), total scrapedlac (without stick weight *i.e* only lac resin, dye and wax etc.) (g), broodlac ratio (output/input) were taken. The performance of all the four host plants was compared for all season crops of *K. lacca*. The experiment was conducted in Randomized Block Design. Three consecutive years' data were pooled. Field level evaluation of the best performing host in the study *i.e. C. calothyrsus* was also conducted at farmer's field at two different villages' *viz*., Lodama and Benyazara of Ranchi district, Jharkhand during 2017-20 to further ensure its potential for commercial lac cultivation. Lac cultures on stunted host plants during different seasons are (Figs. 2 to 5).

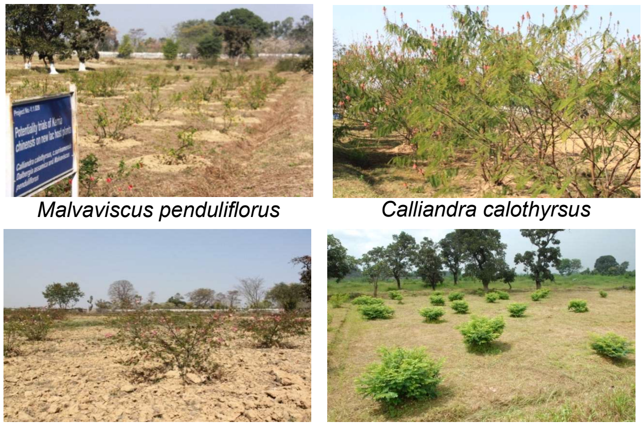
RESULTS AND DISCUSSION

Evaluation of *K. lacca* (*rangeeni*) during summer (*baisakhi*) crop: Though initial settlement density of *K. lacca* (*rangeeni*) on *M. penduliflorus* was more than the other hosts but lac insect mortality was observed before sexual maturation. Initial mortality was minimum in *C. calothyrysis* (12.55 %) and maximum in *C. surinamensis* (27.06 %) (Table 1). Sex ratio ranged between 46.89 to 64.20 per cent, whereas, lac insect mortality was observed on *M. penduliflorus* before sexual maturation. Average fecundity was significantly more on *C. calothyrsus* (337.5) followed by *D. assamica* and *C. surinamensis*. Cell weight (15.41 and 12.46 mg) and resin weight (12.51 and 9.95 mg) was maximum in *C. calothyrsus* and minimum in *D.assamica,* respectively. Yield attributes, *viz.,* broodlac, rejected lac, total scrapedlac and broodlac ratio were significantly higher in *C. calothyrsus* (1712.53, 476.87g, 126.33 and 4.8 g per plant, respectively) than *C. surinamensis* and *D. assamica*. Monobrullah et al (2016) reported that the pre-harvest parameters of *rangeeni* lac insect *viz*., initial mortality, sex ratio and broodlac yield were significantly different between hosts *ber* and *palas*. Initial mortality and sex ratio ranged from 12.86 to 47.85 per cent and 22.97 to 40.86 per cent, respectively and resin weight also significantly differed between these hosts during *rangeeni* summer season crop. Sharma and Jaiswal (2011) observed that, density of settlement of lac insect is on an average about 150 larvae settled in one square cm area. Depending upon the host-

Table 1. Bio-economical parameters of summer season (*baisakhi*) crop of *rangeeni* lac insect during 2014-2016 (Pooled)

Bushy host plants	Pre-harvest productivity parameters			Post-harvest productivity parameters			Yield parameters			
	Settlement density (Nos./cm^2)	Initial mortality (%)	Sex ratio (% Male)	Fecundity (nos./ Female)	Cell weight (mg)	Resin weight (mg)	Broodlac (g)	Rejected lac (g)	Total scraped lac (g)	Broodlac ratio (Output/ input)
C. calothyrsus	90.53 (9.52)	12.55 (3.60)	53.26 (7.33)	337.53 (18.38)	15.41 (3.99)	12.51 (3.61)	1712.53 (41.16)	476.87 (20.61)	126.33 (11.16)	4.80 (2.30)
C. surinamensis	47.18 (6.90)	27.06 (5.25)	64.20 (8.03)	127.69 (11.28)	14.66 (3.89)	11.65 (3.48)	527.00 (22.67)	511.33 (19.67)	16.22 (3.81)	1.40 (1.38)
D. assamica	70.16 (8.40)	11.00 (3.37)	46.89 (6.87)	195.98 (13.98)	12.46 (3.59)	9.95 (3.23)	414.00 (20.35)	20.67 (4.39)	35.92 (5.98)	1.80 (1.52)
M. penduliflorus	91.60 (9.58)	18.87 (4.35)	0.00 (0.71)	0.00 (0.71)	0.00 (0.71)	0.00 (0.71)	0.00 (0.71)	0.00 (0.71)	0.00 (0.71)	0.00 (0.71)
CD (p=0.05)	0.66	0.73	0.50	0.95	0.24	0.23	3.56	10.56	1.67	0.11

*Figures in parentheses are square root √ (X+0.5) transformation values; Means are significant at p< 0.05



Malvaviscus penduliflorus *Calliandra calothyrsus*

Calliandra surinamensis *Dalbergia assamica*

Fig. 1. Field view of bushy host plants at Institute Research Farm, IINRG, Ranchi

plant and season of inoculation, carrying capacity of the host plant varies. Kumar et al (2007) concluded that fecundity of lac insects when grown on *F. macrophylla* was 338.0 and 460.8 nos. and resin weight (9.46 and13.67 mg) during *katki* and *baisakhi* crops, respectively. The density of settlement of lac insect varied between 48.3 to 162.0 no. of crawlers/cm^2 and resin output ranged from 5.60 to 8.15 mg per cell for summer crop of *rangeeni* strain on *F. macrophylla* (Gupta et al 2020).

Evaluation of *K. lacca* (*rangeeni*) during rainy (*katki*) crop: Settlement density was more with lesser initial mortality on *C. calothyrsus* (75.76 crawlers per sq cm and 33.58 per cent) while more than 50 per cent initial morality was recorded on *D. assamica, C. surinamensis* and *M. penduliflorus* (Table 2). Optimum sex ratio recorded was

Fig. 2. *K. lacca* (*rangeeni*) on *C. calothyrsus* during summer (*baisakhi*) crop

Fig. 3. *K. lacca* (*rangeeni*) on *C. calothyrsus* during rainy (*katki*) crop

Fig. 4. *K. lacca* (*kusmi*) on *C. calothyrsus* during summer (*jethwi*) crop

Fig. 5. *K. lacca* (*kusmi*) on *C. calothyrsus* during winter (*aghani*) crop

ranging from 25.94 to 35.50 per cent male except on *M. penduliflorus* (1.59 % male) lac insect died before sexual maturation on *M. penduliflorus*. Average fecundity was significantly higher on *C. calothyrsus* (211.55) and minimum on *C. surinamensis* (32.95). Cell weight and resin weight recorded were maximum on *C. calothyrsus* (17.47 and 12.64 mg) and minimum on *D. assamica* (12.62 and 9.72 mg). Yield attributes, *viz.,*broodlac produced was recorded maximum on *C. calothyrsus* (2937.87 g) and minimum on *D. assamica* (153.33 g). No broodlac was obtained from *C. surinamensis.* Rejected lac was obtained from three hosts *C. calothyrsus, C. surinamensis* and *D. assamica.* Total scrapedlac was significantly more on *C. calothyrsus* (555.67 g) followed by *C. surinamensis* and *D. assamica.* Broodlac ratio could be calculated only from *C. calothyrsus* (4.46) and *D. assamica* (1.75). The results of the present study also corroborated with the findings of Meena et al (2019) on biological parameters. Kalahal et al (2017) revealed that the initial density of settlement of crawlers varied in different parts of pigeonpea (*Cajans Cajan*) during *Katki* season of *rangeeni* strain. The cell and resin weight ranged from 6-24 mg and 4-19 mg per cell, respectively. The highest fecundity and cell weight was recorded from *ber* (450.6 nos. and 10.12 mg) and lowest on *C. cajan* (315.4 and 9.4mg) during *katki* crop whereas it was 525.2 and 14.21 mg on *ber* and 407 and 13.6 mg on pigeonpea respectively, during *baisakhi* .

Evaluation of *K. lacca* (*kusmi*) during summer (*jethwi*) crop: Settlement density of *K. lacca* (*kusmi*) varied between 62.98 and 77.78 crawlers per sq cm on *C. surinamensis, M. penduliflorus, D. assamica* and *C. calothyrsus* while mortality was less on *C. calothyrsus* (19.99 %) followed by *D. assamica, M. penduliflorus* and *C. surinamensis* (Table 3). Sex ratio ranged between 36.42 and 45.05 per cent male but sex ratio could not be obtained on *M. penduliflorus* as lac insect did not prefer this host for further development. Fecundity was more on *C. calothyrsus* (214.92) followed by *C. surinamensis* and *D. assamica*. Major difference was not observed in cell weight and resin weight on *C. calothyrsus*, *C. surinamensis* and *D. assamica*. Broodlac and broodlac ratio was more on *C. surinamensis* (996.00 g and 2.73) followed

Table 2. Bio-economical parameters of rainy season (*katki*) crop of *rangeeni* lac insect during 2014-2016 (Pooled)

Bushy host plants	Pre-harvest productivity parameters			Post-harvest productivity parameters			Yield parameters			
	Settlement density (Nos./cm^2)	Initial mortality (%)	Sex ratio (% Male)	Fecundity (nos./ Female)	Cell weight (mg)	Resin weight (mg)	Broodlac (g)	Rejected lac (g)	Total scraped lac (g)	Broodlac ratio (Output/ input)
C. calothyrsus	75.76 (8.73)	33.58 (5.81)	35.50 (5.99)	211.55 (14.55)	17.47 (4.24)	12.64 (3.62)	2937.87 (53.47)	1097.00 (32.03)	555.67 (23.48)	4.46 (2.22)
C. surinamensis	64.80 (8.08)	81.24 (9.04)	25.94 (5.14)	32.95 (5.28)	5.88 (2.37)	4.33 (2.07)	0.00 (0.71)	493.33 (21.17)	105.80 (10.30)	0.00 (0.71)
D. assamica	62.47 (7.92)	50.88 (7.15)	26.49 (5.18)	126.31 (11.24)	12.62 (3.61)	9.72 (3.18)	153.33 (12.38)	115.33 (10.57)	78.67 (8.89)	1.75 (1.50)
M. penduliflorus	51.07 (7.18)	66.17 (8.16)	1.59 (1.15)	0.00 (0.71)	0.00 (0.71)	0.00 (0.71)	0.00 (0.71)	0.00 (0.71)	0.00 (0.71)	0.00 (0.71)
CD (p=0.05)	0.41	0.78	0.65	1.94	0.59	0.47	7.07	8.75	1.81	0.09

*Figures in parentheses are square root √ (X+0.5) transformation values; Means are significant at p< 0.05

Table 3. Bio-economical parameters of summer season (*jethwi*) crop of *kusmi* lac insect during 2014-2016 (Pooled)

Bushy host plants	Pre-harvest productivity parameters			Post-harvest productivity parameters			Yield parameters			
	Settlement density (Nos./cm^2)	Initial mortality (%)	Sex ratio (% Male)	Fecundity (nos./ Female)	Cell weight (mg)	Resin weight (mg)	Broodlac (g)	Rejected lac (g)	Total scraped lac (g)	Broodlac ratio (Output/ input)
C. calothyrsus	77.78 (8.83)	19.99 (4.48)	39.51 (6.30)	214.92 (14.67)	11.40 (3.45)	8.99 (3.08)	658.00 (25.33)	0.00 (0.71)	102.00 (9.94)	2.03 (1.58)
C. surinamensis	62.98 (7.97)	51.93 (7.23)	36.42 (6.05)	201.02 (14.17)	11.33 (3.44)	9.10 (3.10)	996.00 (30.72)	58.67 (6.27)	70.00 (8.17)	2.73 (1.78)
D. assamica	70.89 (8.45)	33.64 (5.83)	45.05 (6.74)	181.70 (13.47)	11.83 (3.51)	9.68 (3.19)	135.27 (11.42)	131.53 (10.91)	34.00 (5.82)	1.24 (1.30)
M. penduliflorus	66.36 (8.17)	45.21 (6.74)	0.00 (0.71)	0.00 (0.71)	0.00 (0.71)	0.00 (0.71)	0.00 (0.71)	0.00 (0.71)	0.00 (0.71)	0.00 (0.71)
CD (p=0.05)	0.57	0.68	0.73	1.19	0.19	0.16	6.93	4.16	2.08	0.26

*Figures in parentheses are square root √ (X+0.5) transformation values; Means are significant at p< 0.05

Table 4. Bio-economical parameters of winter season (*aghani*) crop of *kusmi* lac insect during 2015-2017 (Pooled)

Bushy host plants	Pre-harvest productivity parameters			Post-harvest productivity parameters			Yield parameters			
	Settlement density (Nos./cm^2)	Initial mortality (%)	Sex ratio (% Male)	Fecundity (nos./ Female)	Cell weight (mg)	Resin weight (mg)	Broodlac (g)	Rejected lac (g)	Total scraped lac (g)	Broodlac ratio (Output/ input)
C. calothyrsus	107.91 (10.40)	20.29 (4.56)	34.04 (5.87)	184.52 (13.58)	24.58 (5.01)	21.73 (4.71)	1606.00 (40.00)	2049.00 (45.22)	849.67 (29.13)	3.52 (2.00)
C. surinamensis	60.71 (7.81)	63.78 (8.01)	41.20 (6.45)	47.78 (6.94)	7.03 (2.74)	6.19 (2.58)	0.00 (0.71)	426.67 (20.40)	17.33 (4.17)	0.00 (0.71)
D. assamica	69.36 (8.35)	31.71 (5.66)	42.39 (6.55)	39.73 (6.31)	7.99 (2.91)	6.95 (2.73)	16.00 (3.41)	255.33 (15.97)	37.67 (6.13)	0.08 (0.76)
M. penduliflorus	85.38 (9.24)	55.39 (7.47)	0.00 (0.71)	0.00 (0.71)	0.00 (0.71)	0.00 (0.71)	0.00 (0.71)	0.00 (0.71)	0.00 (0.71)	0.00 (0.71)
CD (p=0.05)	0.75	0.41	0.28	0.80	0.13	0.12	2.769	3.23	1.13	0.06

*Figures in parentheses are square root √ (X+0.5) transformation values; Means are significant at p< 0.05

by *C. calothyrsus* and *D. assamica* whereas, total scrapedlac obtained was significantly more on *C. calothyrsus* (102.00 g) than others and minimum in *D. assamica* (34.00 g). Mohanta et al (2014), initial settlement density of crawler varied between 104.62-126.74 no/cm^2, sex ratio 1:3 and resin output per female was 19.00 to 25.60 mg for summer crop of *kusmi* strain on *kusum* and *ber* plants. Slight variation of results may be attributed to different host plants and climatic condition.

Evaluation of *K. lacca* (*kusmi*) during winter (*aghani*) crop: Settlement density of *K. lacca* (*kusmi*) was more (107.91 crawlers per sq cm) on *C. calothyrsus* followed by *M. penduliflorus, D. assamica* and *C. calothyrsus.* Initial mortality was less on *C. calothyrsus* (20.29 per cent) than the other three hosts (Table 4). Optimum sex ratio (34.04 to 42.39 per cent male) was from three hosts *C. calothyrsus, C. surinamensis* and *D. assamica* except *M. penduliflorus*. Average fecundity (184.52), cell and resin weight (24.58 and 21.73 mg) were recorded significantly more on *C. calothyrsus* than *C. surinamensis* and *D. assamica. C. calothyrsus* produced higher broodlac (1606 g per plant) compared to others and the least on *D. assamica.* Total scrapedlac and broodlac ratio obtained were more on *C. calothyrsus* (849.67 g and 3.52 per plant) than other three hosts. Sharma and Jaiswal (2011) wherein they reported that the mean density of settlement in *rangeeni* strain of *K. lacca* is lower than that of *kusmi* strain. The *kusmi* strain performed better than *rangeeni*. Results of the present finding of cell and resin weight are significantly more during *kusmi* winter season crop, respectively.

Field level evaluation of *C. calothyrsus:* Field level evaluation of *C. calothyrsus* was conducted at farmers' fields at two different villages' *viz*., Lodama and Benyazara of Ranchi district, Jharkhand during 2017-20 for evaluating its potential for commercial lac cultivation. *Kusmi* broodlac inoculated on *C. calothyrsus* provided broodlac (470 g per plant), brood per meter lac encrustation (144 g), broodlac ratio (10.5), scrapedlac weight per meter lac encrustation (45 g), per cent scrapedlac (29 %) during *aghani*, 2018-19 and 2019-20 at Lodma, Ranchi district. Similarly, broodlac (900 g per plant), Brood per meter lac encrustation (111 g), broodlac ratio (5.5), Scrapedlac weight per meter lac encrustation (21 g), per cent Scrapedlac (19 %) was recorded on *C. calothyrsus* during *aghani*, 2019-20 at Benyazara, Angara block, Ranchi. This study was also carried out during rainy season crop, 2019 at Lodma which yielded 214 g of broodlac per plant with broodlac ratio of 5.35.

CONCLUSION

Lac cultivation on traditional host plants has its own advantages and constraints. Among the bushy host plants studied, *C. calothyrsus* has shown tremendous potential in lac cultivation based on broodlac ratio of 3-4 and 5.35-10.5 at Institute Research Farm and famers' fields, respectively. It was found suitable to culture *kusmi* and *rangeeni* strains of *K. lacca*. It is an indication that this host would perform better as a commercial host.

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Influence of Temperature Variation on Emamectin Benzoate Toxicity in Different *Leucinodes orbonalis* Guenee Populations of Punjab

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Abstract: In present study, larval populations of *L. orbonalis*, collected from different regions of Punjab i.e. Amritsar, Kapurthala, Malerkotla, Ludhiana were exposed to different concentrations of emamectin benzoate at 15, 20, 25 and 30°C for evaluation of LC_{50} values. The LC_{50} decreased from lower (15°C) to higher (30°C) temperature for all populations of *L. orbonalis.* The positive correlation was observed between the temperature coefficient and emamectin benzoate toxicity towards population of *L. orbonalis,* which increased with increase in temperature. The LC_{50} values varied among different populations of *L. orbonalis* i.e. Amritsar populations with higher LC_{50}followed by Kapurthala, Malerkotla and Ludhiana populations. The temperature and insecticide exposure history affected the toxicity of emamectin benzoate toxicity for *L. orbonalis*. The information would be helpful in developing management strategies for *L. orbonalis* according to prevailing environment conditions.

Keywords: *Leucinodes orbonalis*, Emamectin benzoate, Temperature coefficient, Punjab

Brinjal shoot and fruit borer, *Leucinodes orbonalis* Guenee is the obnoxious and destructive pest which is widely distributed throughout world which includes India, East Africa, USA, Germany, Pakistan and Sri Lanka (Rashid et al 2008, Onekutu et al 2013, Chandi and Kaur 2021). In India, this pest is considered as primary and severe pest of brinjal which can cause considerable damage and losses to brinjal crop from 70 to 92 percent (Chakraborti and Sarkar 2011, Onekutu et al 2013).This pest poses serious damage to brinjal crop from the nursery stage till the harvesting The larvae of *L. orbonalis* bore into tender shoots of young plants, causing drooping and withering of growing tips. In the later stage flower buds and fruits are also infested. The high temperature and relative humidity are major factors contributing to major yield losses due to *L. orbonalis*. (Jhala et al 2007, Kaur et al 2014, Singla 2014). Insecticidal control is most preferred control strategy for management of this pest (Chandi and Kaur 2021). The excessive use of insecticides for control of this insect-pest has led to problems such as insecticide residues in fruits and development of resistance (Onekutu et al 2013, Kaur et al 2014, Chandi and Kaur 2021).

Emamectin benzoate, a semisynthetic derivative of abamectin and is effective insecticide against *L. orbonalis* (Anil and Sharma 2011, Chandi and Kaur 2021). The neurotransmitter, γ-aminobutyric acid (GABA) release activating chloride channels are main site of action for this insecticide affecting functioning of nerve impulses in insect pest (Tong et al 2013, Bengochea et al 2014). This compound also exhibits translaminar activity and longer long-term residual pest control by maintenance of active substance in treated leaves for longer through larval feeding (López et al 2011, Bengochea et al 2014). Efficacy of any insecticide towards any insect pest is influenced by temperature variations due to high dependence of insecticide degradation metabolic activities in insects on temperature (Khan and Akram 2014, Glunt et al 2018, Jaleel et al 2019). The present study was conducted to investigate the toxicity of emamectin benzoate towards different populations of *L. orbonalis* collected from different regions of Punjab with respect to variations in temperature.

MATERIAL AND METHODS

Culture of *L. orbonalis*:: The infested shoots and fruits of brinjal were collected from vegetable fields of Amritsar (31° 37' 20.42” N and 74° 52' 31.22” E), Kapurthala (31° 22' 47.99” N and 75° 22' 47.98” E), Malerkotla (30° 31' 23.54” N and 75° 53' 17.70” E) and Ludhiana (30° 53' 60.00” N and 75° 50' 60.00 E) regions. The larvae of *L. orbonalis* were extracted from fruits and shoots of brinjal and reared in the Insect Physiology laboratory. Larvae of *L. orbonalis* collected from brinjal fruits were transferred to the glass jar (10 ×15 cm) containing fresh pieces of brinjal fruit and placed in an incubator at 27° C and 70 per cent relative humidity (RH, and the food was changed daily in the morning hours to prevent fungal contamination till the fifth instar larvae got ready for pupation. The pupae were shifted to second set of glass jars, containing moist sponge at base and covered with muslin cloth for pupation. The emerging adults were sexed and transferred into new jars for mating and oviposition on the same day. A cotton swab dipped in 10 per cent honey solution as a food source to adults. The leaf with eggs laid upon was removed daily and replaced with a new one to facilitate further oviposition.

Rearing of susceptible population of *L. orbonalis:* *L. orbonalis* population collected from infested fruits of brinjal fields of Punjab Agricultural University, Ludhiana was reared for twenty generations to develop susceptible population.

Toxicity bioassay: Populations of *L. orbonalis* collected from different regions of Punjab i.e. Amritsar, Kapurthala, Malerkotla and Ludhiana were reared up to F_1 generation. For conducting toxicity bioassay, six different concentrations of test insecticide i.e. emamectin benzoate were prepared by serial dilutions. The 'fruit dip' bioassay method (Kodandaram et al 2017) was implied to determine LC_{50} values of test insecticide against third instar larvae of all the selected populations. The small slices of brinjal fruits were dipped in different concentrations of insecticide for 30 seconds, air dried and placed in glass jars. The ten 3^{rd} instar larvae of *L. orbonalis* were allowed to feed on treated fruit-discs kept at different temperatures i.e. 15, 20, 25 and 30° C for 48 hours. Experiment was conducted with three replications and ten larvae per replication. The mortality was recorded 48 hours respectively. Mortality in all the treatments was corrected by Abbott's formula (Abott 1925).

Data analysis: The log concentration-mortality regression was worked out by the computer programme POLO (Robertson et al 1980). Temperature coefficients of insecticide (emamectin benzoate) were also calculated (Musser and Shelton 2005).

RESULTS AND DISCUSSION

There was positive influence of temperature variation on toxicity levels of emamectin benzoate in different populations of *L. orbonalis* collected from different regions of Punjab. The positive correlation was observed between tested temperature range and toxicity of emamectin benzoate in both year i.e. 2019 and 2020 (Table 1). In year 2019 the decrease in LC_{50} values was observed from 15° C to 30°C for all populations of *L. orbonalis.* In terms of LC_{50} values, the toxicity of emamectin benzoate was 1.11 and 1.36 times higher at 20°C and 30°C as compared to 15°C for populations of Amritsar region. Similarly for Kapurthala population at 20°C and 30°C was. 1.17 to 1.52 folds respectively. The Malerkotla population showed 1.68 times

Table 1. Temperature variation influence on toxicity of emamectin benzoate in *L. orbonalis* in year 2019

Region	Temperature (°C)	LC_{50} (%)	Fiducial limits		Slope ± S.E	Temperature coefficient		
			Lower limit	Upper limit		5°C	10°C	15°C
Amritsar	15	0.000060	0.000044	0.000061	1.34±0.97	-	-	-
	20	0.000054	0.000042	0.000056	1.08±0.60	1.11	-	-
	25	0.000048	0.000039	0.000053	2.62±1.33	1.12	1.25	-
	30	0.000044	0.000026	0.000052	2.14±1.24	1.09	1.22	1.36
Kapurthala	15	0.000055	0.000039	0.000060	2.08±0.62	-	-	-
	20	0.000047	0.000025	0.000058	2.18±1.40	1.17	-	-
	25	0.000041	0.000032	0.000055	1.52±0.92	1.14	1.34	-
	30	0.000036	0.000028	0.000047	2.17±1.43	1.13	1.30	1.52
Malerkotla	15	0.000042	0.000033	0.000060	1.70±0.56	-	-	-
	20	0.000034	0.000020	0.000041	2.48±1.22	1.23	-	-
	25	0.000030	0.000022	0.000038	1.71±1.90	1.13	1.40	-
	30	0.000025	0.000018	0.000030	2.32±1.52	1.20	1.36	1.68
Ludhiana	15	0.000037	0.000031	0.000062	1.62±0.88	-	-	-
	20	0.000030	0.000015	0.000035	1.65±1.20	1.23	-	-
	25	0.000025	0.000011	0.000038	2.77±1.35	1.20	1.48	-
	30	0.000021	0.000010	0.000040	2.50±0.75	1.19	1.42	1.76
Susceptible	15	0.000030	0.000028	0.000042	1.66±1.05	-	-	-
	20	0.000022	0.000016	0.000035	1.18±0.73	1.36	-	-
	25	0.000016	0.000008	0.000025	2.05±1.11	1.37	1.87	-
	30	0.000012	0.000010	0.000028	2.20±1.03	1.33	1.83	2.50

Table 2. Temperature variation influence on toxicity of emamectin benzoate in *L. orbonalis* in year 2020

Region	Temperature (°C)	LC_{50} (%)	Fiducial limits		Slope ± S.E	Temperature coefficient		
			Lower limit	Upper limit		5°C	10°C	15°C
Amritsar	15	0.000064	0.000053	0.000068	1.16±1.12	-	-	-
	20	0.000058	0.000048	0.000065	2.32±1.98	1.10	-	-
	25	0.000053	0.000050	0.000058	2.61±1.03	1.09	1.20	-
	30	0.000048	0.000047	0.000056	2.18±1.06	1.10	1.20	1.33
Kapurthala	15	0.000061	0.000044	0.000065	1.55±0.95	-	-	-
	20	0.000050	0.000039	0.000053	2.22±1.55	1.22	-	-
	25	0.000047	0.000036	0.000051	1.88±0.52	1.06	1.29	-
	30	0.000040	0.000032	0.000050	2.14±1.35	1.17	1.25	1.52
Malerkotla	15	0.000048	0.000028	0.000034	2.05±1.23	-	-	-
	20	0.000038	0.000023	0.000043	1.15±0.70	1.26	-	-
	25	0.000035	0.000026	0.000056	2.28±1.72	1.08	1.37	-
	30	0.000031	0.000029	0.000047	1.45±1.32	1.12	1.22	1.54
Ludhiana	15	0.000042	0.000026	0.000053	2.66±1.04	-	-	-
	20	0.000034	0.000018	0.000038	2.06±0.80	1.23	-	-
	25	0.000030	0.000022	0.000032	2.83±1.91	1.13	1.40	-
	30	0.000026	0.000020	0.000031	2.28±0.93	1.15	1.30	1.61
Susceptible	15	0.000033	0.000043	0.000054	1.95±1.16	-	-	-
	20	0.000027	0.000036	0.000050	2.71±0.64	1.22	-	-
	25	0.000020	0.000018	0.000042	1.54±0.87	1.35	1.65	-
	30	0.000017	0.000010	0.000038	1.30±1.61	1.17	1.58	1.94

higher emamectin benzoate toxicity at 30°C as compared to 1.23 folds at 20°C. The increase in emamectin bezoate toxicity was observed at 30°C i.e. 1.76 times as compared to 1.23 times at 20°C for Ludhiana population of *L. orbonalis.* The emamectin benzoate toxicity for susceptible population was 2.50 times higher at 30°C as compared to 1.36 at 20 °C. The emamectin benzoate toxicity was low for Amritsar population followed by Malerkotla, Kapurthala and Ludhiana populations. During 2020 (Table 2) the increase in LC_{50} values were recorded as compared to 2019 for all populations of *L. orbonalis.* The trend of toxicity with respective to different temperatures was similar as of 2019 i.e. higher toxicity of emamectin benzoate at 30°C. Khan and Akram (2014) reported positive correlation between the temperature and toxicity of emamectin benzoate in-house fly, *Musca domestica* (Linnaeus). Similarly Teja et al (2018) also observed increase in emamectin benzoate toxicity towards *Plutella xylostella* (Linnaeus) at higher temperature. Li et al (2004) observed that enhancement in toxicity emamectin benzoate of towards *P. xylostella* with increase in temperature. Toxicity of insecticides with a positive temperature coefficient tends to increase at higher temperatures ranges (Glunt et al 2013). The change in toxicity levels of emamectin benzoate could be due to variation in biotransformation process, i.e. at lower temperature the biotransformation might decrease leading to elevated level of the original compounds which possess low toxicity than other secondary compounds formed through biotransformation (Harwood et al 2009, Khan and Akram 2014).

The variation in the LC_{50} values and toxicity between various populations of *L. orbonalis* (Amritsar, Kapurthala, Malerkotla, and Ludhiana) could be due to difference in insecticide exposure history of all populations of *L. orbonalis*. Earlier studies by Chandi and Kaur (2021) also revealed that LC_{50} values of Amritsar population were higher as compared to Kapurthala and Ludhiana for emamectin benzoate. The amount and of insecticide applied for control of any pest in any particular area plays an important role in development of pest resistance along with other physical and biological factors (Helps and Van den Bosch 2017).

CONCLUSION

In present investigation both temperature and insecticide exposure background of *L. orbonalis* acted as vital factors for toxicity of emamectin benzoate, but there is need of detailed study about the mechanism that have led to variation in emamectin benzoate toxicity. The present study would be helpful in developing management strategies for efficient control of *L. orbonalis* by emamectin benzoate in changing scenario of climate change.

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Seasonal Incidence of *Galleria mellonella* in Stored Wax Combs and its Correlation with Weather Parameters

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Abstract: The investigation was carried out at CCS Haryana Agricultural University, Hisar for two years i.e. 2016 and 2017 during June to October. During June, population of larvae of *Galleria mellonella* larvae started increasing till September in both years.. However, during October, the number decreased. This pattern of seasonal incidence was same when eight, nine and ten combs were stored in a hive body (chamber). The number of larvae recorded per comb was highest when ten combs were stored in a hive body followed by 9, 8 and 7 combs. During both the years, pupal and adult population in stored combs also increased with from June to September while in October, the cumulative number of pupae and adults decreased. Correlation studies between number of wax moth population (larvae, pupae and adults) in stored combs related to different frame strength with the different weather parameters showed significant positive correlation with maximum RH and maximum temperature, whereas no significant correlation existed with min. temperature, min. RH and number of bright sunshine hours.

Keywords: Fumigation, Wax moth, *Galleria mellonella*

Galleria mellonella is a cosmopolitan, devastating and economically important pest causing serious economic damage to honey bee combs and stored bees wax during storage (Gillard 2009, Ellis and Hayes 2009). Wax moths are nocturnal pest flying at night and hide in dark places during the day time and stored combs are ideal places for breeding of moths. Larva is the most destructive stage of the pest. Besides damaging wax comb, larvae consume bees wax, destroying frames and wooden parts in the hive (Ellis et al 2013). The population of wax moth fluctuates according to weather conditions. Maximum infestation of wax moth was recorded during July to September, generally in the brood frames and occasionally in the super frames. In Sudan, Fathy et al (2017) reported that the high infestation of larvae of the GWM and LWM in storage in May, June and July but pupae and adult of GWM in storage during June to September. Stored combs without fumigation reported maximum infestation of wax moth (Kumari and Jha 2013). Therefore, the present work aimed to study incidence of the *Galleria* in the storage combs.

MATERIAL AND METHODS

All the combs were used for experimental purpose were initially fumigated with aluminium phosphide (Celphos) tablets. For this purpose, 9 combs were placed in each chamber and a stack of 4 chambers were made. The fumigated combs were used for experimental purpose after 7 days. For recording seasonal incidence of greater wax moth in stored combs 7, 8, 9 and 10 empty combs (without bees) were stored in hive bodies which were placed on bottom board and covered with inner cover. Each of the chambers with frames was made air tight by mud plastering to seal cracks and crevices. After making the chamber airtight, it was covered with top cover. Fortnightly observations were recorded on number of larvae, pupae and adults in experimental stored combs. Temperature and relative humidity (%) data were collected from observatory of Department of Agriculture Meteorology, CCS Haryana Agricultural University, Hisar. Each treatment was replicated five times from June to October.

RESULTS AND DISCUSSION

Seasonal incidence of greater wax moth (*G. mellonella*) larvae: During June, 2016 the number of larvae recorded per comb were 1.40 increased till September (29.60 on 30th September). However, during October, the number decreased to 13.60 on 30th October. This pattern of seasonal incidence was same when eight, nine and ten combs were stored in a hive body (chamber) during both years. On 30th October, the number of larvae recorded per comb was highest (13.60) when ten combs were stored in a hive body followed by nine combs in 2017. Mandal and Vishwakarma (2016) reported highest number of egg clusters and larvae of *G. mellonella* infesting *A. mellifera* combs during 37th and 38th

standard week during storage. Fathy et al (2017) reported the abundance of GWM in different months in 2014 highest population activity of the larvae/ colony were in June (36) followed by May (26).

Pupal population of greater wax moth (*G. mellonella*): During June, 2016 the number of pupae recorded per comb were 0.20 increased till September (26.80 on 30th September). However, during October, the number decreased to 9.40 on 30th October. This pattern of seasonal incidence was same when eight, nine and ten combs were stored in hive body during both years. On 30th October, the number of larvae recorded per comb was highest (12.80) when ten combs were stored in a hive body followed by nine, eight comb and seven comb stored in 2017. Mandal and Vishwakarma (2016) indicated that the highest number of pupae (23.67) of *G. mellonella* infesting *A. mellifera* combs was observed during 37th and 38th standard week in changing environmental conditions. The highest number of GWM pupae (89.67) was observed in September.

Adult population of greater wax moth (*G. mellonella*): During June, 2016 the number of adult recorded per comb were 0.00 increased till September (26.00 on 30th September). However, during October, the number decreased to 8.20 on 30th October. This pattern of seasonal incidence was same when eight, nine and ten combs were stored in hive body during both years. On 30th October, the number of adults per comb was highest (11.00) when ten combs were stored in a hive body followed by nine, eight comb and seven comb stored in 2017. Mandal and Vishwakarma (2016) indicated that the highest number of adult (8.00) of *G. mellonella* infesting *A. mellifera* combs was during 37th and 38th standard week during storage. The

Table 1. Seasonal incidence of Greater wax moth (*G. mellonella*) larvae during June to October in stored combs during 2016 and 2017

Number of combs in hive body	Cumulative number of larvae/comb during different months of 2016										Mean
	June		July		August		September		October		
	15.6.16	30.6.16	15.7.16	30.7.16	15.8.16	30.8.16	15.9.16	30.9.16	15.10.16	30.10.16	
Seven	1.40 (1.54)	3.00 (1.98)	5.60 (2.54)	12.20 (3.61)	19.40 (4.51)	24.00 (4.98)	27.20 (5.29)	29.60 (5.50)	20.00 (4.58)	13.60 (3.81)	15.60 (3.83)
Eight	1.80 (1.65)	3.80 (2.17)	6.20 (2.66)	15.00 (3.99)	20.40 (4.60)	25.20 (5.11)	28.40 (5.41)	31.00 (5.6)	24.40 (5.03)	13.80 (3.84)	17.00 (4.01)
Nine	2.40 (1.82)	4.00 (2.23)	7.60 (2.89)	16.60 (4.19)	23.00 (4.88)	26.60 (5.23)	33.20 (5.83)	35.40 (6.03)	24.80 (5.06)	16.60 (4.16)	19.02 (4.23)
Ten	2.80 (1.92)	4.60 (2.36)	9.80 (3.24)	18.20 (4.37)	25.80 (5.17)	29.00 (5.47)	32.80 (5.80)	36.40 (6.11)	25.60 (5.15)	16.80 (4.21)	20.18 (4.38)
Mean	2.10 (1.73)	3.85 (2.19)	7.30 (2.83)	15.50 (4.04)	22.15 (4.79)	26.20 (5.20)	30.40 (5.58)	33.10 (5.82)	23.70 (4.95)	15.20 (4.01)	-
Factors				C.D.			SE(d)			SE(m)	
Month				0.11			0.05			0.04	
Combs				0.18			0.09			0.06	
Month × Combs				0.36			0.18			0.12	
	Cumulative number of larvae/comb during different months of 2017										Mean
Seven	1.80 (1.66)	3.20 (2.04)	6.00 (2.61)	12.60 (3.66)	19.80 (4.55)	25.00 (5.08)	28.20 (5.38)	30.20 (5.55)	22.60 (4.48)	14.40 (3.91)	16.38 (3.93)
Eight	2.00 (1.72)	4.00 (2.32)	6.40 (2.70)	15.80 (4.09)	21.80 (4.75)	26.80 (5.26)	28.80 (5.44)	31.20 (5.66)	25.40 (5.13)	15.00 (3.99)	17.72 (4.10)
Nine	2.80 (1.92)	4.20 (2.27)	7.80 (2.93)	17.00 (4.23)	23.80 (4.97)	27.60 (5.33)	31.60 (5.69)	34.80 (5.98)	26.40 (5.22)	16.80 (4.21)	19.28 (4.28)
Ten	3.00 (1.96)	4.80 (2.40)	10.20 (3.30)	20.20 (4.59)	26.80 (5.26)	30.20 (5.58)	32.20 (5.75)	35.60 (6.04)	27.60 (5.33)	17.20 (4.26)	20.78 (4.45)
Mean	2.40 (1.82)	4.05 (2.37)	7.60 (2.89)	16.40 (4.14)	23.05 (4.88)	27.40 (5.31)	30.20 (5.57)	32.95 (5.81)	25.50 (5.13)	15.85 (4.09)	-
Factors				C.D.			SE(d)			SE(m)	
Month				0.11			0.05			0.04	
Combs				0.18			0.09			0.06	
Month × Combs				0.36			0.18			0.12	

Figures in parentheses are $\sqrt{(n+1)}$ transformed value

highest number (30.67) of GWM adults were observed in September/. The peak month population was in September 22.01% of total population of the adults. Fathy et al (2017) observed number of wax moths changed greatly in different months.

Correlation between weather parameters and Greater wax moth (*G. mellonella*) incidence in stored comb: During both years, the greater wax moth's larvae starts infesting combs from first fortnight of June and progressively to acquire peak in September in 7, 8, 9 and 10 combs/hive. During September, average of weather parameters of both years were recorded as maximum temperature (35.07°C), minimum temperature (23.63°C), maximum RH (86.72%), minimum RH (51.85%) and number of bright sunshine hour (7.84 hour). During this period, the weather condition for the development of the greater wax moth was very congenial. In June, the average of different weather parameters recorded as maximum temperature (40.2°C), minimum temperature (26.2°C), maximum RH (66.45%), minimum RH (35.3%) and number of bright sunshine hour (8.15 hour). Correlation between number of larvae and weather parameters were positive and significant for minimum temperature and maximum R), positive and highly significant for minimum R). Correlation did not exist between number of larvae and maximum temperature and bright sunshine hours.

The correlation between number of pupae and minimum RH was positive and highly significant. Correlation did not exist between pupal population and weather parameters such as maximum temperature, minimum temperature, maximum RH and bright sunshine hours. The correlation between number of adults and weather parameters were be positive and significant for minimum temperature and positive and highly significant for maximum RH, whereas no correlation existed between number of adults and weather

Table 2. Pupal population of Greater wax moth (*G. mellonella*) during June to October in stored combs during 2016 and 2017

Number of combs in hive body	Cumulative number of pupae/comb during different months of 2016										Mean
	June		July		August		September		October		
	15.6.16	30.6.16	15.7.16	30.7.16	15.8.16	30.8.16	15.9.16	30.9.16	15.10.16	30.10.16	
Seven	0.20 (1.08)	1.40 (1.54)	2.80 (1.93)	8.20 (3.02)	12.80 (3.70)	21.40 (4.68)	25.80 (5.15)	26.80 (5.25)	19.60 (4.52)	9.40 (3.21)	12.86 (3.41)
Eight	0.40 (1.14)	2.20 (1.76)	3.00 (1.99)	12.00 (3.59)	19.20 (4.46)	23.40 (4.92)	26.60 (5.25)	27.40 (5.32)	20.00 (4.57)	10.40 (3.36)	14.44 (3.63)
Nine	1.00 (1.34)	3.80 (2.18)	4.60 (2.36)	14.60 (3.94)	20.80 (4.66)	24.40 (5.03)	30.60 (5.60)	33.00 (5.82)	22.80 (4.87)	10.80 (3.42)	16.64 (3.92)
Ten	1.40 (1.54)	4.80 (2.39)	6.00 (2.64)	15.20 (4.01)	23.00 (4.89)	27.40 (5.32)	32.20 (5.75)	34.80 (5.98)	23.80 (4.97)	12.80 (3.71)	18.14 (4.12)
Mean	0.75 (1.27)	3.05 (1.97)	4.10 (2.23)	12.50 (3.64)	18.95 (4.43)	24.15 (4.99)	28.20 (5.44)	30.50 (5.59)	21.55 (4.73)	10.85 (3.43)	-
Factors				C.D.			SE(d)			SE(m)	
Month				0.12			0.06			0.04	
Combs				0.20			0.10			0.07	
Month × Combs				0.40			0.20			0.14	
	Cumulative number of pupae/comb during different months of 2017										Mean
Seven	0.60 (1.22)	1.80 (1.65)	3.00 (1.97)	8.80 (3.11)	13.60 (3.80)	21.00 (5.64)	26.20 (5.20)	27.60 (5.32)	20.00 (4.56)	10.40 (3.36)	13.30 (3.48)
Eight	1.00 (1.41)	2.00 (1.70)	3.40 (2.08)	12.80 (3.70)	19.80 (4.52)	24.80 (5.06)	27.00 (5.28)	28.40 (5.41)	21.20 (4.71)	11.20 (3.49)	15.16 (3.74)
Nine	1.20 (1.39)	4.00 (2.23)	4.80 (2.40)	15.00 (3.99)	21.60 (4.75)	25.60 (5.15)	30.20 (5.57)	33.20 (5.84)	23.80 (4.97)	12.40 (3.65)	17.18 (3.99)
Ten	1.40 (1.47)	5.00 (2.44)	6.40 (2.71)	17.20 (4.25)	25.00 (5.09)	27.20 (5.30)	32.60 (5.79)	34.40 (5.94)	24.40 (5.03)	13.60 (3.81)	18.72 (4.18)
Mean	1.05 (1.37)	3.20 (2.01)	4.40 (2.29)	13.45 (3.76)	20.00 (4.54)	24.65 (5.04)	29.00 (5.46)	30.90 (5.63)	22.35 (4.82)	11.90 (3.58)	-
Factors				C.D.			SE(d)			SE(m)	
Month				0.13			0.06			0.04	
Combs				0.20			0.10			0.07	
Month × Combs				0.41			0.20			0.14	

Figures in parentheses are $\sqrt{(n+1)}$ transformed value

parameters as maximum temperature, minimum RH and bright sunshine hour. In 8 combs stored per hive, the correlation between number of larvae and weather parameters were positive and highly significant for minimum temperature, maximum RH, minimum RH and negative and significant for bright sunshine hours. Correlation did not exist between larvae and maximum temperature. The correlation between number of pupae and weather parameters were positive and highly significant for minimum temperature), maximum R), minimum RH and negative and significant for bright sunshine hour. Correlation did not exist between number of pupae and maximum temperature. The correlation between number of adults and weather parameters were positive and highly significant for minimum temperature, minimum RH, positive and significant for maximum RH, whereas negative and significant for bright sunshine hour. No correlation existed between adult and maximum temperature. In 9 combs stored per hive. The correlation between number of larvae and weather parameters were found positive and highly significant for maximum temperature, minimum RH and positive and significant for maximum RH. The correlation between number of pupae and weather parameters were positive and highly significant for minimum RH and positive and significant for minimum temperature. No correlation existed between number of pupae and weather parameters for maximum temperature, maximum RH and bright sunshine hours. In 10 frame stored in hive body, the correlation between number of larvae and weather parameters was found positive and highly significant for minimum RH (r= 0.311) but no correlation existed between larval and weather parameters. The correlation between number of pupae and weather parameters were

Table 3. Seasonal incidence of Greater wax moth (*G. mellonella*) adult during June to October in stored combs during 2016 and 2017

Number of combs in hive body	Cumulative number of adults/comb during different months of 2016										Mean
	June		July		August		September		October		
	15.6.16	30.6.16	15.7.16	30.7.16	15.8.16	30.8.16	15.9.16	30.9.16	15.10.16	30.10.16	
Seven	0.00 (1.00)	1.00 (1.37)	1.40 (1.53)	6.00 (2.63)	11.60 (3.53)	17.60 (4.29)	23.40 (4.93)	26.00 (5.18)	15.20 (4.01)	8.20 (3.02)	11.04 (3.15)
Eight	0.40 (1.16)	1.40 (1.54)	2.80 (1.94)	9.40 (3.21)	16.80 (4.21)	20.40 (4.62)	24.00 (4.99)	27.00 (5.27)	16.60 (4.18)	8.80 (3.12)	12.76 (3.42)
Nine	0.80 (1.29)	3.00 (1.98)	4.00 (2.23)	11.80 (3.56)	18.80 (4.44)	22.80 (4.87)	25.20 (5.11)	30.20 (5.56)	19.40 (4.50)	9.80 (3.28)	14.58 (4.68)
Ten	1.20 (1.47)	3.20 (2.03)	4.40 (2.31)	14.60 (3.94)	19.80 (4.55)	23.20 (4.91)	27.80 (5.36)	32.40 (5.77)	19.60 (4.51)	10.40 (3.37)	15.66 (3.82)
Mean	0.60 (1.23)	2.15 (1.73)	3.15 (2.00)	10.45 (3.34)	16.75 (4.18)	21.00 (4.67)	25.10 (5.09)	28.90 (5.45)	17.70 (4.30)	9.30 (3.20)	-
Factors				C.D.			SE(d)			SE(m)	
Month				0.11			0.06			0.04	
Combs				0.18			0.09			0.06	
Month × Combs				0.36			0.18			0.13	
	Cumulative number of adults/comb during different months of 2017										Mean
Seven	0.00 (1.00)	1.60 (1.61)	2.00 (1.71)	6.40 (2.71)	12.60 (3.68)	18.80 (4.42)	25.00 (5.09)	27.00 (5.27)	16.80 (4.19)	9.00 (3.14)	11.92 (3.28)
Eight	0.60 (1.24)	1.80 (1.65)	2.60 (1.89)	9.60 (3.24)	17.80 (4.31)	20.80 (4.66)	25.40 (5.13)	27.80 (5.35)	17.40 (4.27)	9.20 (3.19)	13.30 (3.49)
Nine	1.00 (1.34)	3.40 (2.09)	4.20 (2.27)	12.20 (3.62)	20.40 (4.62)	23.80 (4.97)	26.00 (5.18)	31.60 (5.70)	20.80 (4.65)	10.80 (3.42)	15.42 (3.79)
Ten	1.00 (1.39)	4.20 (2.26)	4.80 (2.40)	15.80 (4.08)	21.40 (4.73)	24.00 (4.99)	28.40 (5.41)	32.40 (5.77)	20.80 (4.64)	11.00 (3.45)	16.38 (3.91)
Mean	0.65 (1.24)	2.75 (1.90)	3.40 (2.07)	11.00 (3.41)	18.05 (4.33)	21.85 (3.76)	26.20 (5.20)	29.70 (5.52)	18.95 (4.44)	10.00 (3.30)	-
Factors				C.D.			SE(d)			SE(m)	
Month				0.12			0.06			0.04	
Combs				0.19			0.10			0.07	
Month × Combs				0.39			0.20			0.14	

Figures in parentheses are $\sqrt{(n+1)}$ transformed value

Table 4. Correlation between weather parameters and greater wax moth, *Galleria mellonella* in stored comb (without bees) with different strength during both years

Weather parameters	Number of empty combs group/ hive body/ chamber during both years											
	7 frame			8 frame			9 frame			10 frame		
	Larvae	Pupae	Adults	Larvae	Pupae	Adults	Larvae	Pupae	Adults	Larvae	Pupae	Adults
Max. temp (°C)	0.138*	0.122	0.119	0.170	0.162	0.194	0.214	0.186	0.146	0.192	0.143*	0.214
Min. temp. (°C)	0.252	0.237	0.217	0.327**	0.289**	0.377**	0.380**	0.378**	0.332**	0.353*	0.251*	0.389*
Max. RH (%)	0.356**	0.373**	0.265*	0.438**	0.343**	0.455**	0.462**	0.469*	0.386**	0.468**	0.350**	0.451**
Min. RH (%)	0.223	0.207	0.121*	0.301**	0.200	0.257*	0.264**	0.270*	0.224	0.311*	0.196	0.194
Bright sunshine (hr)	-0.083	-0.09	-0.076	-0.138	-0.164	-0.189*	-0.164*	-0.248	-0.236	-0.149	-0.046	-0.112

found positive and highly significant for minimum RH. No correlation existed between number of pupae and maximum temperature, minimum temperature, maximum RH and bright sunshine hour. The correlation between number of adults and weather parameters were positive and significant for minimum R). Correlation also did not exist between adult and weather parameters such as maximum temperature, minimum temperature, RH and number of bright sunshine hour. Mandal and Vishwakarma (2016) reported positive and significant in maximum temperature, minimum temperature and minimum relative humidity with the larval population of GWM per hive, whereas the negative non-significant correlation with the maximum relative humidity and positive non-significant correlation with rainfall. Therefore, it is concluded that the GWM population were positively correlated with temperature and minimum relative humidity.

CONCLUSIONS

During both the years, larval, pupal and adult population in stored combs increased with the passage of time from June to September. However, in October, the cumulative number of larvae, pupae and adults decreased. Larval, pupal and adult population was highest when ten combs were stored followed by 9, 8 and 7 combs. Correlation studies between number of greater wax moth population in stored combs related to different frame strength with the different weather parameters and showed significant positive correlation with maximum RH and maximum temperature, whereas no significant correlation existed with minimum temperature, minimum RH and sunshine hours during both the years.

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Diversity and Feeding Habits of Spiders Across Habitats in Coimbatore District

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***Abstract*:** Spiders the generalist predators are considered ecosystem health indicators and are significant predators of insect's pests and play an important role in regulation of ecological balance. The study on the diversity and feeding habits of spiders was undertaken in three different habitats from Coimbatore District viz. the agricultural farms of ICAR- Krishi Vigyan Kendra (KVK), forest ecosystem of Sálim Ali Centre for Ornithology and Natural History (SACON), and a farming village Kondanur. Overall spider diversity from the three study areas comprised of 35 species belonging to 29 genera representing 13 families with a total of 102 individuals. Maximum of 66 individuals representing 16 species and 10 families were noted at KVK followed by Kondanur with 19 individuals representing 14 species and five families, while SACON had 17 individuals representing 13 species and seven families. Shannon diversity index and Evenness index was high at Kondanur followed by SACON and KVK. The spiders fed on 12 different faunal orders occupying habitats as per their prey base niches.

Keywords: Spider fauna, Prey habitat, Ecological balance, Salticidae and Thomisidae

Spiders are generalist predators colonizing almost all habitats and are relatively abundant and diverse in natural systems (Khan and Rather 2012) and are indicators of the health of terrestrial communities and known to play an important role in the regulation of ecological balance (Vijaya et al 2019). Only in recent years, the role of spiders as important components of arthropod communities been recognized, and considerable interest has been displayed in the analysis of spider predation in natural ecosystems (Dharmaraj et al 2020). Spiders are considered important predators as they consume a large number of preys and do not damage plants and can achieve equilibrium in pest control, after which their own numbers are suppressed by their territoriality and cannibalism (Chaubey and Mishra 2017). Many species have become highly specialized to reduce competition with other species some are nocturnal, others are diurnal some build fixed webs (sheets, orbs or tunnels), others throw webs to entangle prey, some hunt prey, other sit and wait in ambush (Anjali and Prakash 2019). Spiders forage using various hunting strategies such as ambushing, chasing after prey and catching trapped prey from their webs and feed on a diverse range of organisms, primarily insects and other arthropods, including other spiders. Victims are usually smaller than or similar in size to the spider, but many spiders can moderate prey several times their own size (Rija et al 2012). Spiders are mostly carnivorous some feed on pollen and nectar and others have been described as being predominantly herbivorous (Rija et al 2012), one of the most prosperous predatory arthropods in agricultural fields they are more sensitive to insecticides than insects, but some spiders have developed tolerance to the harmful effects of pesticides (Tahir et al 2014). Currently the World spider catalogue (2021) provides a description for 49,564 species of spiders from 4219 genera and 129 families. Keswani et al (2012) reported 1686 species of spiders from India that belongs to 60 families and 438 genera. Recently, Caleb and Karthikeyani (2020), reported 250 species of spiders for the State of Tamil Nadu, however there is no specific information from Coimbatore district. For the present study we selected three different habitats from Coimbatore District .

MATERIAL AND METHODS

Study area: The sampling of spiders was undertaken from the three select habitats in Coimbatore District (Fig. 1). Coimbatore district is in the western part of Tamil Nadu, bordering the state of Kerala. It is surrounded by the Western Ghats mountain range on the west and north, with reserve forests and the Nilgiri Biosphere Reserve on the northern side which is one of the biodiversity hotspots in India (Mownika et al 2021). The Noyyal River runs through Coimbatore and forms the southern boundary of the old city limits. The District receives both the north east and the south west monsoon with the annual average ranging between 600 to 700 mm. Most of the district is under the rain shadow region with an annual temperature variation between 18 to 38°C.

ICAR-Krishi Vigyan Kendra: The ICAR Krishi Vigyan Kendra (KVK) is spread over an area of 130 acres at Vivekanandapuram, Karamadai, Coimbatore district, Tamil Nadu. For the present study we selected an area of 10 acres of Krishi Vigyan Kendra. Latitude 11°14'20.88"N and Longitude 76°52'45.95"E, Elevation 440- 450 meters above the mean sea level. The KVK campus is a gated area that has cultivation of coconut and plantation of vetivera *(Chrysopogon zizanioides)*, lemon grass (*Cymbopogon citratus)*, curry leaf (*Murraya koenigii)* and a hybrid multicut fodder sorghum variety CO FS-29 that serves the local farming community. The study area selected in KVK is dry habitat comprising of shrubs of *Lantana camera*, *Cassia auriculata,* and trees *Tamarindus indica*, *Azhardiracta indica*, *Prosopis juliflora*, *Dichrotachys cinerea* and *Tectona grandis*.

Sálim Ali Centre for Ornithology and Natural History (SACON): Sálim Ali Centre for Ornithology and Natural History (SACON) Campus in the Anaikatty Hills (Latitude 11°05'30.9"N & Longitude 76°47'36.2"E) is 30 km away from Coimbatore city. It's comes under Western Ghats and is part of the Nilgiri Biosphere Reserve of Tamil Nadu. The campus vegetation is predominantly tropical thorn forest and tropical mixed dry deciduous scrub forest (Prakash and Karthik 2021). A small patch of Eucalyptus plantation is also found on the north- eastern part of the campus. The campus touches the Anaikatty Reserve Forest on two sides and on other sides it touches patches of private land. On the western side of SACON is a non-perennial stream called the Perumpallam falls, the water flow is restricted for 5-6 months in a year. The campus terrain is undulating with valleys and hills. Another stream flows through the campus and merges with Perumpallam. The observations of spiders were undertaken in an area of 10 acres in the campus

Kodanur village: Kodanur village located at Latitude 11°06'44.45"N and Longitude 76°45'28.07"E. is a small farming village with approximately 80 households that come under the Periyanaikenpalayam Forest range. The sampling was done from the farm land covering an area of 0.4 ha mostly cultivated vegetables, millets, and banana plantation.

The spiders were observed from the three habitats during April 2019 to September 2020. For observing the different behavior of spiders Visual Search Sampling Method and Hands-on method was employed. The feeding habits of the spiders was documented by observing the prey trapped in the spider webs for each of the species and photographed for species identification. Spider specimens were not collected but the pictures and videos of spiders were captured by using a Sony 1500D Zoom lens camera as well as mobile phone (Redmi4A) on the field. The specimens photographed were identified using the spider identification taxonomic keys (Sebastian and Peter 2006 and World Spider catalogue 2020). The individuals were counted as per the identified species and Univariate analysis was done to assess Shannon Weaver diversity and Evenness index using the PAST software 4.05. The Kruskal-Wallis test was used to determine the difference between the three sampling habitats (Hammer et al 2001).

RESULTS AND DISCUSSION

The overall spider diversity comprised of 35 species belonging to 29 genera representing 13 families with a total of 102 individuals (Table 1). The species belonging to family Salticidae and Thomisidae were observed in all the three habitats. Ten species belonging to family Salticidae were recorded followed by family Araneidae and Oxyopidae represented by five species each, while Thomisidae had 4 species the remaining families were represented by either one or two species. Statistical comparison using the Kruskal-Wallis test revealed there was no significant difference between the three sampling habitats. The KVK campus had 17 species of spiders representing 12 families with 66 individuals recorded. Maximum species belonged to the Salticidae i.e. five species, Oxyopidae (four species) and one species each of Araneidae, Eresidae, Hersiliidae, Pholcidae, Sparassidae, Tetragnathidae, Thomisidae, Uloboridae. In the SACON campus 17 individuals representing 13 species and seven families were recorded. Maximum species belonged to the Araneidae family (four species) Oxyopidae, Salticidae and Thomisidae family have two species each while Eresidae, Pholcidae, Scytodidae were represented by one species per family. The farming village Kondanur had 19 individuals of spiders representing five families. Maximum species belongs to the Salticidae family with eight species and Theridiidae three species, Thomisidae two species followed by Lycosidae, Sparassidae represented by one species each.

The univariate statistics showed highest Shannon diversity index and Evenness at Kondanur followed by SACON and KVK (Table 2). The spiders from Western Ghats can be classified into the following seven ecological guilds based on their foraging mode i.e. stalkers, orb weavers, ground runners, space web builders, ambushers, foliage runners and sheet web builders. Seven feeding guilds were recorded during our study with the spiders belonging to family Salticidae common in all the three habitats and more dominant at KVK and Kondanur (Table 3). This can be attributed to the spider's adaptation to the changed landscape and their stalking behavior. At SACON the spiders belonging to Araneidae i.e. orb-weavers dominated this is due to the presence of undisturbed vegetation and very little human interference. This was coupled by the presence of

Table 2. Univariate analysis for the three sampling stations

Statistical tests	KVK	SACON	Kondanur
Shannon weaver diversity	2.332	2.558	2.625
Evenness Index	0.572	0.922	0.920

Table 1. Spiders recorded from KVK, SACON and Kondanur village

Family	Species	KVK	SACON	Kondanur village	Total
Araneidae	*Argiope anasuja*	0	3	0	3
	Crytophora citricola	0	1	0	1
	Gasterocantha germinata	1	1	0	2
	Neoscona sp	0	1	0	1
	Nephilengys malabarensis	0	1	0	1
Eresidae	*Stegodyphuss arasinorum*	2	2	0	4
Hersiliidae	*Hersilla sp*	1	0	0	1
Lycosidae	*Hippasa sp*	0	0	1	1
Oxyopidae	*Oxopes shweta*	1	0	0	1
	O.. birmanicus	1	0	0	1
	O. javanus	9	0	0	9
	Oxyopes sp	0	1	0	1
	Peuctia viridana	4	1	0	5
Pholcidae	*Crossopriza lyoni*	3	1	0	4
Salticidae	*Carhotus viduus*	1	0	2	3
	Hyllus semicupreus	6	0	0	6
	Myrmarachne sp	0	0	1	1
	Myrmarachne melanocephala	0	0	1	1
	M. plataleoides	1	0	1	2
	Plexippus paykulli	22	0	3	25
	P. petersi	4	0	1	5
	Rhene sp	0	1	1	2
	Stenaelurillus jagannathae	0	1	0	1
	Telamonia dimidiata	0	0	1	1
Scytodidae	*Scytodes sp*	0	1	0	1
Sparassidae	*Olios milleti*	2	0	0	2
	Sparassid sp	0	0	1	1
Tetragnathidae	*Leucauge decorata*	2	0	0	2
Theridiidae	*Achaearanea sp*	0	0	1	1
	Argyodes sp	0	0	1	1
	Chrysso sp	0	0	2	2
Thomisidae	*Thomisus sp*	0	0	1	1
	T. lobobus	4	0	1	5
	Tmarus sp	0	1	0	1
	Xytics sp	1	1	0	2
Uloboridae	*Ulobrius sp*	1	0	0	1
	Total	66	17	19	102

Oxyopidae (Stalkers) and Thomisidae (Ambushers) spiders that prefer undisturbed trees and flowers. Spiders possess diverse prey capturing techniques that play a key role in the regulation of pest population in agricultural areas. The populations observed in agro-ecosystems as well as modified plant structure, may be designated as environmental stressors, especially in agricultural areas. Spiders have amazing adaptations which facilitate better survival. The study of feeding habits in the present study

Table 3. Number of individuals based on Guild

Guild	Family	No. of species
Ambushers	Thomisidae	4
Foliage runner	Lycosidae	1
	Sparassidae	2
Ground runners	Hersiliidae	1
	Scytodidae	1
Orb-weavers	Araneidae	5
	Tetragnathidae	1
	Uloboridae	1
Sheet-web builders	Eresidae	1
Space web builders	Pholcidae	1
	Theridiidae	3
Stalkers	Oxyopidae	5
	Salticidae	10

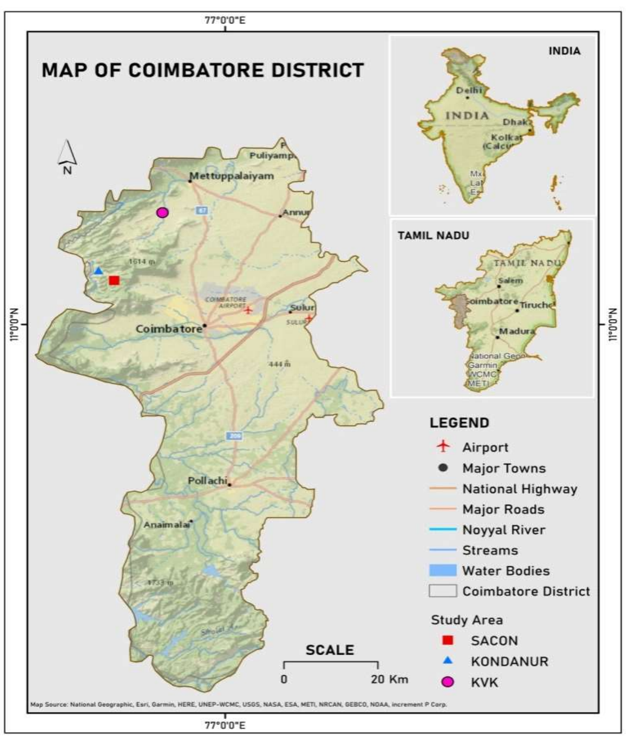

Fig. 1. Map showing the study area

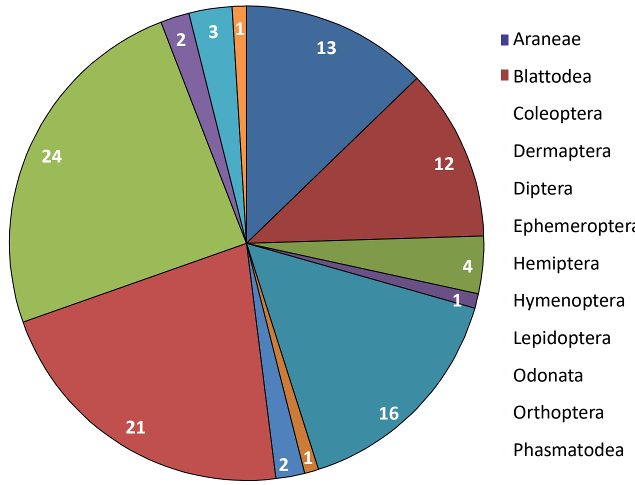

Fig. 2. Different fauna fed by the spiders

showed that the spiders fed on 12 different faunal orders (Fig. 2) dominated by 29 spider species that fed on Diptera, followed by 25 that fed on Lepidoptera, 22 fed on Hymenoptera, 13 fed on Araneae, 12 fed on Balttodea followed by other groups like Coleoptera, Orthoptera, Odonata, Dermaptera, Ephemeroptera, Hemiptera and Phasmatodea. The diversity within the different species, within the family, between the families, between the genera and between the guilds, in predation, prey capturing, adaptation and habitat selection are factors which render spiders, as potential dominant predators in agro ecosystem (Joseph and Premila 2016).

CONCLUSION

The study revealed that the species belonging to family Salticidae and Thomisidae were observed in all the three habitats. The maximum species diversity was observed in the farming village followed by the forest and agro forest habitat. The higher diversity in the village farm is attributed to the environmental stressors providing habitat for different spider species.

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Evaluation of Attractiveness and Volatile Profiling of Food Baits for Monitoring of Stored Product Pests in Paddy

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Abstract: Food baits are one of the strategies for monitoring and mass trapping of the stored product insects. Based on this principle, a study was conducted at central farm storage godown, Agricultural College and Research Institute, Madurai during March-April, 2021 by placing wheat flour, sorghum flour, pearl millet flour, rice flour, cracked corn, crushed groundnut, rice bran + rice flour as luring materials. Observations on trapped adult insects were taken on 25 days after placement of bait traps. Amongst the baits tested, wheat flour, cracked sorghum, pearl millet flour were the most attractive for stored grain pests of paddy. Wheat flour attracted 21.01% of Angoumois grain moth, *Sitotroga cerealella* and 13.38% of rice weevil, *Sitophilus oryzae*. Cracked sorghum registered attraction of 10.93% lesser grain borer, *Rhyzopertha dominica* and 13.10% of red flour beetle, *Tribolium* spp. Pearl millet flour attracted 11.65% of saw-toothed grain beetle, *Oryzaephilus surinamensis.* These effective baits were also test verified through four-arm olfactometer and found the highest orientation in the arm containing wheat flour by attracting *S. oryzae, Tribolium* spp. and *R. dominica* of 43.19, 39.61 and 37.41% respectively which possessed nonane, undecane, 3-octen-1-ol, butanal and pentanal volatile compounds. Therefore, the wheat flour may be exploited as an effective bait material for monitoring and mass trapping of *S. cerealella, R. dominica, Tribolium* spp. and *O. surinamensis* in storage godowns of paddy.

Keywords: Bait traps, Olfactometer, Rice godown, Stored product insects, Wheat flour, Volatile compounds

Rice is one of the most important food crops for more than half of the world's population. Losses in storage due to insects greatly influence food availability. Most commonly the insects, birds, mites, fungi, rodents and moisture are the major problems in storage godowns causing damage to rice. Stored product insects particularly adult beetles, due to their harbourage seeking behaviour, seek refuge in cracks and crevices of warehouse and storage godown. Lesser grain borer, *Rhyzopertha dominica* (Fabricius) (Bostrichidae; Coleoptera), rice weevil, *Sitophilus oryzae* (L.) (Curclionidae; Coleoptera), red flour beetle, *Tribolium* spp. (Tenebrionidae; Coleoptera), and Angoumois grain moth, *Sitotroga cerealella* (Olivier) (Gelechidae; Lepidoptera) are the most destructive insects which are found in stored cereals, flour mills, and storage godowns/warehouses (Kim et al 2010, Ahmed and Raza 2010, Duehl et al 2011, Ahmad et al 2013). Food attractant and repellent are used to manage several stored product insects (Mohan and Fields 2002). The food bait material used for detecting stored product insects may be a liquid or solid. Volatile chemical olfactory cues play an important role as attractants and diversity of substances such as kairomone can be exploited for the management of stored product insects (Mahroof and Phillips 2007). The granary weevil, *Sitophilus granarius* is the most widely studied storage insect species concerning its response to kairomone, with its reaction to crushed seed or whole seed (Rietdorf and Steidle 2002). Pheromones are normally species specific and a lot of insect species feed on one food stuff due to the volatiles from this food attract more than one species (Collins et al 2007). Combining food volatiles and pheromone odour can increase the pitfall traps efficiency against *Sitophilus* spp. (Likhayo and Hodges 2000, Wakefield et al 2005). Accordingly, the present study is aimed to exploit easily available, cheap, effective and attractive bait sources for the management of major pests in stored paddy.

MATERIAL AND METHODS

Trapping efficiency of different food baits: The test was conducted at Central Farm storage godown (14.5 x 6.5 x 3.5 m), Agricultural college and Research Institute, Madurai. The crushed grains and flours of wheat, sorghum, maize, groundnut, rice, rice bran and pearl millet were taken and filled in the polythene receptacles of probe trap-like structures, which contain rustproof silver metal hollow cylinders (23 x 5 cm) with 280 evenly spaced 4 mm holes. One end of the trap was closed by a removable cap. The bait traps were inserted in the interspaces between the bags arranged in a stack and the trap was filled with 50 g of bait material. The insects were crawled by orientation through the 4 mm hole and dropped into the bottom part of the receptacle.

The trap catches were recorded for 25 days. The number of insects caught in control (without bait material) was compared with the number of insects caught in the other treatments. The attraction index was calculated by using the formula (Smith et al 1993).

$$Attraction\ Index\ = \frac{T - C}{N} \times 100$$

Where, N- Number of insects attracted in treatment, C- Number of insects trapped in the control, N- Total number of individuals

Olfactometer bioassay: To study the chemoreception and attraction an experiment was conducted using specially designed four-star shaped olfactometer made of plastic (25 x 25 x 11.5 cm), with a 2.5 cm diameter opening in four corners. Each corner had a small tube, through which air could go from the arena along the central tube. The corner tubes were linked to Tygon tubing with four different gas washing bottles, all filled with a 10 g of olfactory stimulus (food attractants). This set-up provided the insects to recognize the olfactory cues of the food attractants. Air was blown to each of the four arms by the pump. The odour residue in the arena of the tubes was cleaned with 70% ethanol (Arnold et al 2012). The test adults viz*., R. dominica, Tribolium* spp. and *S. oryzae* were starved for 24 h in Petri plates before the commencement of olfactory bioassay. Twenty unsexed adults were released in the centre of the olfactometer (7 mm hole) and it was covered with cloth to minimise the phototactic response of insects. After 10 minutes, the location of the insects was observed (Ukeh et al 2010). Three different best odour/volatile sources were used to observe the response of *R. dominica, Tribolium* spp., *S. oryzae*. Each treatment was replicated 10 times.

Volatile Profiling of Food Baits in GC-MS/MS

Sample preparation: Spectroscopic analysis of food baits was done with Gas chromatograph-mass spectrometer (GC-MS/MS) to find out the chemical cues. For this purpose, a fresh sample of the selected food bait was dried and ground into powder. Samples (10 g each) were extracted with 30 ml of methanol in an ultrasonic bath for 30 min and filtered through a 0.45 μm polyvinylidene fluoride syringe filter for GC-MS/MS analysis (Kim et al 2020)

GC- MS/MS analysis: The methanol extract was characterized using GC- MS/MS (GC 2010 plus, GCMS – TQ 8040 SHIMADZU), in Central Instrumental Laboratory, Department of Agricultural Entomology, Agricultural College and Research Institute, Madurai. The compounds were separated on the capillary column (Rxi® - 5 Sil MS). The carrier gas was helium (purity percentage > 99.99%) with a column flow rate of 1ml/min and the injection was done in split less mode. The oven temperature was scheduled at 110 °C, which was constantly increased to 150°C at a rate of 10°C/min and held for 5 min, then increased to 200°C at a rate of 10 °C/min. After holding 20 min again, it was finally increased to 240 °C at a rate of 10°C /min and held for 5 min. The MS was operated in electron ionization (EI) mode at 70 eV, ion source temperature 200°C, interface temperature was 230°C and scan range was 45–600 m/z. The solvent cut time was 3 min. Each sample was allowed to run for 30 minutes. The spectrum of the unknown volatile compounds was identified by the NIST 17 (National Institute of Standards and Technology) MS library database. The obtained compounds were tabulated along with the per cent area of the peaks and retention time (RT).

Statistical analysis: The attraction index and the difference in the behavioural response/orientation of the beetles were analysed using Completely Randomized Design by using Duncan's Multiple Range Test (DMRT) with IBM SPSS 22.0 software.

RESULTS AND DISCUSSION

The attraction of *S. cerealella R. dominica, Tribolium* spp., *S. oryzae, O. surinamensis* adults varied with food attractants (Table 1). Among the food bait attractants tested, wheat flour (21.01%) was the most attractive to *S. cerealella* followed by pearl millet flour, rice bran and the least attraction was noticed in crushed groundnut (4.62%). For *R. dominica,* the cracked sorghum was highly attractive (10.93%) followed by pearl millet flour, cracked corn and the least attraction with rice flour (4.04%). Cracked sorghum (13.10%) was highly attractive to *Tribolium* spp. followed by sorghum flour, wheat flour and the least attraction was in cracked corn (3.35%). The attraction of *S. oryzae* to wheat flour and sorghum flour was high (13.27 and 11.67% respectively) followed by cracked sorghum, pearl millet flour and crushed groundnut. Pearl millet flour was highly attractive for *O. surinamensis* (11.65%) followed by rice bran (7%), sorghum flour, cracked sorghum. wheat flour and the least attraction with cracked corn (2.10%). Wheat flour attracted more *S. oryzae* (13.38%) compared to other food attractants. Earlier studies indicated that larger grain borer, *Prostephanus truncatus* and *R. dominica* had a positive attraction towards cereal host odour (Bashir et al 2001, Edde and Phillips 2006). The cracked wheat alone attracted *Sitophilus zeamais* six times more than *S. oryzae* (Likhayo and Hodges 2000). The maximum attraction of *R. dominica* was due to some odour/volatile produced by cracked sorghum (10.93%) and *S. cerealella* to wheat flour (21.01%) and *O. surinamensis* to pearl millet flour (11.65%). Ahmad et al (2013) who reported that *R. dominica* had been attracted more to wheat flour. The comparative efficacy of different food baits to various storage insect pests revealed that the wheat flour was more attractive to *S. cerealella, S. oryzae and O. surinamensis* sorghum flour/ cracked sorghum to *R. dominica, S. oryzae, Tribolium* spp. and *O. surinamensis* and the pearl millet flour to *S. cerealella, R. dominica, S. oryzae* and *O. surinamensis* (Fig. 1). The total attraction index of wheat flour > sorghum flour > cracked sorghum > pearl millet flour was found to be 56.60, 45.73, 45.23 and 43.71% respectively (Table 1). Proving that wheat, sorghum and pearl millet flours were effective attractants to different stored grain pests of paddy.

Olfactometer bioassay: Olfactometer bioassay revealed the significant differences in the orientation behaviour of *R. dominica, Tribolium* spp. and *S. oryzae* towards food bait attractants in a four-armed olfactometer. Among the three food baits tested, the highest attraction (43.19%) of *S. oryzae* was in the arm containing wheat flour followed by *Tribolium* spp. and *R. dominica*. Sorghum flour attracted *S. oryzae, Tribolium* spp. and *R. dominica.* The least attraction was in pearl millet flour with 21.83, 18.07, 17.62% of *S. oryzae, Tribolium* spp., *R. dominica*, respectively (Fig. 2).

The orientation response of *R. dominica* to wheat volatiles in two-arm olfactometer bioassay was proved by Dowdy et al (1993). However, in our study a four-arm olfactometer bioassay, multi choice test a greater number of *S. oryzae* (43.19%), *R. dominica* (37.41%) and *Tribolium* spp. (39.61%) was attracted to the test arm containing wheat flour. *R. dominica* spent more time in the olfactometer arm containing de-oiled groundnut odour/volatile compared to the arm contained maize or wheat odour/volatile (Bashir 2000). In the present study also *R. dominica, Tribolium* spp. and

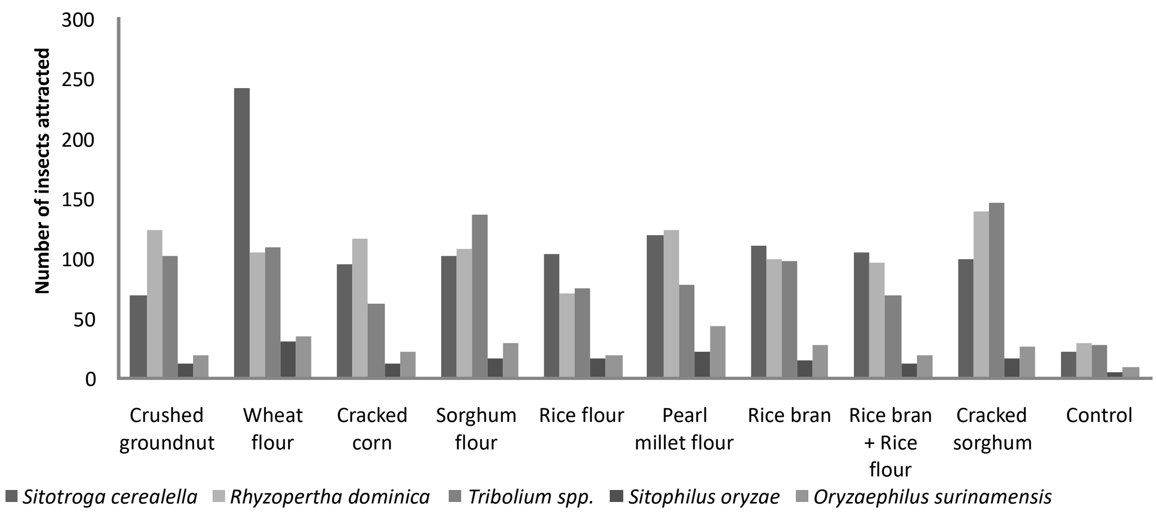

Fig. 1. Response of stored product insects to various food attractants in bait traps

Table 1. Comparative response of stored product insects of paddy to various food bait attractants

Attractants	Relative attraction index (%)					Total attraction index (%)
	Sitotroga cerealella	*Rhyzopertha dominica*	*Tribolium* spp	*Sitophilus oryzae*	*Oryzaephilus surinamensis*	
Crushed groundnut	4.62^{g}	9.31^{b}	8.07^{d}	2.59^{de}	2.99^{cd}	27.58
Wheat flour	21.01^{a}	7.42^{e}	8.93^{c}	13.27^{a}	5.97^{b}	56.60
Cracked corn	7.09^{f}	8.48^{c}	3.35^{h}	5.51^{bcd}	2.10^{de}	26.53
Sorghum flour	7.50^{e}	7.75^{d}	11.94^{b}	11.67^{a}	6.86^{b}	45.73
Rice flour	7.44^{e}	4.04^{g}	5.21^{f}	7.13^{bc}	1.79^{de}	25.61
Pearl millet flour	9.27^{b}	9.34^{b}	5.36^{f}	8.09^{b}	11.65^{a}	43.71
Rice bran	8.35^{c}	6.92^{f}	7.66^{e}	7.12^{bc}	7.16^{b}	37.22
Rice bran + Rice flour	7.97^{d}	6.66^{f}	4.39^{g}	4.21^{cd}	3.45^{c}	26.68
Cracked sorghum	7.12^{f}	10.93^{a}	13.10^{a}	8.10^{b}	5.98^{b}	45.23
Control	0.00^{h}	0.00^{h}	0.00^{i}	0.00^{e}	0.00^{e}	0.00
SEd	0.1177	0.1504	0.1542	1.4152	0.6018	-

Mean followed by the same letter (s) in a column are not significantly different by DMRT (P=0.05)

S. oryzae spent more time in the arm containing wheat flour. Vijay et al (2020) reported that the highest orientation (50.5%) of *S. oryzae* females and males were recorded towards sorghum in 20 minutes after release. In present study the orientation of *S. oryzae* towards sorghum flour (30.12%) was within 10 minutes after release. In the current study, the baits were arranged in the order of the number of visits or entries towards the wheat flour (37.41%), sorghum flour (28.75%) and pearl millet flour (17.62%), which are comparable with earlier works. Behavioural response of *R. dominica* to host plant (maize grain and winter wheat grains) bioassay indicated that both male and female *R. dominica* attracted to maize and wheat grain than the control (Ukeh and Umoetok 2007).

GC- MS/MS: The separation of the volatile compound was obtained using the R_xi – 5 Sil MS capillary column. There were over 89, 85 and 80 peaks on the chromatogram of wheat, sorghum and pearl millet respectively (Fig. 3). The major attractive volatile compounds present in the three flours analyzed were hexanol, butyric acid, propionic acid, nonane, undecane, 3-octen-1-ol, hexanal, nonanal, octanal, butanal and hexanoic acid (Table 2).

The food bait attraction to *S. cerealella* and *S. oryzae* in wheat flour may be due to the presence of volatile compounds like nonane, undecane, butanol and 3-octen-1-ol which were found in the present analytical study. E-2-nonenal and 4-ethylacetophenone compounds induced positive response from *O. surinamensis, Sitophilus granarius* and *Cryptolestes ferrugineus* in accordance with earlier findings (Collins et al 2007, Dooley et al 2018). Hexanoic acid, 2-phenylethanol and E-3-octen-2-one had elicited a response for *O. surinamensis* and *S. granarius* (Collins et al 2007). The present investigation corroborates with other studies where the chemical compounds like hexanol and butyric acid were found to be the attractive volatile compounds present in sorghum, which resulted the orientation of *R. dominica* and *Tribolium* spp. (Giliomee et al 2007, Collins et al 2007).

Hexanal, nonanal, undecane, octanal, butanal and hexanoic acid were identified as attractive compounds (Giliomee et al 2007, Collins et al 2007, Dooley et al 2018) which are responsible for greater catch of *O. surinamensis*. Different doses of benzaldehyde and aliphatic aldehyde have been tested for *O. surinamensis* and *O. Mercator* observed positive response of both species. The present investigation corroborates with other studies that hexanol and butyric acid were the attractive volatile compounds present in sorghum flour which attracted *R. dominica* and *Tribolium* spp. . Balakrishnan et al (2017) . reported a related findings that undecane, octanal, 1-hexen-3-ol, 2-heptanone, ethyl hexanoate and hexanoic acid had elicited the strongest electroantennographic (EAG) responses to *Tribolium castaneum.* Adults of *Callosobruchus sinensis* showed preferential behaviour towards benzaldehyde and 2-hexanal (Wang et al 2020) while *Callosobruchus maculatus* was attracted by 3-octanol, linalool oxide, 3-octanone, nonanal and 1-octanol (Adhikary et al 2015). The results of present study is also comparable with the reports of Germinara et al (2008) that *Sitophilus oryzae* and *S. granarius* showed repellent effects towards propionic acid. Appalasamy et al (2021) reported that octadecanoic acid, pentadecanoic acid and cis- Vaccenic acid acted as repellent and insecticidal activity against termites, *Macrotermes carbonarius* and cockroaches, *Periplaneta americana,* which are in line with

Table 2. Volatile profiles of food bait attractants

Volatile compounds	Peak area (%)		
	Wheat	Sorghum	Pearl millet
3-Hexanol	-	0.09±0.0008	-
1-Butanol	0.25±0.004	-	-
3-Octen-1-ol	0.24±0.006		
7-Octen-4-one	-	0.12±0.0003	0.26±0.002
1-Octanal	-	-	0.78±0.005
Pentanal	0.32±0.0005	-	-
Hexanal	-	-	0.58±0.014
Butanal	-	-	0.24±0.001
Nonanal	-	-	1.55±0.008
Undecane	1.73±0.029	-	0.73±0.009
Nonane	0.3±0.005	-	-
Propionic acid	-	0.12±0.001	0.23±0.002
Butyric acid	-	0.10±0.001	-
Hexanoic acid	-	-	0.57±0.001
n-Hexadecanoic acid	12.65±0.022	15.42±0.181	20.36±0.512
cis-Vaccenic acid	-	-	-

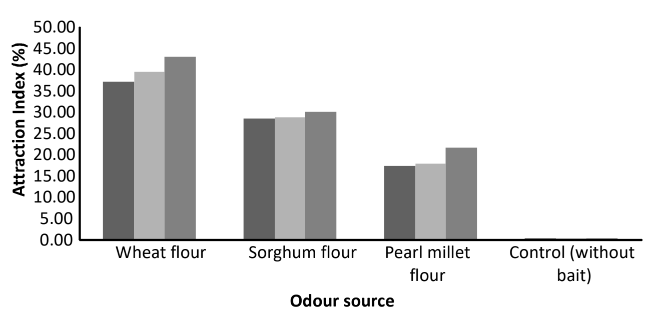

Fig. 2. Behavioural/Orientation response of *Rhyzopertha dominica, Tribolium* spp. and *Sitophilus oryzae* to various food attractants

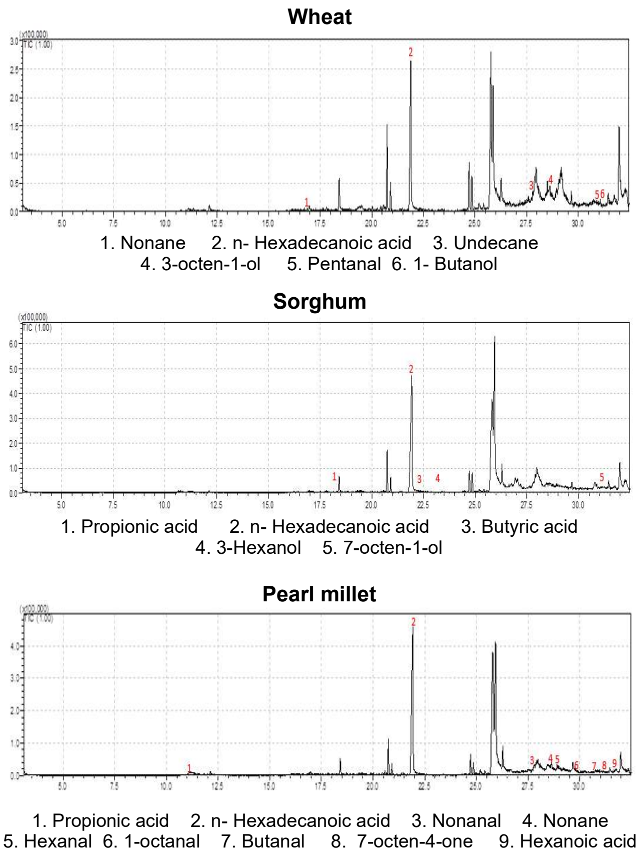

Fig. 3. GC MS/MS volatile profile of wheat, sorghum and pearl millet

our investigation. In study, the cis-Vaccenic acid present in rice bran (59.06%), so attraction per cent was very low towards this bait. The n-Hexadecanoic acid was present in a lower amount in wheat (12.65%), had exhibited very high attraction per cent in wheat compared to others (Table 1 and 2).

CONCLUSION

This study emphasized the attraction efficiency of different food baits to various storage insect pests that can be used to develop a multi-species lure for the control of stored grain pests. An effective food bait lures can be formulated using multiple millet-based flours like wheat flour, sorghum flour/cracked sorghum and pearl millet flour and that can be further exploited for monitoring and mass trapping of storage insect pests in rice godowns.

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Abundance and Foraging Behaviour of Entomophilous Pollinators on Sesame, *Sesamum indicum* L.

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Abstract: The present study focused on the community of insect pollinators, abundance and foraging behavior of different pollinators on sesame. During the study period 32 species of insect visitors were observed in sesame. The order Hymenoptera shared maximum abundance (81.25 %) followed by Diptera (12.50 %) and Coleoptera (6.25 %). Among them *Apis dorsata* acted as dominant forager contributing 24.72% followed by *Apis cerana indica* (22.44%) and *Apis florea* (11.29%). Most of the bees visited sesame flowers, but the density of *A. dorsata, A. c. indica* was maximum and peaked during 1000- 1200 hours with a mean population of 14.06 and 12.0 individuals / m^2/ 5 min whereas the activity of *A. florea* peaked (7.05 individuals/ m^2/ 5 min) at 0800-1000 hours and a steady decline in abundance of bees was observed during evening hours. The flower visitation frequency was found maximum (9.14 flowers/ min) in *A. c. indica* followed by *A. dorsata* (7.44 flowers/ min) during 1000- 1200 hours meanwhile the sequence of flower visitation reduces during evening 1600-1800 hours as 3.12 and 3.18 flowers/ min respectively. The time spent by different bees was in the order *A. florea* (18.05 sec/ flower) > *A. cerana* (15.04 sec/flower) >*A. dorsata* (11.14 sec/ flower) between 0600-0800 hours.

Keywords: *Apis cerana indica,* Abundance, Foraging behaviour, Foraging rate, Pollinator, *Sesamum indicum*

The edible oil plays a crucial role in stabilization of human health. India shares an eminent place in global oilseeds production with 12-15 per cent of cultivation area and 9-10 per cent of the total edible oil consumption. Sesame *Sesamum idicum* L. belongs to the family Pedaliaceae is one of the oldest oil seed crop and indigenous to Africa due to the preponderance of wild species in that region (Azeez et al 2017). It ranks third among the world nine major edible oil seed crop after groundnut and mustard (Rakesh et al 2017) Next to Sudan, India cruises 14.31 percent of sesame production to global market. In Tamil Nadu, sesame is cultivated in an area of 0.446 lakh ha with a production of 0.244 lakh tones and productivity of 548 kg per ha (Anonymous 2020) The complimentary pollination carried out by honey bees in sesame improves seed germination, vigour of seeds and augments the crop yield to an extent of 22 to 33 percent. Insect pollinators serve as the effective source for enhancing the crop yield both qualitatively and quantitatively (Patidar et al 2017). It is estimated that global annual economic value of insect pollination is €153 billion (Das and Jha 2018). Being a self-pollinated crop the tubular floral structure of sesame facilitates cross pollination up to an extent of 65 percent (Kamel et al 2013). Hence this basic research was carried out to document the pollinator fauna and abundance of insect pollinators in sesamum.

MATERIAL AND METHODS

The experimental trial was laid out at Agricultural College and Research Institute (9.96 °N, 78.20 °E), Madurai during March - May 2021 to study the diversity of insect pollinators, foraging behavior, relative abundance, foraging rate and speed of insect pollinators on sesame. The experimental plot was laid out in randomized block design. The number of insect pollinators from each species visiting sesame flowers were recorded from 10 percent flowering stage of the crop to flowering cessation period and were collected using sweep net, subsequently killed and preserved in ethanol for identification. The foraging behavior of insect pollinators was observed for 5 minutes from 0600 - 1800 hours at two hours interval in five plants during alternate flowering days and expressed as mean No. of individuals/m^2/5 min (Das and Jha, 2019). The relative abundance of insect pollinators was calculated as

$$\text{Relative abundance (\%)} = \frac{\text{Population of particular species visiting flowers}}{\text{Total population of all species visiting flowers}} \times 100$$

Total population of all species visiting flowers

The foraging rate (mean no. of flowers visited / minute) and foraging speed (time spent/ flower/minute) of insect pollinators were counted using electronic stop watch at two hours interval from 0600-1800 hours for five sunny days (Pashte and Shylesha, 2013). During the experimental period the cropping area was free from chemical applications to allow the frequency of natural pollinators. The data obtained were analysed using descriptive statistics and SPSS software package.

RESULTS AND DISCUSSION

Pollinator fauna: The sesame flowers attracted diverse group of insect visitors. A sum of 32 insect visitors belonging to four different orders such as Hymenoptera (16 species), Lepidoptera (8 species), Diptera (6 species) and Coleoptera (2 species) (Table 1, Fig. 1) In that 16 species of Hymenoptera 13 species was identified from seven different families such as Apidae, Megachilidae, Halictidae, Xylocopidae and Crabronidae, Formicidae and Chrysididae. In Hymenoptera the family Apidae was most abundant with six species namely *A. dorsata*, *A. cerana indica*, *A. florea, Ceratina* sp.*, Braunsapis* sp. and *Amegilla zonata.* It was followed by the family Megachilidae, which shared three species *Megachile lanata, Megachile disjuncta* and *Anthidum* sp. However the family Xylocopidae and Halictidae contributes two species. Next to Hymenoptera the order of diversity was followed by Lepidoptera comprising eight species from four families namely, Nymphalidae, Pieridae, Papilionidae and Lycaenidae. Most of the insects visit sesame flowers for collecting pollen or nectar but those who carry considerable amount of pollen grains on their body were considered as pollinators and remaining insect visitors were considered as flower visitors, a visual observation was made to record foraging activity of insect foragers on pollen and nectar to substantiate the role of flower visitors in pollination service (Table 2).

Insect pollinators with their activity of extending their proboscis into the flowers were considered as nectar collectors and those carrying pollen on their hind legs were determined as pollen collectors. In the sesamum ecosystem only 16 species were confined as pollinators. Lepidoptera shares maximum species than Dipteran but did not have significant role in pollination service as they mainly gather only nectar by extending their proboscis. Due to the tubular floral structure of sesame flowers sometimes they probe over the corolla or by holding them to suck the nectar present inside the extra nectaral disc surrounding the ovary that does not aid in adhering of pollen grains as like sunflower, mustard, to their legs whereas Dipterans flight over the flowers to collect the floral rewards abundantly as like Hymenopterans. Mahfouz et al (2012) reported Hymenoptera, Diptera, Lepidoptera and Coleoptera where the order Hymenoptera pertains to maximum number of pollinators (Pashte et al 2013) witnessed 22 species of insect pollinators foraged on sesame flowers. Among them Hymenoptera shared 17 species associated by three species from Diptera and two species from Lepidoptera. Kamel et al (2013) recorded 29

Table 1. Flower visitors of sesame (*Sesamum indicum* L.) during 2020-21

Common name	Scientific name	Family
Hymenoptera		
Indian bee	*Apis cerana indica*	Apidae
Rock bee	*Apis dorsata*	Apidae
Little bee	*Apis florea*	Apidae
Small carpenter bee	*Ceratina* sp.	Apidae
Blue banded bee	*Amegilla zonata*	Apidae
Reed bee	*Braunsapis* sp.	Apidae
Large carpenter bee	*Xylocopa* sp. 1	Xylocopidae
Large carpenter bee	*Xylocopa* sp. 2	Xylocopidae
Wooly wall bee	*Megachile lanata*	Megachilidae
Resin bee	*Megachile disjuncta*	Megachilidae
Wool carder bee	*Anthidium* sp.	Megachilidae
Sweat bee	*Halictus* sp.	Halictidae
Sweat bee	*Nomia* sp.	Halictidae
Wasp	Unidentified	Crabronidae
Cuckoo wasp	*Stilbum cyanurum*	Chrysididae
Black ant	*Camponotus* sp.	Formicidae
Diptera		
Hoverfly	*Eristalinus* sp.	Syrphidae
Marmalade hover fly	*Episyrphus* sp.	Syrphidae
Green tailed fly	*Hedriodiscus* sp.	Stratiomyidae
Robber fly	Unidentified	Asilidae
House fly	*Musca* sp.	Muscidae
Blow fly	*Lucilia* sp.	Calliphoridae
Lepidoptera		
Monarch butterfly	*Danaus chryssipus*	Nymphalidae
Tawny coster	*Acraea terpsicore*	Nymphalidae
Blue pansy	*Junonia* sp.	Nymphalidae
Cabbage butterfly	*Pieris brassicae*	Pieridae
Orange tip butterfly	*Anthocharis cardamine*	Pieridae
Citrus butterfly	*Papilio demoleus*	Papilionidae
Swallow tail	*Papilio polytes*	Papilionidae
Pulse blue butterfly	*Lampides boeticus*	Lycaenidae
Coleoptera		
Chaffer beetle	*Oxycetonia versicolor*	Scarabaeidae
Pumpkin beetle	*Aulacophora foveocolis*	Chrysomelidae

species of insect pollinators in sesame flowers, in which the order Hymenoptera contributed 18 species, followed by seven species from the order Diptera, three species from Lepidoptera and one species from Coleoptera. Ngongolo et al 2015) reported 24 species of insect visitor aids in pollination service of sesame. Meanwhile, Das and Jha 2019) recorded minimum pollinators in sesame holding 10 insect visitors belonging to the order Hymenoptera comprising of five species *viz.*, *A. dorsata, A. mellifera, Megachile* sp., *Vespa cincta* and *Camponotus sericius* followed by Diptera holding two species *viz., Sacrocophaga* sp. and *M. domestica* and Lepidoptera comprising three species *viz., D. chrycippus, Amata bicincta* and *Pieris* sp.

Foraging behaviour: Due to the presence of sufficient sunshine hours the foraging activity of *A. dorsata* and *A. c. indica* was maximum at 1000- 1200 hours and drastically reduced during evening 1600- 1800 hours. The activity of *A. florea* was peaked at 0800- 1000 hours with 7.05 individuals/m^2/ 5min. During 0800- 1000 hours, *Ceratina* sp. act as the most abundant pollinator with 2.74 individuals/m^2/ 5 min while its activity was nil between 1200-1400 hours. 1000-1200 hours was the predominant time for foraging on sesame flowers by *A. zonata* whereas very low activity was observed at 1400-1600 hours. The dominance of *Braunsapis* sp. was during 1000-1200 hours with 3.76 individuals/m^2/ 5 min. Both the *Xylocopa* sp. started their foraging on 0800-1000 hours and actively foraged on flowers at 1200- 1400 hours. The bounciness of Megachillid bees, *M. lanata* and *M. disjuncta* was soared at 1000-1200 hours. However a slow decline on individuals of *M. lanata* was recorded at 1200 - 1400 hours and complete cessation of *M. disjuncta* during 1200- 1800 hours. The activity of unidentified Hymenopteran, initiated at 0800- 1000 hours spired at 1000-1200 hours and terminated at 1200- 1400 hours. The foraging period of Halictid bees namely *Halictus* sp. and *Nomia* sp. on sesame flowers was maximum at 1000-1200 hours. Dipteran flies, *Eristalinus* sp. and *Episyrphus* sp. showed maximum abundance at 0800- 1000 hours and 1000-1200 hours respectively (Table 3). When the sesame flowers are exposed with adequate pollen and nectar source the difference in densities of pollinators on flowers occurs. The longer lower lip of sesame flowers is kept folded over the short upper lip until the flower opening which takes place usually around 0630 hours. As soon as opened, it provides running strip for bees and they blemishes over the foraging rewards in peak hours. Later, the tender flowers slowly closes their floral openings in late sunshine hours restricting the movement of bees thereby reporting low densities of individuals in evening hours. In the present study, the abundance of *A. dorsata* was maximum in the experimental

Table 2. Major floral pollinators of sesame in AC & RI, Madurai

Pollinators	Family	Collection of	
		Pollen*	Nectar*
A. c. indica	Apidae	+	+
A. dorsata	Apidae	+	+
A. florea	Apidae	+	+
Ceratina sp.	Apidae	+	+
A. zonata	Apidae	+	+
Braunsapis sp.	Apidae	+	+
Xylocopa sp. 1.	Xylocopidae	+	+
Xylocopa sp. 2.	Xylocopidae	+	+
M. lanata	Megachilidae	+	-
M. disjuncta	Megachilidae	+	-
Halictus sp.	Halictidae	+	+
N. crassipes	Halictidae	+	-
Unidentified	Crabronidae	-	+
Eristalinus sp.	Syrphidae	-	+
Episyrphus sp.	Syrphidae	-	+
O. versicolor	Scarabaeidae	+	-

*+ collected, - did not collect

site this was mainly due to the presence of adequate number of natural hives in nearby locations. Mahfouz et al (2012) recorded the maximum and minimum activity of honey bees at 0900- 1100 hours and 1500- 1600 hours respectively. They also observed that abundance of bee activity decreased with diminishing flowers per plant due to the increase in age of the crop. Bhagawati and Rahman (2016) observed the foraging behaviour of *A. cerana* on sesame and concluded that 0900-1000 hours was the peak period of visitation that is concurred with our present study results.

Relative abundance of pollinators: The relative abundance of various insect pollinators was in the order Hymenoptera (81.25%) > Diptera (12.50%) > Coleoptera (6.25%) (Fig. 2).

The share of abundance contributed by *Apis* and Non *Apis* was 37.50 and 43.75 per cent respectively. *A. dorsata* was considered as dominant forager is representing an average population of 7.05 individuals/ m^2 constituting 24.72% of total insect pollinators. This was followed by *A. c. indica* composing 22.44 % of insect fauna whereas the *A. florea* showed less abundance of 11.29%. The *Ceratina* sp. exhibited 3.01% of abundance. Meanwhile *Braunsapis* sp. from the family Apidae shared 5.20 per cent abundance. The abundance of *Halictus* sp. and *Nomia* sp. was 6.80 and 3.26 percent followed by Megachillid bees, *M. lanata* and *M. disjuncta* shared 1.64 and 1.43 per cent of dominance among the pollinators respectively. Both the *Xylocopa* sp. occupied

1.71 and 1.64 % share of insect visitors. Among 12.50 % shared by the order Diptera, the *Eristalinus* sp. and *Episyrphus* sp. recorded 3.43 and 4.62 percent abundance. Coleoptera is the least abundant order where *Oxycetonia versicolor* contributed 1.50 percent (Table 4, Fig. 2). The population of pollinator increased in subsequent flowering period. On reaching the peak flowering period the abundance of pollinators gradually declined due to the cessation of flowers. It was stated that during the peak flowering period the abundance of pollinators were 43.55 insects/ m^2 but at the time of cessation of flowers the pollinator abundance was reduced to 18.63 insects/ m^2.

The abundance of *A. dorsata* was maximum (24.72%) during the course of study might be due to the natural nest congregation in the experimental area. The presence of suitable environmental condition and the availabilty of floral rewards like attractive colour, pollens from freshly opened flowers, copious flow of nectar throughout the foraging period strongly influence the dominance of pollinator species. Kamel et al (2013) observed abundance of order Hymenoptera was higher in two consecutive study seasons of sesame flowering period (90.94 and 89.59) followed by Diptera (3.93 and 5.38), Lepidoptera (3.58 and 3.62) whereas the least percent abundance was shared by order Coleoptera (1.53 and 1.39). Bhagwati and Rahman (2016) reported that *A. cerana* as dominant forager (32.66%) adhered by *A. dorsata* (26.54%) and *A. florea* (4.76%) during the entire blooming period of sesame. The present reports are in close relation with Das and Jha (2019) where they documented, the abundance of Hymenoptera was 89.87 % followed by Diptera (6.47 %).

Foraging rate: During 0800-1000 hours, *A. c. indica* visited more number of flowers (9.14 flowers / min) besides *A. dorsata* visited 7.44 flowers/ min as freshly opened flowers are maximum during morning hours however their activity drastically reduced in evening hours (3.12 and 3.18 flowers /

Table 3. Foraging behaviour of pollinators on sesame (AC&RI, Madurai)

Pollinators	*Mean No. of individuals/m^2/ 5 min						
	0600-0800	0800-1000	1000-1200	1200-1400	1400-1600	1600-1800	Mean
Apis bees							
Hymenopterans							
A. c. indica	5.06^{a}	8.13^{b}	12^{b}	7.04^{a}	4.13^{b}	2.06^{b}	6.40
A. dorsata	5.05^{b}	9.05^{a}	14.06^{a}	6.08^{b}	5.05^{a}	3.04^{a}	7.05
A. florea	2.17^{c}	7.05^{c}	5.04^{c}	3.25^{c}	1.01^{d}	0.8^{c}	3.22
Braunsapis sp.	0.00^{g}	2.66^{de}	3.76^{e}	1.94^{e}	0.65^{e}	0.00^{h}	1.50
A. zonata	1.26^{d}	2.42^{ef}	4.15^{d}	1.14^{h}	0.3^{f}	0.11^{g}	1.56
Ceratina sp.	0.00^{g}	2.74^{d}	1.51^{i}	0.00^{l}	0.61^{e}	0.30^{e}	0.86
Mean	2.25	5.34	6.75	3.24	1.95	1.05	3.43
Non- apis bees							
Halictus sp.	0.69^{f}	2.86^{d}	3.74^{g}	2.44^{d}	1.41^{c}	0.14^{f}	1.94
Nomia sp.	1.09^{e}	2.14^{g}	3.21^{h}	1.21^{h}	0.00^{f}	0.29^{e}	0.93
Xylocopa sp. 1	0.00^{g}	0.06^{m}	1.14^{l}	1.61^{f}	0.01^{f}	0.00^{h}	0.47
Xylocopa sp. 2	0.00^{g}	0.08^{m}	1.41^{j}	1.45^{g}	0.00^{f}	0.00^{h}	0.49
M. disjuncta	0.00^{g}	1.05^{i}	1.43^{ij}	0.00^{0}	0.00^{f}	0.00^{h}	0.41
M. lanata	0.00^{g}	0.77^{j}	1.26^{k}	0.92^{i}	0.00^{f}	0.00^{h}	0.49
Unidentified	0.00^{g}	0.49^{jk}	1.30^{k}	0.57^{k}	0.00^{f}	0.16^{f}	0.43
Mean	0.25	1.06	1.78	1.36	0.23	0.09	0.79
Dipterans							
Eristalinus sp.	1.08^{e}	2.06^{h}	0.90^{n}	1.17^{h}	0.68^{e}	0.00	0.98
Episyrphus sp.	0.45^{f}	2.04^{h}	3.06^{f}	1.53^{g}	0.84^{d}	0.00	1.32
Mean	0.76	2.05	1.98	1.35	0.76	0.00	1.15
Coleopteran							
O. versicolor	0.00	0.17	0.47	0.63	0.67	0.67	0.43

In a column means followed by same letter(s) are not significant with each other, DMRT (P ≤ 0.05)
Mean ± Standard Error

min during 1600- 1800 hours respectively) (Table 5). *A. florea* visited 5.95 flowers/ min during 1000-1200 hours and their foraging activity was minimum during afternoon 1600-1800 hours (1.54 flowers/ min). Higher the foraging rate may enhance the efficiency of pollination.

Decline in foraging rate of honeybees in evening hours

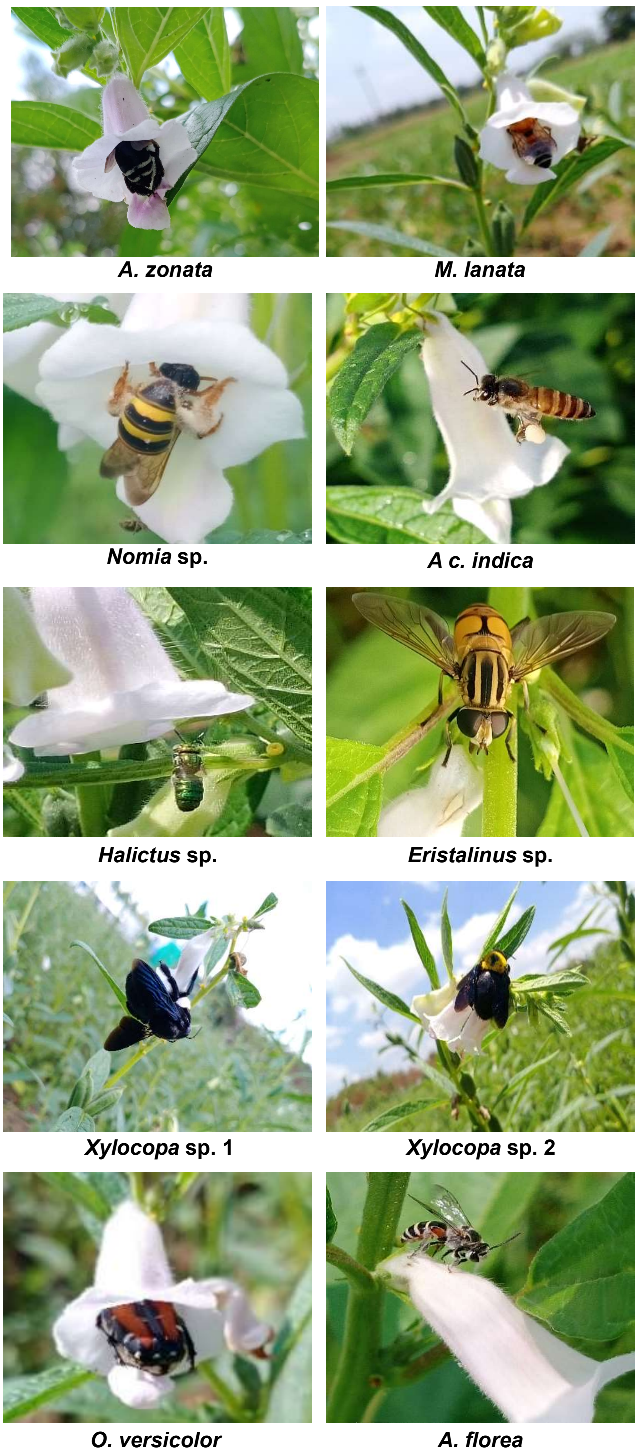

Fig. 1. Major pollinators in sesamum at AC & RI, Madurai

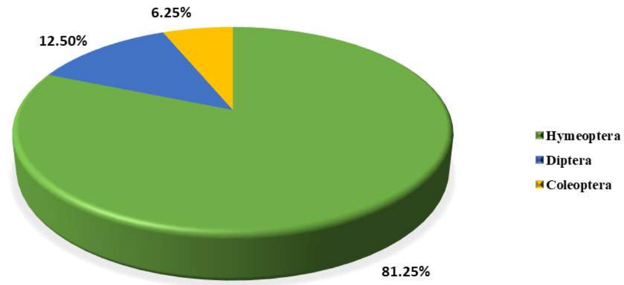

Fig. 2. Relative abundance of major pollinators of sesame at AC & RI, Madurai

and maximum foraging rate of 12.6 florets/min at 1230-1330 hours in Niger was recorded by Gebremedhm et al (2014). Bhagwati and Rahman (2016) observed number of flowers visited by *A. cerana* was maximum) during 0500-0600 hours and minimum at 1600-1700 hours in sesame while our present study recorded maximum foraging by *A. c. indica* was at 1000-1200 hours and minimum at 1600-1800 hours. This may vary due to the difference in the observations in different time period and made evident as the increase in sunshine hours will decrease the visitation frequency. Vishwakarma and Chand. (2017) concluded that foraging rate of insect pollinators in forenoon hours was 1.5-1.7 times higher than in afternoon hours in mustard. Ahmad et al. (2018) documented the maximum visitation of sunflower heads was at 0900 hours by *A. mellifera* while the *Xylocopa* visited maximum at 1300-1700 hours .

Foraging speed: *A. florea* spent maximum time of 18.05 sec/ flower on sesame. However, *A. c. indica* and *A. dorsata* spent 15.04 and 11.14 sec/ flower at 0600 -0800 hours for foraging on sesame flowers. This might be due to either low visitation of flowers, availability of maximum pollen and nectar source in the morning hours (Table 6). Even as they visited minimum flowers at 1400-1600 hours, the time spent by *A. dorsata* and *A. florea* tend to decline at 1600- 1800 hours (4.15 and 3.30 sec/ flower respectively) while the *A. c. indica* spared 3.31 sec/ flower. On observing the time spent by bees in evening hours, very low amount of pollens sticked on their bodily hairs. As soon as completion of peak anthesis period in the morning hours, the pollens started to dehisce and the sesame flowers ran out of floral rewards gradually from afternoon to evening hours. Bhagwati and Rahman (2016) quoted that maximum time spent per flower by *A. cerana* was 6.83 seconds during 0900- 1000 hours and minimum was 3.87 seconds during 1600-1700 hours of the day. Kaur et al. (2021) stated that the mean foraging speed of *A. mellifera* was 4.42 seconds compared to *A. cerana (*4.10 seconds) and *A. dorsata (*3.53 seconds) in mustard. In sunflower, *A. mellifera* spent 60.97, 74.46 and 62.12 seconds

Table 4. Relative abundance of pollinators during different flowering period in sesamum

Pollinators	Abundance of pollinators during different flowering period of sesamum (No. of individuals/ m^2/ 5 min)					Abundance (%)
	15 % flowering	50 % flowering	100 % flowering	< 50% flowering	Mean	
A. c. indica	3.41	7.68	9.03	5.48	6.40	22.44
A. dorsata	5.03	7.89	8.82	6.47	7.05	24.72
A. florea	2.06	4.31	5.07	1.45	3.22	11.29
Ceratina sp.	0.61	1.09	1.41	0.35	0.86	3.01
A. zonata	0.52	2.09	2.73	0.92	1.56	5.47
Braunsapis sp.	0.68	2.16	2.59	0.57	1.50	5.26
Xylocopa sp. 1	0.23	0.85	0.91	0.0	0.49	1.71
Xylocopa sp. 2	0.17	0.81	0.92	0.0	0.47	1.64
M. lanata	0.21	0.71	0.85	0.13	0.47	1.64
M. disjuncta	0.23	0.56	0.78	0.08	0.41	1.43
Halictus sp.	1.19	2.15	2.85	1.57	1.94	6.80
Nomia sp.	0.44	1.17	1.65	0.46	0.93	3.26
Unidentified	0.14	0.67	0.82	0.11	0.43	1.50
Eristalinus sp.	0.45	1.28	1.82	0.37	0.98	3.43
Episyrphus sp.	0.38	2.14	2.25	0.53	1.32	4.62
O. versicolor	0.17	0.38	1.05	0.14	0.43	1.50
Mean	15.92	35.94	43.55	18.63	28.51	100

Table 5. Foraging rate of different *Apis* bees on sesame flowers during different hours of the day

Time/ pollinator	No. of flowers visited/min*						Mean
	0600-0800	0800-1000	1000-1200	1200-1400	1400-1600	1600-1800	
A. dorsata	5.30^b	7.44^a	6.18^b	4.74^c	2.46^d	3.18^e	4.88
A. c. indica	4.23^b	9.14^a	7.07^b	4.05^d	5.13^c	3.12^e	5.45
A. florea	3.21^c	4.02^b	5.95^a	3.07^c	2.32^d	1.54^e	3.35

In a row, means followed by same letter(s) are not significantly different from each other, DMRT (P ≤ 0.05)

Table 6. Foraging speed of different *Apis* bees on sesame flowers during different hours of the day

Time/ pollinator	Time spent (sec/ flower)*						Mean
	0600-0800	0800-1000	1000-1200	1200-1400	1400-1600	1600-1800	
A. dorsata	11.14^a	10.21^b	9.24^c	5.90^d	5.23^e	4.15^f	7.64
A. c. indica	15.04^a	6.20^c	8.12^b	4.14^d	3.31^e	8.03^b	7.47
A. florea	18.05^a	14.18^b	11.14^c	10.49^c	4.85^d	3.30^e	10.33

Figures in the parenthesis are square root transformed values.
In a row, means followed by same letter(s) are not significantly different from each other, DMRT (P ≤ 0.05)

per flower compared to *X. fenesterata* 66.65, 68.19 and 67.79 seconds during different sunshine hours_*viz.,* 0900, 1300 and 1700.

CONCLUSION

The present study concludes that *A. dorsata* and *A. c. indica* were the efficient pollinators of sesamum ecosystem as they played vital role in pollination with maximum foraging activity. By conserving the natural pollinators in sesame growing areas will definitely enhance its productivity.

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Design of Pokkali Paddy Harvester

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***Abstract*:** The term 'Pokkali' used in the common parlor refers to a salt tolerant traditional rice cultivar grown in the coastal saline soils of Kerala. The conventional method of harvesting of pokkali paddy crop by using sickles. The various farming operations in Pokkali paddy cultivation, the harvesting is done by women labourers by walking on the swampy and marshy inundated paddy fields at waist-deep water, which is laborious, tedious and cumbersome. Though a number of paddy combine harvesters are commercially available, none cannot be used in such marshy water logged areas for harvesting paddy. Hence, a power operated floating harvester with provisions for harvesting and conveying the ear heads (panicles) of submerged paddy. Design of harvester is sequentially carried out for the floating barge, harvesting unit and hydraulic system. The capacity of the hydraulic tank was 150 litres and double acting hydraulic pump has 61.0 min^{-1}. Harvesting unit of the harvester consists of a reel, cutter bar and conveyor. The overall size of the harvester is 6.2 x 1.7 x 1.7 m with a total weight of about 1700 kg.

***Keywords*:** Harvester, Hydraulic, Pokkali paddy, Water logged, Saline

The Pokkali field is a unique eco system prevailing in the coastal tract of Kerala with rich bio diversity and amazing capacity to produce organic rice and shrimp alternatively. Rice is grown during non-saline period and the farmers carry out shrimp culture during the saline phase with both having unique symbiotic benefits. Rice plants get their nutrients from the left over of the shrimps and the shrimps in turn, feed on the stalks and decaying remnants of the rice crop. Neither chemical fertilizers nor insecticides and pesticides are used. The usual ploughing and transplantation are not required for Pokkali. Pokkali areas lie in Trissur, Ernakulum and Alappuzha districts covering a total area of 8500 ha. In more than 90% of the single cropped lands, rice cultivation is done during the low saline phase from May-June to September-October. The traditional prawn filtration is taken up during the high saline phase which sets in December-January. Generally manuring and plant protection operations are not necessary for pokkali farming systems. The crop matures at about 120 days. The ear heads alone are harvested, leaving the straw behind. The average yield of rice with traditional rice varieties is 1500 kg ha^{-1}. The conventional method of harvesting of pokkali paddy crop by using sickles. The various farming operations in Pokkali paddy cultivation, the harvesting is done by women labourers by walking on the swampy and marshy inundated paddy fields at waist-deep water, which is laborious, tedious and cumbersome. Jayan and Sathyanathan (2010) conducted a study on overview of farming practices in the water logged areas of Kerala. Studies reviewed that the fields are situated below the mean sea level and having the problems of water-logging and have no addition of chemical pesticides or fertilizers in the Pokkali rice fields which make them different from the other farming practices in Kerala.Bautista et al (2005) designed a rotary cutting reaper for rice. Their purpose was replacing the reciprocating cutter bar assembly with a rotary cutting system borrowed from grass cutters. These rotary cutters required fewer blades and less manufacturing. Study physical and mechanical properties of Pokkali soil and design features of the Pokkali paddy harvester.

MATERIAL AND METHODS

The Pokkali paddy harvester is designed for harvesting and collecting of panicle (ear head) of the paddy, while moving through the waist depth water. It is also designed as an amphibian harvester where it can traverse in water and land or both along with the harvesting operation.

Design of floating barge: Floating barge is an air filled structure providing buoyancy. The floats contain a lot of reserve buoyancy and allow to carry loads. Floating body is partially immersed in a fluid that experiences an upward force equal to the weight of the fluid displaced. The float be constructed with MS sheet metal (Gauge-12) of thickness 2.0 mm as that of the original prototype. But, each float should have dimensions of 3.0 x 0.45 x 0.6 m. The two floats have to be provided on either sides of Pokkali paddy harvester. In addition to the two floats, a separate air chamber be provided in between the two floats. The chamber also be constructed with MS sheet metal of thickness 2 mm and of size 3.0 x 0.6 x 0.4 m.

Traction belt: Tractive force is the ability of a vehicle tractive element to generate sufficient forces to overcome the soil resistance. Tractive belts made of polypropylene having a thickness of 10 mm and size 6.60 x 0.45 m is provided to generate enough traction.

Paddle: Paddle is a mechanical device for propelling a floating machine attached to the rear side. A revolving shaft attached with eight broad and angle blades is provided. It should be connected to hydraulic motor (MAT 500SH) through chain drive. The size of the paddle is 0.4x0.75m.

Design of hydraulic system: Hydraulic tank is closed type reservoir which is the integral part of a system and reservoir tank act as the main oil container for the entire system. The reservoir is designed in such a way that to drain the old, used oil and contaminants from the tank (Fig. 1). Oil filter is placed on the top of the hydraulic tank and same is connected to return line hydraulic hoses so as to filter the contaminants in the oil. Sight and level gauges offer an inside view of fluid levels in the hydraulic tank. Based on the design and requirement of oil for the operation an around 150 litre capacity tank was fabricated and placed with good structural support in back of the operator seat. The overall dimension of the hydraulic tank is 0.5 x 0.6 x 0.5 m. Hydraulic pump is constant volume of fixed displacement pump and can work 61 l min^{-1}. They are relatively quiet and of simple construction. The pump is coupled to and driven by the prime mover of the system. The inlet side of the pump is connected to the reservoir: the outlet or pressure side is connected to the direction control valve and thus to rest of the system. Hydraulic motor used here is gerotor which is coupled with the gear box for rotation of complete assembly up to 360^0 on both the sides. Hydraulic motors can be instantly started, stopped, or reversed under any degree of load; they can be stalled by overload without damage.

The most familiar double acting cylinder is the single rod end is used to lift the front conveyor along with cutter bar and reel to the operational height. This type of cylinder provides power in both directions, with a pressure port at either end. In total there are five numbers of motors are used for the operations. In that two motors are fixed as floats in the left and right side. The two numbers of hydraulic motors are used as front and centre conveyor and one motor for the cutter bar operators at the time of operation. The diameter of the cylinder bore and piston are 40mm and 30mm. Seamless tubes with high wall thickness, higher tensile strength, better bending quality, etc. are some of the specific properties which make such tubes most suitable for use in many high pressure hydraulic systems. Hence, for the operation of floating harvester the seamless pipes with two size (22 OD/18 ID and 16 OD/12 ID). The 22 OD/18 ID pipes are used for inlet and outlet of hydraulic oil and 16 OD/12 ID pipes were used for the MAT 500SH hydraulic motors. The arrangements are made in such a way that all the operations like lifting and rotation can be done by the operator at the time of operation itself.

Design of harvesting unit: Harvesting unit of the Pokkali paddy harvester consist of a reel, cutter bar and conveyor.

Reel: Reel delivers the stalks to the cutting mechanism. It holds the crop upright during cutting and delivers the cut stalks to the front conveyor (Fig. 2). It has a pentagonal frame fitted with five bats of length 120 cm fixed at a uniform spacing of 30 cm. The diameter of each bat shall be 5 cm. A total of eight fingers, each would and firmly at uniform intervals of 15 cm. The reel assembly can be operated by a hydraulic motor (MR50) through chain drive. The design of the reel can be made according to the reel position with respect to cutter bar, reel speed with respect to forward speed, delivering the stalk to the cutting mechanism with minimum losses, holding the stalk upright while cutting and delivering the stalk to the conveyor. Also, the absolute velocity of the reel should be greater than the forward speed of the harvester.

The reel index was calculated based on the standard design procedures:

Reel index or velocity ratio (λ_i) for reels is given by (Kanafojski and Karwowski, 1976):

$$\lambda_i = \frac{u_t}{v_m}$$

Where: u_t = tangential velocity of tip of the bats, m s^{-1}

v_m = forward velocity, m s^{-1}

Cutter bar: Cutter bar shall be operated by a hydraulic motor (MR50) through a crank pitman. A reciprocating type cutter bar of 1.2 m length having 16 knife sections, each having a stroke of 76.2 mm shall be provided. In order to avoid slipping off the stalks serrated knife sections were attached with the cutter bar. The pitch of serrated knife sections selected has to be two times smaller than the diameter of paddy stalk. Accordingly the pitch provided was 1.2 mm. The velocity of knife section shall be 0.54 m s^{-1} at a forward speed of 1.5 km hr^{-1}. Design of the cutter bar was carried out for finding the optimum speed of knife sections and number of knife sections based:

The velocity of knife section is expressed as: $V_k = R \times V_m$

Where: V_k = Average knife velocity, m s^{-1}

V_m = Forward speed of harvester, m s^{-1}

R = Velocity ratio

The value of R shall be in the range of between 1.3 to 1.4 with available cutter knife (Basal, 1989).

Taking R = 1.3 and Vm = 0.416 m s^{-1} (1.5 km h^{-1}) and putting values in above equation.

$V_k = 1.3 \times 0.416$

$V_k = 0.54$ m s^{-1}

Front conveyor: The crop cut by the cutter bar is conveyed to the conveyor for easy collection. It is made of 3.0 mm polypropylene sheet with equidistantly spaced rubber bars. The conveyor has to convey the bunch of cut crop continuously without blockage. It can be operated by a hydraulic motor MAH-400CB through the driving roller. This roller actuates the motion of the conveyor. The driven roller provided at the tail end, trails the conveyor forward and ensures continuous movement. The length of the conveyor belt shall be 1.7 x 0.6 m. The conveyor belt has to be wrapped over two rollers of 100 mm diameter and fixed on plummer blocks to stretch it firmly.

Speed of conveyor belt: For lugged belt conveyor the belt speed is given by

$$V_b = \pi \frac{D_{PNP}}{60}$$

Length of conveyor belt: It is calculated based on length of platform required for supporting the crop. Hence, centre to centre distance (C) between driving and driven roller is provided as 1.7 m.

The length of belt is given by

$$L = 2C + \pi \frac{(D+d)}{2} + \frac{(D+d)^2}{4C}$$

$$= 2x1.7 + 3.142 \frac{(0.1+0.1)}{2} + \frac{(0.1+0.1)^2}{4x1.7}$$

$$= 3.71m$$

Pitch of lugs: According to Devnani (1985), number of lugs on conveyor belt is

$$N = \frac{L}{P}$$

Centre conveyor: The crop is conveyed from the front conveyor to the centre conveyor for easy collection and storage of the ear heads. It shall be made of 3.0 mm polypropylene sheet. The conveyor has to convey the bunch of cut crops. It shall be operated by a hydraulic motor MAH-400CB through the driving roller. The length of the conveyor belt shall be 3.7 x 0.6 m. The conveyor belt has to be wrapped over two rollers of 100 mm diameter, which should be fixed on plummer blocks to stretch firmly.

Length of conveyor belt: It is calculated based on length of horizontal platform required for supporting the crop. Hence, centre to centre distance (C) between driving and driven roller is provided as 3.7 m. The length of belt is given by

$$L = 2C + \pi \frac{(D+d)}{2} + \frac{(D+d)^2}{4C}$$

Prime mover: The capacity to meet the power requirement for harvesting is taken into consideration for the selection of the prime mower. The total weight of the Pokkali paddy harvester comes around 1700 kg. In order to operate cutter bar, reel assembly, front conveyor, centre conveyor and float with hydraulic motors and then to lift the front conveyor with

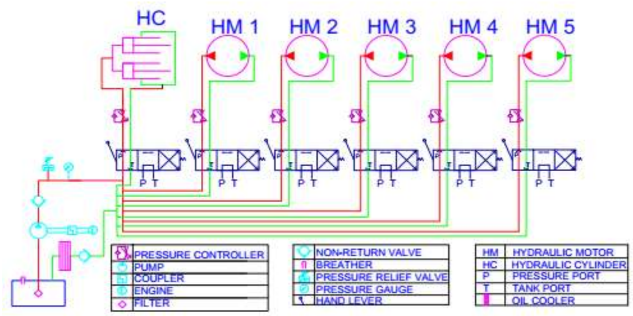
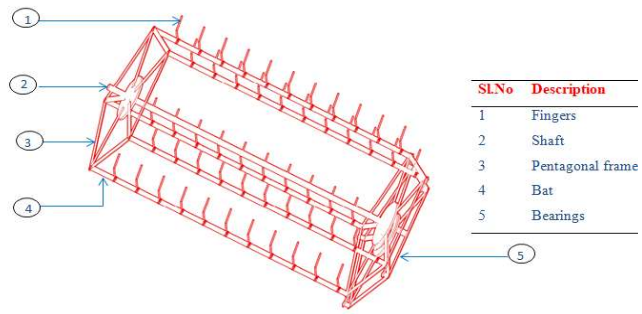


Fig. 1. Hydraulic system of pokkali paddy harvester



Isometric view

Fig. 2. Reel assembly

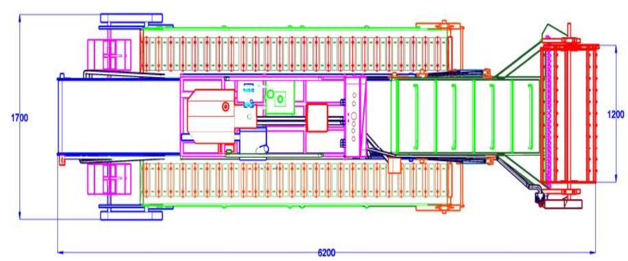


Fig. 3. Top view

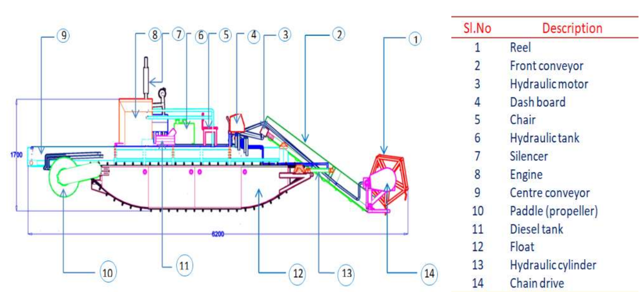


Fig. 4. Side view

Table 1. Specifications of Pokkali paddy harvester

Parts	Specifications
Overall dimensions	Length- 6.2 m
	Width- 1.7 m
	Height - 1.7 m
Float	Length - 3.0m
	Width-0.45m
	Height - 0.60 m
Engine	24 HP Diesel engine
Pump	Double acting hydraulic pump
Motors for conveyors and cutters	Hydraulic motors (M+S make)
Lift	Hydraulic cylinders
Conveyors	polypropylene
Fuel & oil storage tanks	Fuel Tank – 40 litres; Oil Tank – 150 litres
Operator cabin	Comfortable seat with canopy storage boxes for tools, life jackets etc.
Controls	Hydraulic DC valves with levers for hand operation
Control panel	Ammeter, Voltmeter, RPM meter, Oil Pressure Gauge, Temperature gauge, Hour Meter, Light Switches
Transportation & handling	Hooks provided for lifting and hauling
Finish	Epoxy - Corrosion resistant ; Colour – As per customer choice
Material for construction	Marine aluminum steel

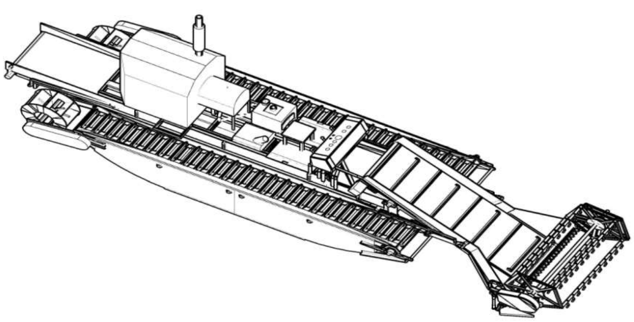


Fig. 5. Isometric view

hydraulic cylinders sufficient energy should be supplied. Hence, 24 hp diesel engines have to be selected as the prime mover.

RESULTS AND DISCUSSION

The reel was designed for the Pokkali paddy harvester and index is 1.2 and pitch of reel is 30 cm. The front conveyor designed for the Pokkali paddy. The overall dimension of conveyor was 1700 x 600 x 100 mm and 3 mm thickness polypropylene conveyor belt was selected to convey the cutting paddy stalk at operating speed of 0.47 m s^{-1}. The centre conveyor was designed for the Pokkali paddy harvester. The overall size provided for conveyor was 3700 x 600 x 100 mm. A thickness of 3 mm polypropylene conveyor belt was selected to convey and store of the cutting paddy stalk at operating speed of 0.416 ms^{-1}.The capacity to meet the power requirement for harvesting is taken into consideration for the selection of the prime mower. The total weight of the Pokkali paddy harvester comes around 1700 kg. In order to operate cutter bar, reel assembly, front conveyor, centre conveyor and float with hydraulic motors and then to lift the front conveyor with hydraulic cylinders sufficient energy should be supplied. Hence, 24 hp diesel engines have to be selected as the prime mover.

CONCLUSION

In conventional method of pokkali paddy harvesting, manual harvesting using sharp sickles are practiced. For the harvesting, highly labour intensive, drudgery and more time consuming operations are required. The paddy cultivation goes on decreasing every year. Hence, there was a great demand for a suitable harvesting machine, especially for harvesting the paddy. The Pokkali paddy harvester was designed for harvest panicles (ear heads) of paddy crop. The harvester was operated by a hydraulic system. The total weight of the Pokkali paddy harvester comes around 1700 kg. The overall dimension of the harvester is 6.2x1.7x1.7 m (LxWxH).

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Improving Egyptian Honeybee Characteristics by Crossing with Carniolan Drones using Instrumental Insemination (I) Improve Honeybee Queen Characters

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Abstract: *Apis mellifera*, the Western honeybee, is a widespread species that has differentiated into numerous geographical strains or subspecies. These subspecies differ in various characteristics, such as morphology, behavior, and ecology. In the present investigation, different morphometric characteristics of the Carniolan (*Apis mellifera carnica*) and Egyptian (*Apis mellifera lamarckii*) subspecies were compared with their hybrids and backcrosses. The rates of increase in some morphometric characteristics as evidence of hybridization between an Egyptian virgin queen and Carniolan drones being 1.7, 3.2, 0.15, 0.5. 2.4, 0.33 and 1.43 percent for forewing length, width, ovariole number, spermatheca diameter, third tergit length, width, and fourth tergit length. Moreover, the backcross generation showed reductions for all queen characteristics resulting from hybridization between an Egyptian virgin queen and Carniolan drones being 2.35, 4.058.6, 3.1, 0.93,4.2, 1.04, 0.34,and 11.5% for forewing width, ovariole number, spermatheca diameter, third tergit length, third tergit width, fourth tergit length, fourth tergit width and for queen weight.

Keywords: Carniolan subspecies, Egyptian subspecies, Morphometric parameters, Queen honeybee

Honey bees are one of the most important beneficial insects worldwide. Their positive impact can be measured by the value they contribute to the agricultural economy, their ecological role in providing pollination services, and the hive products they produce. The vital characteristics of a beehive with tens of thousands of honeybee workers largely depend on the extension of the queen's health and its reproductive capacity and the number of mated drones (Rangel et al 2013). The actual attributes and mating achievement characterizing the reproductive quality of queens are associated with colony health and productivity. Queen weight is an actual trademark that is basic for assessing the nature of honeybee queens (Tarpy et al 2012). Such variety is impacted by an assortment of variables, including the hereditary foundation, the age at which the hatchling is first raised as a honeybee queen, the season, and the raising circumstances of the colony (Collins and Pettis 2013). However, the local adaptation of *A. mellifera* subspecies and ecotypes within the same subspecies (Büchler et al 2014) shows that there is potential for targeted selection and selective breeding programs. Modification of the genetics of honey bees has been attempted several times, usually geared towards enhancing specific characteristics that promote disease resistance, and a widely used system for queen genetic evaluation. The European study indicated that local genotypes fared better in their local environment (Büchler et al 2014 and Hatjina et al 2014). Russian honey bee breeding programs have been developed by the United States Department of Agriculture laboratory in Baton Rouge, LA (Rinderer et al 2010) and the Minnesota Hygienic line developed by researchers at the University of Minnesota, St. Paul, MN (Ibrahim et al 2007, Spivak et al 2009).

Mating flight requires a lighter body for suitable lift and flight duration; in any case, a heavier weight might decrease her mating success (Hayworth et al 2009). Numerous reports have shown positive correlations between adult queen weight, mating flight number, and overall mating success (Tarpy et al 2011, 2012).Queens who are heavier at emergence tend to initiate oviposition later than queens with lower weight after being artificially inseminated. The weight of the queen has also been shown to correlate with the weight of the ovaries, the size and number of the ovaries, the diameter of the spermatheca, and the number of stored spermatozoa (Tarpy et al 2011, Collins and Pettis 2013). In any case, external measurements of queen size, such as thorax width, head width, and wing length, are likewise correlated with the queen's reproductive organs. For instance, thorax width was discovered to decidedly correspond with stored sperm number; however, no relationship was found between thorax width and ovariole number or ovary weight (Tarpy et al 2011).Therefore, spermatheca size is another valid measure of the physical quality of a queen because a bigger spermatheca size can hold more sperm (Carreck et al 2013). Spermatheca size is likewise affected by rearing conditions and the queen's genetics and conversely corresponds to larval age. This variable has been used by straightforwardly assessing the volume and indirectly assessing the hypothetical greatest number of sperm stored in the spermatheca (Tarpy et al 2011 and Carreck et al 2013). Wing morphometrics can be successfully used to distinguish between *A. m. mellifera, A. m. ligustica* and *A. m. carnica* (Oleksa and Tofilski 2015) and can be successfully applied to Africanized honey bees (Francoy et al 2018). This process could further be automated making the results rapidly available (Santana et al 2014). However, wing morphometric approach could be less reliable in areas of more recent invasion as is the case with southern USA(Francoy et al 2008).

The queen takes 1-5 mating flights during which mates with an average of 12-14 dronesstoring all the sperm she will use during her lifetime(Tarpy and Pettis 2013). After mating, queens undergo behavioral, physiological and transcriptional changes signaling their new role in the hive. The both seminal fluid components (such as proteins) and insemination volume trigger and maintain particular aspects of queen post-mating changes (Ninoet al 2013) which can in turn affect the entire colony (Peso et al 2013). Numerous mating has also been shown to provide benefits, including an expanded number of stored sperm, improved appeal of the queen (Richard et al 2007), upgraded division of work inside the colony , stabilized brood nest temperature (Oldroyd and Fewell 2007), further developed correspondence with laborers (Mattila et al 2008, Carr-Markell et al 2013), diminished occurrence of disease, and further developed colony fitness (Mattila and Seeley 2007), all of which positively influence colony development and survival . The mating number is generally used as a proxy for genetic diversity. The assessed sperm number stored in a queen spermatheca was used to evaluate the queen's reproductive quality (Tarpy et al 2012). Factors influencing results of instrumental insemination: (1) The optimal age for insemination of queens is 5 to 14 days post emergence. Queens inseminated older than 2 weeks tend to store less sperm in their spermathecae. Queens inseminated less than 4 days old have high mortality. (2) The standard semen dosage given to each queen is 8 to 12 µl. An insufficient semen dose can result in premature queen supersedure or premature queen failure. The (3) Post-insemination care of queens influences sperm storage, (a) Active movement of queen, appropriate brood nest temperatures, and attendance by worker bees promote sperm migration into the queen's spermatheca. (b) Queens confined in cages after insemination tend to store less sperm and retain semen in their oviducts (Cobey et al 2013). This work focuses on the important morphological characteristics of the honey bee queens of Egyptian and Carniolan honey bee races and their hybrids.

MATERIAL AND METHODS

The present investigation was carried out during the seasons of 2020 at the Department of Beekeeping, Plant Protection Research Institute, Dokki, Giza, Egypt. There are two regions that were chosen as isolated areas in Egypt according to their special geographical races. The first region was Al-Manzala center, which is in the northern part of the Nile Delta, where the pure Carniolan race is found. The second region was Manfalot Province, Assiut Governorate, where the pure Egyptian race is found. Three colonies from each of the Carniolan strain and Egyptian races were included in this study.

Hybridization between Carniolan and Egyptian races: Hybridization was performed via instrumental insemination at the Department of Beekeeping, Plant Protection Research Institute. The first hybrid of the mentioned pure subspecies was established as follows: Egyptian queen × Carniolan drone. The hybrids from backcrossing between the Carniolan strain and the Egyptian strain were established as follows: (Egyptian queen × Carniolan drone) × Carniolan drone.

Instrumental Insemination Techniques According to Cobey et al 2013

Saline diluent method: Two saline diluent methods are recommended. The simple formula (0.9% NaCl, 0.1% glucose and antibiotic) is for insemination with fresh collected semen used for insemination the same day (Cobey et al 2013). The second formula is recommended when mixing and storing semen, including storage at temperatures above freezing and in liquid nitrogen (Hopkins et al 2012).

Insemination Techniques

Eversion of the endophallus: Semen is collected directly from mature drones, 14 days post-emergence or older. For identification purposes, drones can be collected immediately after emergence (i.e. capturing “fuzzy” drones that are newly enclosed) and stored in cages placed in a bank colony (another honey bee colony that will tend the drones (Büchler et al 2013).

Semen collection: Semen is collected directly from the endophallus of many drones into a syringe and stored in glass capillary tubes. The amount and consistency of semen obtained from each drone varies and depends on skill and experience. Generally, each drone will yield approximately 1 µl of semen. The standard volume of semen to inseminate one queen is ~8 to 12 µl. Maintain sanitary conditions, as drones often defecate during eversion.

Insemination of the queen: Inseminate queens between 5 and 12 days post-emergence. Carbon dioxide is used to anesthetize the queen during the procedure and also stimulates oviposition. Queens can be emerged in a queenless bank or, preferably, in their own colonies .If mating nuclei are used, cage the queen cells or be sure that the hive entrances are covered with queen excluder material to prevent unwanted natural mating flights. Check the spermatheca to determine the degree of insemination success. Sperm migration requires about 40 hours post insemination. After insemination, a subset of queens can be held in a nursery colony until tested.

Maintenance of queens and drones and factors affecting queen performance: The quality of the insemination, in terms of technique and sanitation, are critical. The treatment of queens before and after the insemination will influence the amount of semen stored and queen performance. Natural conditions should be maintained as much as possible.

Maintenance of drones for instrumental insemination: Producing a large number of mature drones from select sources can be more challenging then queen rearing, especially if seasonal conditions are not optimal. Drones have a high rate of attrition and drift heavily among colonies. Free flying drones have better survival and have a prior opportunity to void faeces.

Maintenance of queens before and after instrumental insemination: The pre-and post-insemination treatment of queens will influence their performance. Maintain queens with a high proportion of nurse bees in well-fed nursery and/or nucleus colonies (Büchler et al 2013). Direct release of queens into colonies after insemination enhances sperm migration.

Statistical analysis: Data of all treatments were analyzed in a randomized complete block design analysis of variance. All means were compared using Duncan's multiple range tests at level of 0.05.

RESULTS AND DISCUSSION

Measurement of various parameters: Various anatomical measurements of honeybee queens are important for identifying bee subspecies for breeding. In the present investigation, the morphometric parameters of different vital organs were compared between the Carniolan and Egyptian subspecies and their hybrids and the backcross. The morphometric parameters of honeybee queens that were analyzed were length and width of the forewing, number of the ovarioles, diameter of the spermatheca, length and width of the third tergit, length and width of the fourth tergit, and the weight of the queen.

Honeybee queen characteristics: There were no significant differences in the mean length of forewing of honeybee queens for Egyptian and Carniolan subspecies and their F_1 hybrids and backcross being 8.98, 9.35, 9.13, and 8.92 mm, respectively (Table 1). Regarding the mean width of forewing, there were no significant differences among the Egyptian and Carniolan races and their F_1 hybrids and backcross at 2.98, 3.15, 3.08, and 2.96 mm, respectively. The number of ovarioles of honeybee queens showed a significant difference among the Egyptian and Carniolan subspecies, their F_1 hybrids, and the backcross being 130.77, 168.47, 131.07, and 120.65, respectively. Moreover, for the diameter of the spermatheca of honeybee queens, there were no significant differences among the Egyptian and Carniolan subspecies, their F_1hybrids, and the backcross at 1.005, 1.04, 1.01, and 0.98 mm, respectively. For the length of the third tergit of honeybee queens, there were no significant differences among the Egyptian and Carniolan subspecies, their F_1 hybrids, and the backcross at 8.40, 8.91, 8.60, and 8.52 mm, respectively. Furthermore, for the width of the third tergit, there were no significant differences among the Egyptian and Carniolan strains, their F_1 hybrids, and the backcross at 2.89, 3.05, 2.99, and 2.87 mm, respectively. However, the statistical analysis showed a significant difference in the length of the fourth tergit among the Egyptian and Carniolan subspecies, their F_1 hybrids, and the backcross at 9.62, 10.13, 9.76, and 9.65 mm, respectively. In addition, for the width of the fourth tergit, there was a significant difference among the means for Egyptian and Carniolan races, their F_1 hybrids, and the backcross at 2.89, 3.36, 2.92, and 2.91 mm, respectively. Regarding the weight of honeybee queens, there were significant differences among the Egyptian and Carniolan races, their F_1 hybrids, and the backcross at 0.143, 0.173, 0.165, and 0.148 mg, respectively.

Increasing percentage of honeybee queen characteristics: There was increase in characteristics as evidence of hybridization between Egyptian virgin queens and Carniolan drones including 1.7, 3.2, 0.15, 0.5, 2.4, 0.33, 1.43, 1.03 and 13.03 percent for forewing length, forewing width, ovariole number, spermatheca diameter, third tergit length, third tergit width, fourth tergit length, fourth tergit width and queen weight (Table 1). The backcross generation showed reductions for all queen characteristics because of hybridization between Egyptian virgin queens and Carniolan drones: 2.35, 4.05, 8.6, 3.1, 0.93, 4.2, 1.04, 0.34 and 11.5 percent for forewing length, forewing width, ovariole number, spermatheca diameter, third tergit length, third tergit width, fourth tergit length, width and queen weight. Searching to improve honey bee queen reproductive quality is one of the main goals of apicultural research. The queens reared naturally or artificially are critical component to colony fitness and productivity. Thus, maximizing their reproductive potential is of fundamental importance to both colonies and beekeepers (Amiri et al 2017). The body weight of the queen is impacted by the age at which the young larva is grafted, genetic factors, and generally external rearing conditions. Carr-Markell et al (2013) showed that queens reared from 1-day-old hatchings had an average of 154 ovarioles and queens reared from 2-day-old hatchings had 146 ovarioles, and those from 3-day-old hatchings had 136 ovarioles, while high-quality queens ought to have 150 ovarioles. The technique overcomes the problems resulting from lack of rigorous mating control under natural conditions. The queen is typically inseminated with semen from 8 to 12 drones (Cobey et al 2013).

Large volume sperm mixing may set the stage to implement novel breeding strategies. It allows for homogenous mixing of 3000 µL sperm (approx. 7000 drones), sufficient to inseminate up to 250 honeybee queens (Van Praagh et al 2014). The technique may set the stage to establish custom design colonies not just for honey production but also for other colony phenotypes of apicultural interest. Migration of sperm from the oviducts into the spermatheca is a complex process involving contraction of muscles mediated by the specialized composition of fluids in the semen and the oviduct as well as active sperm movement. Queens are very active after natural mating which also promotes sperm migration; therefore, use a direct queen introduction release method (Büchler et al 2013). The after effects of this investigation should assist queen breeders to work on improving rearing technologies and queen mating conditions, which are fundamental for affirming queens for commercial sale. The present study will add to a better understanding of how morphological measurements can give a norm by which to rear higher-quality queens with more prominent mating success and improved productive fitness.

The selection and improvement program could be developed in the native strain population. Oldroyd and Fewell (2007) suggested that this selective breeding should be able to produce a suitable genotype. Insemination is one measure of queen mating success, but arising data shows that mating variety is also significant for queen and colony productivity. The genetic variety inside a colony is an immediate expression of the number of drones and worker offspring (Tarpy et al 2004). Numerous experimental investigations have shown that genetically diverse colonies improve the function of laborers and decrease the degree of pathogens and parasites in the brood. The aims of queen breeding are both to preserve native wild-type strains and maintain desirable honeybee traits, such as honey production, population brood viability, brood quality and quantity, swarming tendency, disease resistance, pollen production, morphometric measurements and genetic traits (Eliza et al 2010). Al-Abbadi (2005) reported that the length and width of the forewings of new Carniolan hybrid queens were 10.15 and 3.18 mm, respectively. Furthermore, Kamel et al (2013) found that the forewing length and width, hindwing length and width, and head capsule length and width were 9.7, 3.05,

Table 1. Morphometric characteristics (mm) of *Apis mellifera lamarckii* and *Apis mellifera carnica* queens, F_1 hybrids, and backcross

Character	Subspecies		F_1 hybrid	Backcross hybrid	Significance	Increasing percentage (F1)	Reduction percentage (backcross)
	Egyptian	Carnica					
Forewing length	8.98±0.03	9.35±0.14	9.13±0.06	8.92±0.20	NS	1.7%	2.35 %
Forewing width	2.98±0.03	3.15±0.07	3.08±0.03	2.96±0.05	NS	3.2%	4.05%
Number of ovariole	130.77±2.5	168.47±5.42	131.07±2.36	120.65±5.17	*	0.15%	8.6%
Diameter of spermatheca	1.005±0.005	1.041±0.10	1.010±0.01	0.98±0.07	NS	0.5%	3.1%
3rdtergite length	8.40±0.19	8.91±0.23	8.60±0.14	8.52±0.14	NS	2.4%	0.93%
3rdtergite width	2.98±0.015	3.05±0.15	2.99 ±0.06	2.87±0.14	NS	0.33%	4.2%
4thtergite length	9.62±0.19	10.13±0.21	9.76±0.14	9.65±014	*	1.43%	1.04%
4thtergite width	2.89±0.27	3.36±0.27	2.92±0.58	2.91±0.58	*	1.03%	0.34%
Weight of queen	0.143±0.007	0.173±0.006	0.165±0.005	0.148±0.08	*	13.03%	11.5%

Values are the mean ± S.D.; *P<0.05 between subspecies, hybrid(F1) and backcross; ^{NS} P>0.05 between subspecies, hybrid(F1) and backcross

6.97, 2.03, 4.01, and 3.81, respectively. Taha and Alqarni (2013) observed that the mean body weight and forewing length and width of newly emerged Carniolan queens were 165.87 mg, 9.37 mm, and 3.08 mm, respectively. Shaheen (2018) indicated that the *Apis mellifera carnica* honeybee queens have a mean fresh body weight ranging from 137 to 177 mg. *A. mellifera carnica* honeybee virgin queens have a mean ovariole number ranging from 238.3 to 318.7, and the mean forewing length ranged from 9.40 to 9.71 mm, while the forewing width ranged from 3.10 to 3.27 mm. Taha and Alqarni (2013) found that the ovariole number in the right ovary of *A. mellifera carnica* queens was 156.89. Hasanat (2018) observed that the mean body weight of all queens collected from different districts was 160.0 mg, mean thorax width was 4.28 mm, mean queen spermatheca radius was 0.48.0 mm and mean spermatheca area was 0.75 mm. However, there was an attempt to prove that there is a very strong correlation of the queen size with the reproductive potentiality of the queens where larger queens have larger spermathecae, store greater number of sperm and full spermathecae are heavier than the smaller one (Collins and Pettis, 2013). The average weight of queen is 160.75 mg which may vary (Tarpy et al 2011) .Theaverage weight of queens was 206.6 mg in United States. Gonzalez et al (2017) reported their naturally mated queens' fresh body weight as 199.01 mg and the thorax width as 4.55 mm, in California. Delaney et al (2010), in another experiment in United States, reported an average naturally mated queen wet weight as 184.8 mg and an average thorax width as 4.35 mm, But, the queens collected from different districts of Bangladesh produced an average thorax width of 4.28 mm. Hasanat (2018) likely other researchers, the study also revealed very strong significant positive correlations between body weights, body lengths with spermatheca radius, spermatheca area of the queens.Also found that significantly correlated with strong queens and heavier spermatheca with good storage capacity of sperms. So, bigger queens' progenies should be bigger than the usual.

CONCLUSIONS

The characteristics of the Egyptian honeybee queen were improved because of hybridization between an Egyptian virgin queen and Carniolan drones (F1), while the backcross generation showed a reduced percentage for all queen characteristics.

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Seasonal Variation in the Population of Whitefly (*Bemisia tabaci*) and Incidence of Web Blight in Black Gram, *Vigna mungo* (L.) Hepper under Sub-mountainous Region of Punjab

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Abstract: The increasing incidence of whitefly (*Bemisia tabaci*) and web blight disease (*Rhizoctonia solani* Kuhn) cause huge yield loses in black gram. Keeping this in view, a study was conducted at research farm of Dr. D.R. Bhumbla Regional Research Station, Ballowal Saunkhri, (SBS Nagar), Punjab during *kharif* 2019 and 2020 to ascertain the impact of different meteorological parameters on the occurrence and development of whitefly population and web blight disease on black gram. The whitefly attained peak population of 12.88 and 16.56 whiteflies/leaf in 38th SMW during 2019 and 2020 respectively. Among all weather parameters, maximum temperature showed significant positive correlation with whitefly population during 2019 (r=0.71) and 2020 (r=0.73) respectively. In case of web blight, maximum disease severity and PDI (54.7 and 65.9 %) were in 34th SMW in 2019 while in 2020, maximum disease severity (42.0%) was in 38th SMW. A positive correlation of disease severity and per cent disease index was found with maximum temperature and relative humidity (morning) during both crop seasons. The results will help in formulation of insect-pest and disease monitoring system followed by sustainable integrated pest and disease management programme.

Keywords: Black gram, Whitefly, Web blight, Weather, *Rhizoctonia solani*, *Bemisia tabaci*

Pulses in India are cultivated over an area of 29.46 million hectare with an annual production of 23 million tones and productivity about 779 kg ha^{-1} (Tiwari and Shivhare 2017). Black gram, *Vigna mungo* (L.) Hepper, also known as urdbean or mashbean, belongs to the family leguminosae. This is an important pulse crop cultivated throughout the world however; it is usually grown during *kharif* (July) season and summer (March-April) in Northern India. In Punjab black gram is grown on 2.0 thousand hectares with the total production of 1.2 thousand tonnes and average grain yield of 5.78 quintals per hectare during the year 2019-20 (Anonymous 2021). Black gram is attacked by several insect-pests and diseases not only in the field from sowing to harvest but also the harvested produce is likely to vulnerable in storage, and it is one of the reasons behind lesser production and productivity than the potential yield of recommended varieties of legumes. Among insect pests aphid, jassid, whitefly, thrips, semiloopers, hairy caterpillar, blister beetle, tobacco caterpillar are predominant while several viral and fungal diseases are the important and play a vital role to diminish the yield (Rana et al 2016, Rajawat et al 2021). Out of these, the sucking insect-pests like whitefly, *B. tabaci* occur at all the stages of the crop growth and causing substantial yield losses in direct and indirect way (Shrivastava and Prajapati 2012, Nitharwal 2013, Marabi et al 2017). Among foliar diseases caused by fungal pathogens, powdery mildew, Cercospora leaf spot and web blight are responsible for enormous yield loss in farmers' field (Akhtar et al 2014, Pandey et al 2018). However, web blight (*Rhizoctonia solani* Kuhn) of urdbean is one of the major fungal diseases in tropical zones of the world having hot and humid climate causes yield losses up to 20-30 per cent (Shailbala and Tripathi 2007). It appears every year at varying level of intensity causing significant qualitative and quantitative yield loss in India (Dubey et al 2007, Gupta et al 2010, Singh et al 2012). The fungus can attack on the leaves during heavy rains after germination of soil borne inoculum. Weather parameters greatly influence the whitefly population and activity either directly or indirectly (Arif et al 2006) and environmental factors *viz.* aerial temperature, relative humidity and rainfall are very crucial for a rapid development of web blight disease of urdbean with high severity (Sharma and Tripathi 2007). Many studies had been conducted to study the influence of abiotic factors on the incidence of insect-pest and diseases in pulses (Yadav et al 2015, Garg and Patel 2018, Amin et al 2018, Singh et al 2019). For developing weather based pest forewarning system, information regarding pest incidence in relation to prevalent meteorological parameters (temperature, relative humidity, rainfall etc.) is prerequisite which is lacking in sub-mountainous area of Punjab. Hence, the present studies were focused on location specific seasonal progression and development of whiteflies and web blight at different crop growth stages and its relation with abiotic factors which is of great significance in formulating efficient integrated pest and disease management tactics.

MATERIAL AND METHODS

The present field experiment was conducted at Dr D R Bhumbla Regional Research Station, Ballowal Saunkhri, Punjab, India during 2019 and 2020 *Kharif* season. The study was conducted on black gram and crop was sown in a plot size of 10m x 15m with three replications during second week of July in both years of study. All the recommended agronomical practices were followed from time to time to raise a good crop. The crop was regularly monitored from germination till harvest for the population dynamics of whitefly. Observations regarding the population of whitefly was recorded at weekly intervals from three compound leaves (upper, middle, lower) per ten randomly selected plants. The observations on web blight incidence were started just after appearance of web blight disease. The data were recorded for percentage of foliage infected by web blight on 10 randomly selected plants following 1-9 scale where, 1 = No lesions on leaves; 3 = 1-25% area covered by lesions; 5 = 25.1-50% area covered by lesions; 7 = 50.1-75% area covered by lesions; 9 = 75.1-100% area covered by lesion (Stonehouse 1994). It was used to calculate per cent disease intensity (PDI) as per the formula given below:

$$\text{Percent disease intensity} = \frac{\text{Sum of individual rating scale}}{\text{No. of disease plant observation} \times \text{Maximum disease rating}} \times 100$$

In order to study the effect of the weather parameters, viz., maximum temperature, minimum temperature, relative humidity and rainfall on population of whitefly and severity of web blight and its correlation coefficient was worked out. Meteorological data on the relative humidity, rainfall, wind velocity, minimum and maximum temperature were obtained from the Meteorology observatory at Dr D R Bhumbla Regional Research Station, Ballowal Saunkhri, during the period of study. The mean weekly population of whitefly and severity with PDI of web blight was correlated with weekly weather parameters.

RESULTS AND DISCUSSION

Seasonal incidence of Whitefly, (*Bemisia tabaci*): During 2019 and 2020 the pest marked its first appearance during 29^{th} and 30^{th} standard meteorological week with scanty population of 0.88 whiteflies leaf^{-1} and 0.42 whiteflies leaf^{-1} respectively (Table 1 and Table 2). Thereafter there was gradual increase in pest population and attained peak population of 12.88 whiteflies leaf^{-1} in 38^{th} SMW during 2019 when minimum and maximum temperature was 22.7^{0}C and 32.8^{0}C, with wind velocity 2.3 km hr^{-1}, rainfall 3.8 mm along with 90 and 67 per cent morning and evening relative humidity respectively. During 2020 peak population of 16.56 whiteflies leaf^{-1} was attained in 38^{th} SMW when minimum and maximum temperature was 25.1^{0}C and 36.3^{0}C, with wind velocity 2.3 km/hr, with no rainfall along with 88 and 69 per cent morning and evening relative humidity respectively. There was decline in the whitefly population in the following standard meteorological weeks and this declined was marked in following weeks (39^{th} to 41^{st} standard meteorological weeks) and attained lowest population (1.14 whiteflies leaf^{-1}) in 40^{th} SMW during 2019 when the minimum and maximum temperature was 19.1^{0}C and 30.4^{0}C, with wind velocity 3.1 km hr^{-1}, with no rainfall along with 91 and 67 per cent morning and evening relative humidity respectively. Similarly during 2020 lowest population of whitefly (1.22 whiteflies leaf^{-1}) was attained in 41^{st} SMW when minimum and maximum temperature was 18.1 ^{0}C and 35.6^{0} C, with wind velocity 2.4 km hr^{-1}, with no rainfall along with 83 and 42 per cent morning and evening relative humidity respectively. Nitharwal (2013) reported maximum population of white flies during 37^{th} SMW. Marabi et al (2017) observed that highest population of whitefly in second fortnight of September (38^{th} SMW). Shrivastava and Prajapati (2012) recorded peak whitefly population was in 38^{th} SMW and maximum temperature, mean relative humidity and rainfall play an important role in whitefly population built-up. Yadav and Singh (2013) observed highest population of whitefly in second fortnight of September.

The significant positive correlation with maximum temperature and rainy days was observed in *Kharif* 2019 but correlation coefficient was non-significant negative between rainfall and relative humidity (morning) and minimum temperature showed a non-significant positive correlation with the population of whitefly (Table 3). Similarly during *Kharif* 2020 correlation coefficient was significant positive between mean population of whitefly and maximum temperature) while there was no correlation with minimum temperature . The white fly also exhibited positive correlation with sunshine hours. The non-significant negative correlation was observed between mean population of whitefly and wind speed and relative humidity on green gram, black gram and soybean. Yadav et al (2017) observed that population fluctuation of whitefly is dependent on the prevailed climatic conditions of season and maximum temperature and minimum temperature showed positive correlation whereas relative humidity showed negative correlation with the population of whitefly. Marabi et al (2017) observed population of adults whitefly were exhibited significantly positive correlation with maximum temperature whereas, negative correlation was expressed with morning RH%. The weather parameters like maximum temperature and sunshine hours are playing a favourable factor while relative humidity and rainfall are limiting factors for building whitefly population in mash agro-ecosystem.

Seasonal incidence web blight disease: The symptoms appeared in 31st standard meteorological week (SMW) during both years, *kharif* 2019 and 2020 (Table 1 and 2). Lowest severity of web blight of 2.3 per cent followed by 25.3 per cent with 18.5 per cent and 45.2 per cent PDI of were during 31st and 32nd SMW of 2019. However, minimum disease severity (11.0%) with lowest PDI (31.9%) was during 32nd SMW in 2020. The disease progressed gradually with increase of maximum temperature and relative humidity (morning) during both years which exhibited highest level of 54.7 per cent with 65.9 per cent PDI during 34th SMW in 2019 when maximum and minimum

Table 1. Seasonal incidence of whitefly and disease severity of Web blight on black gram in relation to abiotic factors of environment studies on 2019

Standard meteorological weeks (SMW)	Dates	T^{max}	T^{min}	Relative humidity (%)		Wind velocity (Km/Hr)	Total rainfall (mm)	Sun shine (Hrs)	Rainy days	No. of whiteflies Leaf^{-1}	Disease severity (%)	Per cent disease index (PDI)
				Morning	Evening							
29	16-22	31.4	24.3	93	77	2.9	21.4	4.5	2	0.88	0	0
30	23-29	32.8	25.8	91	76	3.2	13.4	4.6	2	2.22	0	0
31	30-05	30.9	24.5	92	89	3.2	80.5	3.7	5	0.76	2.3	18.5
32 (August)	06-12	33.0	25.3	90	79	2.6	42.0	4.7	3	4.16	25.3	45.2
33	13-19	30.9	24.4	95	84	3.2	316.8	3.3	2	1.16	43.3	55.6
34	20-26	33.4	23.9	93	75	2.3	34.8	8.2	1	5.22	54.7	65.9
35	27-02	34.0	25.7	92	73	1.4	16.6	6.4	1	6.98	52.7	63.0
36 (September)	03-09	34.0	25.4	93	73	1.7	20.0	6.3	1	10.76	54.0	64.4
37	10-16	33.7	24.5	92	72	2.1	13.6	5.7	1	8.14	50.0	57.0
38	17-23	32.8	22.7	90	67	2.3	3.8	7.8	0	12.88	47.3	55.6
39	24-30	30.2	22.2	93	76	2.6	23.1	3.9	2	3.12	50.7	57.0
40 (October)	01-07	30.4	19.1	91	67	3.1	0.0	7.8	0	1.14	40.0	55.6

Table 2. Seasonal incidence of whitefly and disease severity of Web blight on black gram in relation to abiotic factors of environment studies on 2020

Standard meteorological weeks (SMW)	Dates	T^{max}	T^{min}	Relative humidity (%)		Wind velocity (Km/Hr)	Total rainfall (mm)	Sun shine (Hrs)	Rainy days	No. of whiteflies Leaf^{-1}	Disease severity (%)	Per cent disease index (PDI)
				Morning	Evening							
30	23-29	34.2	25.9	86	71	4.2	35.2	6.3	2	0.42	0	0
31	30-05	33.6	26.1	90	72	2.6	21.0	4.9	2	0.36	0	0
32 (August)	06-12	34.5	26.5	87	75	4.6	188.6	2.7	4	3.44	0	0
33	13-19	32.7	26.2	88	75	3.2	35.2	3.6	3	1.42	11.0	31.9
34	20-26	33.1	24.8	88	75	8.2	21.2	2.3	2	2.56	15.3	33.3
35	27-02	33.6	23.9	87	69	6.5	3.4	3.1	0	1.76	18.0	36.3
36 (September)	03-09	34.2	24.1	86	69	5.8	4.2	2.3	1	5.48	26.0	39.3
37	10-16	36.1	25.1	83	56	1.8	0.0	7.8	0	11.64	29.3	46.7
38	17-23	36.3	25.1	80	59	2.3	0.0	9.4	0	16.56	37.3	49.6
39	24-30	35.3	22.5	82	54	3.0	8.6	7.9	1	8.42	42.0	51.1
40 (October)	01-07	35.6	19.2	83	52	2.9	0.0	9.7	0	4.98	16.7	31.9
41	08-14	35.6	18.1	83	42	2.4	0.0	8.8	0	1.22	18.7	33.3

Table 3. Correlation of whitefly population, disease severity and PDI during 2019 and 2020 with different meteorological parameters

Year	Independent factor	Dependent factor	Correlation coefficient (r)
2019	Maximum temperature (^{0}C)	No of whitefly leaf^{-1}	0.71
		Disease severity (%)	0.41
		PDI (%)	0.43
2020	Maximum temperature (^{0}C)	No of whitefly leaf^{-1}	0.73
		Disease severity (%)	0.57
		PDI (%)	0.46
2019	Minimum temperature (^{0}C)	No of whitefly leaf^{-1}	0.16
		Disease severity (%)	-0.05
		PDI (%)	-0.06
2020	Minimum temperature (^{0}C)	No of whitefly leaf^{-1}	0.04
		Disease severity (%)	0.08
		PDI (%)	0.22
2019	Relative humidity (%) (Morning)	No of whitefly leaf^{-1}	-0.29
		Disease severity (%)	0.27
		PDI (%)	0.23
2020	Relative humidity (%) (Morning)	No of whitefly leaf^{-1}	-0.78
		Disease severity (%)	0.00
		PDI (%)	0.10
2019	Relative humidity (%) (Evening)	No of whitefly leaf^{-1}	-0.58
		Disease severity (%)	-0.68
		PDI (%)	-0.68
2020	Relative humidity (%) (Evening)	No of whitefly leaf^{-1}	-0.37
		Disease severity (%)	-0.18
		PDI (%)	-0.04
2019	Wind velocity (Km Hr^{-1})	No of whitefly leaf^{-1}	-0.78
		Disease severity (%)	-0.62
		PDI (%)	-0.60
2020	Wind velocity (Km Hr^{-1})	No of whitefly leaf^{-1}	-0.38
		Disease severity (%)	-0.32
		PDI (%)	-0.21
2019	Rainfall	No of whitefly/leaf	-0.36
		Disease severity (%)	-0.16
		PDI (%)	-0.15
2020	Rainfall	No of whitefly leaf^{-1}	-0.23
		Disease severity (%)	-0.56
		PDI (%)	-0.44
2019	Sun shine (Hrs)	No of whitefly leaf^{-1}	0.56
		Disease severity (%)	0.48
		PDI (%)	0.53
2020	Sun shine (Hrs)	No of whitefly leaf^{-1}	0.50
		Disease severity (%)	0.41
		PDI (%)	0.23
2019	No of rainy days	No of whitefly leaf^{-1}	-0.54
		Disease severity (%)	-0.83
		PDI (%)	-0.84
2020	No of rainy days	No of whitefly leaf^{-1}	-0.52
		Disease severity (%)	-0.72
		PDI (%)	-0.57

temperature was 23.9°C and 33.4°C, coupled with wind velocity 2.3 km hr^{-1}, rainfall 34.8 mm, along with 93 and 75 per cent morning and evening relative humidity respectively. The same trend of disease development with respect to increasing temperature was also observed in crop season of 2020 though intensity of the web blight was decreased as lesser humidity was recorded this year. However, maximum severity of disease 42.0 per cent with 51.1 per cent PDI was during 38th SMW of 2020 in presence of maximum and minimum temperature of 36.3°C and 25.1°C coupled with wind velocity 2.3 km hr^{-1}, morning and evening relative humidity of 88 and 69 per cent respectively, and without rainfall during this period. There was a gradual decline was noticed in the web blight severity after 34th SMW and reached at lowest level of 40 per cent in 2019 when maximum and minimum temperature was 30.4°C and 19.1°C, with wind velocity 3.1 km/hr, with no rainfall along with 91 and 67 per cent morning and evening relative humidity respectively. Similarly in 2020, web blight severity decreased after 38th SMW which was touched at lowest level of 18.7 per cent in 40th SMW when maximum and minimum temperature was 35.6°C and 19.2°C, with wind velocity 2.9 km hr^{-1}, with no rainfall along with 83 and 52 per cent morning and evening relative humidity respectively. In case of web blight of legumes, the plant are susceptible from seedling stage until maturity with maximum severity was observed during 30-70 days old plants probably because of dense canopy of the crop which provide favourable microclimate and facilitates the early spread of the pathogen through contact of plants and leaves with one another, forming mycelial bridges (Singh et al 2013). The maximum disease severity of web blight in our study was also observed during this aforesaid period i.e. 34th SMW and 38th SMW in 2019 and 2020 respectively.

There was a strong positive correlation with maximum temperature and sun shine hours including morning relative humidity while negative correlation with evening relative humidity, wind velocity, rainfall, and rainy days during both years 2019 and 2020 respectively. Moreover, correlation coefficient was expressed non-significant negative in 2019 between severity of web blight and minimum temperature however, non-significant positive correlation was observed for aforesaid variables during 2020 (Table 3). The similar findings were reported by other worker (Copes and Scherm 2005, Sharma and Thripathi 2007) indicating occurrence and severity of web blight disease was dependent on the prevailed climatic conditions and observed that higher aerial temperature (26 to 32°C), relative humidity near 100% and soil temperature 30-33°C favoured the development web blight disease.

CONCLUSION

Significant correlation values indicated that occurrence and progression of whitefly population and web blight disease on black gram due to the prevailing weather conditions and it will help in formulation of insect-pest and disease monitoring system followed by sustainable integrated pest and disease management programme.

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Caterpillar Complex: A Rise in Threat to Mango Panicle

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***Abstract*:** The lepidopteran pest complex sheltering in the mango panicle is a rising threat to production and productivity. The caterpillar complex causing menace to the reproductive phase of the crop is collected, reared and documented for further studies. The samples of infested panicle were collected from four random districts of Kerala and 17 specimens belonging to 7 families of Geometridae, Lycaenidae, Torticidae, Nolidae, Noctuidae, Erebidae and Crambidae were recorded.

***Keywords*:** Lepidoptera, Pest, Mango, Inflorescence

Mango; the marvel fruit from family Anacardiaceae has been plagued by several primary, secondary, occasional and key pests (Dangi et al 2017). In the Indian scenario, about 250 insect and other mite pests were recorded. Only about 30 insect species among these were found to cause a serious threat to the yield (Kapadia 2003). The reproductive and vegetative stages of the plants are prone to severe pest and disease infestations. In recent times, heavy toll of lepidopteran incidence in the panicle is a rising concern among the growers. The obscure nature of damage by a plethora of polyphagous caterpillar complex in panicle went unnoticed for a quite long period. The ravage in infestation level anticipated a surge in pest status of these caterpillars in near future to reach an outrageous extend (Jayanthi et al 2018). Since flowering is a decisive element concerning the mango production, a particular focus needs to be made on pests affecting this stage of growth. Considering this aspect, the study was programmed with the aim of documentation of various caterpillar pests infesting the mango inflorescence.

MATERIAL AND METHODS

As a part of the documentation studies, inflorescence samples were collected randomly from four different districts of Kerala viz., Thiruvananthapuram, Pathanamthitta, Thrissur and Palakkad. The collected inflorescence samples were placed separately in polythene covers bearing details of sample number, date and place of collection. Infested samples were taken from diverse locations and got them labelled after individually separating the caterpillars.

They were thereafter provided with fresh inflorescence samples free of any other eggs or larvae. The morphological characters of larvae and time taken for pupation were later on recorded. The adults emerged from pupae were killed by using chloroform and pinned in the thoracic region with the aid of minuten pins. The wings of moths were stretched with the support of forceps and pins of convenient size. The setting of wings was done immediately, to avoid damage of specimens, loss of scales and inability to stretch the wings. Since many of them were microlepidopterans, they were double mounted to eliminate further damage. Plastazole foams (2x4x15 mm) were used to pin the specimens after proper setting. The well-arranged specimens were preserved with naphthalene balls and labelled, for identification by expert taxonomists.

RESULTS AND DISCUSSION

Mango panicle was infested with a complex of insect pests representing various orders of insects. Abundant number of lepidopteran infestation was recorded from the inflorescence samples. The samples collected were comprised of specimens belonging to various families of order Lepidoptera including Geometridae, Lycaenidae, Tortricidae, Nolidae, Noctuidae, Erebidae and Crambidae. Many individual larvae formed webbings whereas a few others were found inside boreholes made on peduncle and pedicel of flowers. Another common trend observed was the shift of shoot feeders to inflorescence.

The identified specimens are tabulated (Table 1) and the details regarding the specimens are depicted below:

***Thalassodes* nr. *dissita*:** The larvae of *Thalassodes* nr. *dissita*, Geometridae; were light greenish in colour resembling the stalks of panicle with patch like dark reddish spots on the dorsal surface of the caterpillars (Fig. 1). The adult moths had dark green coloured wings (Fig. 2). Preetha (2013) reported *Thalassodes sp.* infesting mango from Kerala.

***Perixera illepidaria* Guenee:** The larvae of *Perixera illepidaria* Guenee, Geometridae, were recorded from inflorescence of mango grown in Kollengode area of Palakkad district. The larvae were loopers moving from one panicle to other by hanging on a silken thread formed by them. The larvae were yellowish to dark brown in colour with banded appearance. There were a lot of variation in the colour of larvae during different instars. The newly formed pupae were green in colour, which subsequently turned brown before emergence of adults. The adults were fawn coloured with small dots on the margins of both the wings (Fig. 3). The larvae were found voraciously feeding on the floral parts leaving the stalks behind. Kumar et al (2014) reported the severe outbreak of *P. illepidaria* on litchi grown in many parts of India. Soumya et al (2017) in a study conducted in the orchards located at Karnataka to ascertain the activity on two major varieties of mango viz., Alphonso and Totapuri, the attack of this looper pest was found more evident during the peak flowering period of mango.

***Comostola laesaria* (Walker):** The caterpillar of *Comostola laesaria* (Walker), Geometridae, the red dotted emerald moth, is a looper of pale green or brown colour. The adult is light greenish coloured medium sized with reddish dots on the wings with slight orange coloured border. The pest incidence was severe in a few panicles while others showed a medium level of infestation. The adults took eight days for emergence from pupal stage (Fig. 4). Reddy et al (2018) reported that *C. laesaria* caused webbings while feeding on the flowers of mango inflorescence.

***Eublemma* spp.:** *Eublemma* nr. *quadripunctata,* was a stout dirty white coloured specimen from Erebidae (Fig. 5). *Eublemma versicolor* Walker, Erebidae; was collected from Thrissur district (Fig. 6). The moths had a stout buff coloured body with a transverse brown coloured line running along the forewing and hindwing. The pupal case was hard and found having an outer cover of dried floral parts. Another two moth species from the family Erebidae, subfamily Boletobiinae, were reared, and the larvae had capitate setae spread all

Table 1. Lepidopterans documented from mango inflorescence

Specimen	Family	Location	Co ordinates
Thalassodes nr. *dissita*	Geometridae (Geometrinae)	Thiruvananthapuram	8° 25' 21. 71" N, 76° 58'37. 23” E
Perixera illepidaria	Geometridae (Sterrhinae)	Palakkad	10° 35' 8. 47716" N, 76° 43'43. 61556” E
Comostola laesaria	Geometridae (Geometrinae)	Pathanamthitta	9° 16' 9. 71904" N, 76° 44'35. 043” E
Eublemma nr.*quadripunctata*	Erebidae (Boletobiinae)	Thiruvananthapuram	8° 21' 8. 64" N, 77° 4'40. 44” E
Eublemma versicolor	Erebidae (Boletobiinae)	Thrissur	10° 55' 30. 239" N, 76° 29'05. 494” E
Eublemma sp.	Erebidae (Boletobiinae)	Thiruvananthapuram	8° 25' 29. 90388" N, 77° 1'53. 64588” E
Eublemma abrupta	Erebidae (Boletobiinae)	Thiruvananthapuram	8° 25' 29. 75376" N, 77° 1'53. 2002” E
Lymantria nr.*ampla*	Erebidae (Lymantriinae)	Thiruvananthapuram	8° 25' 27. 56712" N, 77° 1'52. 55256” E
Lymantria sp.	Erebidae (Lymantriinae)	Thiruvananthapuram	8° 25' 27. 56712" N, 77° 1'52. 55256” E
Anthene lycaenina lycaenina	Lycaenidae (Lycaeninae)	Thiruvananthapuram	8° 25' 27. 56712" N, 77° 1'52. 55256” E
Rapala manea	Lycaenidae (Lycaeninae)	Thiruvananthapuram	8° 22' 36. 12" N, 77° 6'45. 36” E
Nanaguna breviuscula	Nolidae	Thrissur	10° 55' 30. 239" N, 76° 29'05. 494” E
Gatesclarkeana erotias	Tortricidae (Olethreutinae)	Pathanamthitta	9° 16' 9. 71904" N, 76° 44'35. 043” E
Archips micaceana	Tortricidae (Tortricinae)	Pathanamthitta	9° 16' 9. 71904" N, 76° 44'35. 043” E
Aetholix flavibasalis	Crambidae	Thiruvananthapuram	8° 25' 56. 58755" N,
Bombotelia jocosatrix	Noctuidae (Euteliinae)	Thiruvananthapuram	8° 25' 21. 71" N, 76° 58'37. 23” E
Chlumetia transversa	Noctuidae (Euteliinae)	Thrissur	10° 55' 30. 239" N, 76° 29'05. 494” E

over the dorsal surface of the body with sparsely dispersed non capitate setae. The larva of *Eublemma* sp. is bright yellow in colour with brownish patches spreading all over the body (Fig. 7). Adult is dull coloured having a dual transverse line running along the wings and bordering the outer margin (Fig. 8). The larvae of *Eublemma abrupta* was blackish in colour with a yellow coloured 'v' shaped band near the head region and four eye like spots on the middle of dorsal surface (Fig. 9). The moths were dull brown coloured with dual transverse lines of bland white shade running towards the inner side of forewings and the hind wings had black dots towards the lower end (Fig. 10). Babu et al (2001) and Kaushik (2009) reported the infestation of *Eublemma versicolor* on mango inflorescence at its full bloom state. Yadav et al (2014) reported the incidence of *E. angulifera* M. from mango flowers in Kerala.

***Lymantria* spp.:** Larvae of *Lymantria nr. ampla* Walker, Erebidae; a hairy caterpillar was collected from full bloom panicles of mango grown in the Nemom area of Thiruvananthapuram. The adult moth is slightly more than medium in size having a golden brown coloured forewings with brown and black patches on it. The hindwings are light brown in colour (Fig. 11). There were already reports regarding infestation of these pests from Kerala. *Lymantria* sp., another one from Erebidae family was collected from Nemom area of Thiruvananthapuram district. The larvae were hairy caterpillars. The adult moth was whitish in colour with blackish brown patches smeared all over the surface of forewings and hindwings. The antennae of the moth were unipectinate type (Fig.12).

Anthene lycaenina lycaenina: *Anthene lycaenina lycaenina*, Lycaenidae; infesting mango inflorescence was recorded from Athiyannur area of Thiruvananthapuram district. There were about 1- 5 larvae per panicle. The larvae were stout reddish brown coloured with paired rows of yellowish pattern on the dorsal surface. The larvae in later instar stages were voracious feeders with only the stalks left behind.

***Rapala manea* (Hewitson):** *R. manea* (Hewitson), Lycanidae, was observed infesting on the inflorescence of homestead grown mango trees from different areas of Thiruvananthapuram district. The stout dull yellowish larva showed spine like projections along the sides of the body and a dark reddish brown line over the dorsal surface in the two ends (Fig. 13). The early instar larva was found feeding on the floral parts while the later instars were more voracious feeders, only the stalks of the inflorescence remained. The adult males were dark winged with a tinge of purple colour (Fig. 14). Female moths were lighter in colour. The ventral side showed black coloured markings towards the anal angle with an orange colour topping. Robinson et al (2010) also reported mango as a host of *R. manea.*

***Nanaguna breviuscula* Walker:** *Nanaguna breviuscula* Walker, Nolidae; was another caterpillar recorded from the inflorescence. The larva was translucent pale green yellowish in colour with light red coloured lines running along whole length of the body (Fig. 15). The larva had a brown coloured head. The adult moth was brownish in colour having a diffused blackish band on the forewings (Fig. 16). The hindwings were dull white coloured.

***Gatesclarkeana erotias* Meyrick:** A wide range of moths belonging to Tortricidae were collected and reared from the inflorescence. *Gatesclarkeana erotias* Meyrick, Tortricidae; is a bell shaped moth reared from mango inflorescence. The larva is dark green coloured caterpillar with a brownish head (Fig. 17). The forewings are dark dull coloured with metallic reddish brown streaks and the hindwings are with dark yellowish coloured shade all over (Fig. 18).

***Archips micaceana* (Walker):** The moths of *Archips micaceana* (Walker) had a bell shaped structure like most of the tortricid moths. The larvae were found feeding on the inflorescence. The moths were having reddish orange forewings with red coloured wavy lines in between. There were greyish markings on the inner side of light yellowish coloured hindwings (Fig. 19). Similar observations were recorded by Prakash et al (2002) in flowers of vanilla grown in Karnataka. The larvae webbed the flowers and bored the flower stalks which resulted in withering of vanilla flowers.

***Aetholix flavibasalis* Guenee:** *Aetholix flavibasalis* Guenee, family Crambidae was collected from mango inflorescence of the trees grown in homestead of Athiyannur area of Thiruvananthapuram district. The moths had a medium body. The forewings were purplish in colour with pale spots. There was a white band across the hind wings (Fig. 20). Sundararaju (2009) reported the incidence of *A. flavibasalis* from cashew.

***Bombotelia jocosatrix* Guenee :** The larvae of *Bombotelia jocosatrix* Guenee, Noctuidae; was found feeding on flowers of mango grown in a homestead located at Athiyannur block of Thiruvananthapuram. The larvae of these moths are stout, light greenish in colour with dark reddish pink tinges towards the anal region (Fig. 21). The adult has blackish brown forewings; the margin of each of the forewing has an arc cut out of the tornus (Fig. 22). The hindwings are white with a central black spot and a broad dark border. The moth has an unusual resting posture. Crest of scales are found raised over the head, the abdomen curled up over the body. The fifth instar larva was collected, which pupated within two days. The pupal period was for 11 days.

***Chlumetia transversa* Walker:** The larva of *Chlumetia*

Fig. 1. Larva - *Thalassodes* nr. *dissita*

Fig. 2. Adult - *Thalassodes* nr. *dissita*

Fig. 3. *Perixera illepidaria*

Fig. 4. *Comostola laesaria*

Fig. 5. *Eublemma* nr. *quadripunctata*

Fig. 6. *Eublemma versicolor*

Fig. 7. Larva - *Eublemma* sp.

Fig. 8. Adult- *Eublemma* sp.

Fig. 9. Larva - *Eublemma abrupta*

Fig. 10. Adult - *Eublemma abrupta*

Fig. 11. *Lymantria* nr.*ampla*

Fig. 12. *Lymantria* sp

Fig. 13. Larva - *Rapala manea*

Fig. 14. Adult - *Rapala manea*

Fig. 15. Larva- *Nanaguna breviuscula*

Fig. 16. Adult - *Nanaguna breviuscula*

Fig. 17. *Larva- Gatesclar-keana erotias*

Fig. 18. *Adult - Gatesclar-keana erotias*

Fig. 19. *Archips micaceana*

Fig. 20. *Aetholix flavibasalis*

Fig. 21. Larva - *Bombotelia jocosatrix*

Fig. 22. Adult - *Bombotelia jocosatrix*

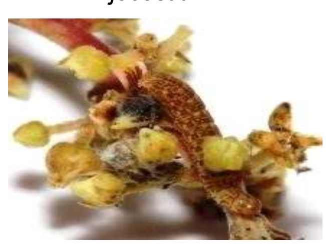

Fig. 23. Larva - *Chlumetia transversa*

Fig. 24. Adult - *Chlumetia transversa*

transversa Walker, Noctuidae was another caterpillar pest, found infesting the peduncle and pedicles of flowers with boreholes. The larva is yellowish with peculiar red coloured pattern on the dorsal surface (Fig. 23). The adults emerged within six days of pupal period. The adult moth has shining greyish brown coloured forewings and hind wings. The submarginal bands on the fore wings were found broken (Fig. 24). This pest infest all the varieties of mango, with considerable damage caused by boring of shoots (Singh and Kaur 2014). The symptoms of damage exhibited by this pest was similar to one recorded by Soumya et al (2017). Reddy et al (2018) reported the incidence of shoot borers in mango including *C. transversa* and *Gatesclarkeana erotias*.

CONCLUSION

The infestation level and species composition of lepidopterans on the mango panicle vary with season and climatic conditions. But, the threat to reproductive phase of the crop, caused by these caterpillars cannot be neglected.

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Morphometric Analysis of Some Nymphalidae Butterflies (Rhopalocera) from the Bannerghatta Biological Park (BBP), Bengaluru, Karnataka

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***Abstract*:** The current study was carried out to delineate the interrelationship of Nymphalidae (brush-footed butterflies) viz., *Ariadne merione, Danaus genutia, Europa core, Phalanta phalantha* and *Tirumala limiace* in and around Bannerghatta Biological Park (BBP), Bengaluru, Karnataka. To understand morphometrics of Nymphalidae, measurement of the body, proboscis, antenna, wings, and legs of these butterflies was carried out and analyzed. Principal Component Analysis (PCA) was performed for nine variables to examine the principle variable components among the species. The first Principal Component accounted for 84.70% between females and 87.30% between males, followed by the second PCA. Thus, we conclude that morphometric analysis of the five species revealed the importance of interspecies descriptions in characterizing the butterfly species and would also help in conserving the species.

***Keywords*:** Antenna, Body, Brush-footed butterflies, Legs, Morphometry, Proboscis, Wings

A rich heritage of biological diversity is seen in India, consisting of over 89,000 species of organisms and 45,000 plants in very diverse bio-geographical regions (Mudgal and Hajra 1999). Butterflies are arguably the best-loved group of invertebrates and have been a source of inspiration for generations of natural historians and scientists (Wahlberg et al 2005). The butterfly family Nymphalidae approximately contains 6000 species, placed into 542 genera, distributed worldwide. Currently, these genera are put into 12 subfamilies and 40 tribes. These are generally average-sized to large butterflies; some are smaller in size. The butterflies are brightly coloured from above, but their underwings are dull in colour. The majority of the subfamilies species has a reduced pair of forelegs except for the subfamily Libytheinae and holds their iridescent wings flat when at rest. They are also referred to as brush-footed butterflies or four-footed butterflies and all other butterflies have three pairs. The reason is the foreleg pair is reduced as compared to other legs.

The classification of butterflies and skippers is extensively based on the morphology of adults for close to 250 years (Ackery et al 1999). Regardless of the extensive homoplasy in these morphologically variable insects (Kjer 2004). However, character's effectiveness from juvenile stages has long been acknowledged for species analysis (Freitas et al 2001), but they have only recently been automatically incorporated in a phylogenetic context (Penz and Peggie 2003, Freitas and Brown 2004). Generally, butterflies' classification is based on morphometric characters which body, proboscis, antenna, wings, and legs are mainly dependent on body length, proboscis, antenna, wings, and legs. Henceforth, morphometric analysis generally reveals the interrelationship between the various features such as length, leg spinnerets, and other body parts. Therefore, it is a reliable technique for recognizing the degree of reproduction maturity without sacrificing the animal (Ramakrishnaiah et al 2018). Morphological characteristics of various butterflies have certain connections with their evolution environment and natural selection (Azrizal-Wahid et al 2015). In this regard, only beneficial characters for survival are usually retained, while those not beneficial characteristics are lost. The lost features often serve have taxonomic keys in species identification and characterization (Pollard and Yates 1994). As a result, a revision of the current status of butterflies is required to verify the accuracy of taxonomic keys butterfly identification and conservation. Therefore, in the present study, a morphometric approach applying PCA was carried out to give the complete description of the variation in body length, proboscis, antenna, wings, and legs for five species belonging to the Nymphalidae family from Bannerghatta biological park, Bengaluru, Karnataka.

MATERIAL AND METHODS

Butterflies were collected using the standard insect (butterfly) nets or using the ground hand collection methods. The specimens were collected in a live insect box and taken to the laboratory. The work was conducted in the Bannerghatta Biological Park (Butterfly Park), Bengaluru and permission number for the present work is No. A3/BBP/Research Work/2018-19. The identification of the species was accomplished based on the morphology as presented in Kunte (2000) and Butterflies of India, v. 3.17. Indian Foundation for Butterflies (Website reference: http://www.ifoundbutterflies.org/tx/8-Nymphalidae), along with the support from the staff of Bannerghatta Biological Park. The morphometric measurements were carried out using the electronic digital Vernier calipers in mm scale, and the data were analyzed for mean ± standard deviation (n=10). Principal Component Analysis (PCA) was performed using 'ClustVis', a web tool for visualizing clustering multivariate data.

RESULTS AND DISCUSSION

Five species viz**.,** *Ariadne merione, Danaus genutia, Europa core,* and *Phalanta phalantha Tirumala limiace* (Fig. 1 and Table 1), collected from in and around Bannerghatta

Table 1. Morphological characteristics and morphometrics of adult nymphalid butterflies

Scientific names	Character Code (CC)	*Ariadne merione* (Mean ± SD)	*Danaus genutia* (Mean ± SD)	*Euploea core* (Mean ± SD)	*Phalanya phalantha* (Mean ± SD)	*Tirumala limiace* (Mean ± SD)
Antenna	-	Reddish-brown to brownish ochraceous club-shaped antennae small in size	Black Club shaped antennae	Black to Dark brown Club shaped antennae	Brownish black to Reddish-brown club-shaped antennae	Black Club shaped antennae
Legs	-	Three sets of Brownish black legs with non-functioning forelegs	Three sets of black legs with non-functioning forelegs with white dots/stripes.	Three sets of dark brown/black legs with sparsely spotted with white	Three sets of Brownish black to reddish-brown legs with sparsely dotted with white	Three sets of black legs with non-functioning forelegs with white spots/stripes.
Abdomen / body	-	Brownish ochraceous abdomen and body	Black with bluish-white semihyaline spots, Tawny abdomen.	Black with bluish-white semihyaline spots with glossy black and brown underside	Bright yellowish ochreous body and abdomen with a brown underside.	Black with bluish-white semihyaline spots & streaks, the abdomen is brownish-black
Body length (Head+abdomen)	BL	M:26.214 ± 0.02 F:16.584 ± 0.05	M:26.214 ± 0.03 F:26.692 ± 0.03	M:28.922 ± 0.01 F:29.830 ± 0.04	M:17.720 ± 0.05 F:19.001 ± 0.02	M:29.072 ± 0.05 F:29.658 ± 0.04
Abdomen length	AL	M:8.416 ± 0.03 F:8.484 ± 0.04	M:15.680 ± 0.02 F:15.850 ± 0.03	M:17.698 ± 0.04 F:18.750 ± 0.05	M:9.210 ± 0.05 F:9.370 ± 0.03	M:16.836 ± 0.03 F:17.174 ± 0.02
Abdomen width	AW	M:2.310 ± 0.02 F:3.290 ± 0.04	M:3.634 ± 0.03 F:4.108 ± 0.03	M:3.250 ± 0.01 F:3.307 ± 0.04	M:2.790 ± 0.05 F:3.070 ± 0.05	M:3.684 ± 0.01 F:3.990 ± 0.02
Probosis length	PL	M:8.975 ± 0.02 F:8.824 ± 0.05	M:11.101 ± 0.02 F:11.663 ± 0.03	M:11.720 ± 0.02 F:13.32 ± 0.03	M:9.210 ± 0.04 F:9.655 ± 0.03	M:11.542 ± 0.01 F:12.235 ± 0.02
Antenna length	AnL	M:11.110 ± 0.04 F:11.145 ± 0.03	M:13.778 ± 0.05 F:13.900 ± 0.02	M:14.146 ± 0.01 F:15.457 ± 0.02	M:11.890 ± 0.02 F:12.420 ± 0.03	M:13.470 ± 0.02 F:13.832 ± 0.03
Wings	W	M: FW L:26.050 ± 0.04 W:15.360 ± 0.05 HW L:21.966 ± 0.01 W:19.130 ± 0.04 F: FW L:26.098 ± 0.04 W:16.418 ± 0.05 HW L:21.778 ± 0.05 W:16.418 ± 0.03	M: FW L:38.960 ± 0.05 W:24.101 ± 0.01 HW L:28.042 ± 0.02 W:24.360 ± 0.03 F: FW L:39.654 ± 0.01 W:24.088 ± 0.03 HW L:28.382 ± 0.03 W:24.896 ± 0.04	M: FW L:41.150 ± 0.01 W:23.880 ± 0.03 HW L:28.384 ± 0.02 W:26.476 ± 0.01 F: FW L:41.660 ± 0.01 W:24.352 ± 0.02 HW L:29.490 ± 0.03 W:27.452 ± 0.04	M: FW L:24.860 ± 0.01 W:15.500 ± 0.01 HW L:18.460 ± 0.02 W:17.870 ± 0.03 F: FW L:27.860 ± 0.01 W:16.030 ± 0.02 HW L:18.590 ± 0.03 W:18.330 ± 0.01	M: FW L:41.598 ± 0.01 W:24.068 ± 0.02 HW L:30.530 ± 0.03 W:25.272 ± 0.01 F: FW L:42.686 ± 0.04 W:24.894 ± 0.05 HW L:29.792 ± 0.01 W:25.676 ± 0.02
Leg 1	L1	M:5.880 ± 0.01 F:6.750 ± 0.02	M:5.760 ± 0.01 F:5.985 ± 0.03	M:7.220 ± 0.02 F:7.230 ± 0.03	M:5.590 ± 0.01 F:8.030 ± 0.04	M:6.306 ± 0.02 F:6.773 ± 0.03
Leg 2	L2	M:11.112 ± 0.02 F:11.330 ± 0.04	M:13.620 ± 0.03 F:14.090 ± 0.02	M:15.375 ± 0.01 F:15.116 ± 0.02	M:11.820 ± 0.02 F:12.520 ± 0.03	M:14.245 ± 0.04 F:14.673 ± 0.05
Leg 3	L3	M:11.930 ± 0.03 F:11.980 ± 0.02	M:14.010 ± 0.04 F:14.330 ± 0.03	M:15.120 ± 0.05 F:15.326 ± 0.05	M:11.310 ± 0.02 F:11.990 ± 0.04	M:14.429 ± 0.05 F:14.649 ± 0.04

CC= Character code, M= Male, F= Female, FW= Fore wing, HW= Hind wing, L/W= Length/Width

Biological Park, Bengaluru, Karnataka. The measurements (in mm) and description of the morphometrics of the five species studied are given in Table 1.

***Ariadne marione*:** The female body length represents 16.584±0.05 mm and males presents 16.572±0.05 mm; females are generally larger than males. The main host plant for this butterfly is *Ricinus communis*.

Danaus genutia: The body length of the female represents 26.692±0.03 mm and males presents 26.214±0.03 mm; females are generally larger than males. The main host plants for this butterfly are *Asclepias curassavica* and *Ceropegia intermedia*.

Euploea core: The body length of the female represents 29.830±0.04 mm and males presents 28.922±0.04 mm; females are generally larger than males. The main host plants for this butterfly are *Nerium oleander* and *Icnocarpus fruitescens*.

Phalanta phalantha: The female body length represents 19.001±0.02 mm and males presents 17.720±0.02 mm; females are generally larger than males. The main host plants for this butterfly are *Flacourtia montana* and *Salix tetrasperma*.

Tirumala limiace: The body length of the female represents 29.658±0.04 mm, and males presents 29 females are generally larger than males. The main host plant for this butterfly is *Wattakaka volubilis*. The morphometric lengths of different traits such as wingspan, body length, forewing length, forewing width, hindwing length, hindwing width and basal length of *Eurema* species showed the variations in wing and body size that can be used for taxonomic delineation (Azrizal-Wahid et al 2015). Accordingly, the present study characterizes the phenotypes based on metric properties and typifies differences by measuring the body and leg parts, emphasizing the size assessment. The significant phenotypic variations observed in the length of the total body, abdomen, proboscis, antenna, wings, and legs between the five species studied were brought out. Understanding the mechanics of evolution, its cause, and consequences on the phenotypic variation are significant (Miner et al 2005). Further, the data were tested for normal distribution and the Principal Component Analysis using a correlation matrix and varimax rotation. PCA method adopted herein is used as a dimension reducing technique (Foottit and Mackauer 1990) to investigate morphological variations. PCA is specifically designed to analyze a set of correlated variables without the prior assumption of multiple groups and helps in the minimum selection of the parameters for correct groupings (Humphries et al 1981). In the present study, PCA analysis showed that a clear separation of the two morphs was possible along with PCI, which explains 84.70% for females and 87.30% for males of the variance. Additionally, clustering is one of the foremost techniques of multivariate analyses (Kettenring 2006). In the current study

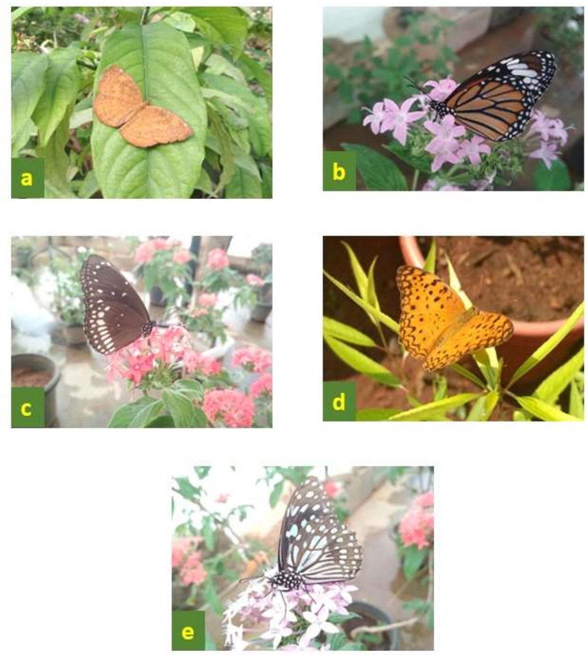

Fig. 1. Photographs of studied Nymphalid butterflies a. *Ariadne merione,* b. *Danaus genutia,* c. *Europa core,* d. *Phalanta phalantha* and e. *Tirumala limiace*

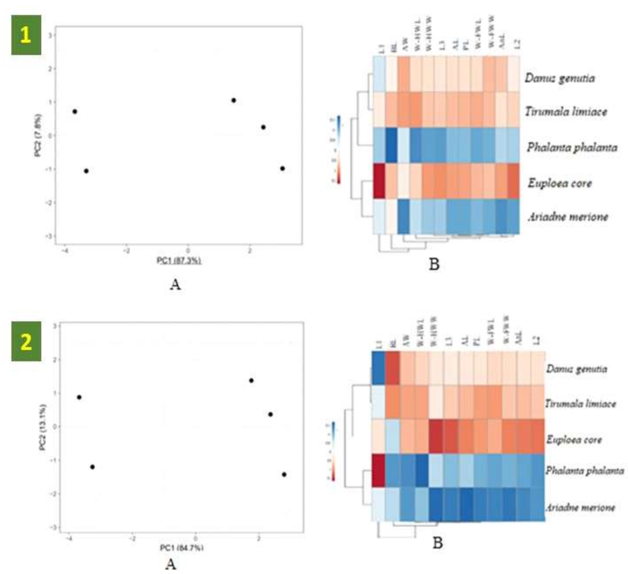

Fig. 2. 1A) Principle component analysis depicting the percentage of principle variables in males. 1B) Heat map morphological characters relationship between the Nimphalidae species (Males). 2A) Principle component analysis depicting the percentage of principle variables in females. 2B) Heat map morphological characters relationship between the Nimphalidae species (Females)

cluster, overall morphological characters were represented in the form of a scatter plot based on PCA (Fig. 2). In conclusion, the identification of Nymphalidae species based on morphological characteristics can be made confidently. Each species possesses unique features that can aid in its identification and conservation efforts.

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Variability in 'Rough Lemon' × 'Sour Orange' Hybrids for Foliar Traits and their *In vitro* Screening against *Phytophthora nicotianae*

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Abstract: *Phytophthora nicotianae*, a deadly fungus, causes huge damage to citrus. Developing tolerant rootstocks is an eco-friendly solution to manage it. In this study, we characterized 21 'Jatti khatti' (a strain of 'Rough lemon') × 'Sour orange' hybrids for four leaf traits and determined their tolerance against *Phytophthora nicotianae* using *in vitro* leaf inoculation method. For leaf traits, the hybrids displayed a higher magnitude of variation than the parents. The hybrids represented five different leaf lamina shapes, six leaf apex types, three leaf margins and three petiole wing shapes. The appearance of novel leaf variability pointed to the possibility of recombination in parental gametes. In leaf inoculation based screening, the susceptibility to *Phytophthora* infection was related to the size of lesions on leaf discs. The parents 'Jatti khatti' and 'Sour orange' recorded significantly different sized lesions of 2.6 and 1.3 cm, respectively. The hybrid 83-3 produced significantly smaller lesion size (1.0 cm) while six other hybrids recorded lesions of size similar to 'Sour orange'. Hence, these seven hybrids can be considered tolerant to *Phytophthora* and can be further tested for other biotic and abiotic stresses to ultimately find a rootstock that possess most of the desirable features of the two parents.

Keywords: Citrus, Rootstock, Hybrids, *Phytophthora nicotianae,* Tolerance, *In vitro* leaf inoculation

Rough lemon (*Citrus jambhiri* Lush.) is the commercial citrus rootstock. It is tolerant to most of the viruses including citrus tristeza virus and induces prolific bearing in the budded scion varieties (Kumar et al 2010). In addition, it has a high degree of polyembryony, which is an important trait for clonal propagation of rootstocks. 'Rough lemon' is highly susceptible to a soil borne fungus *Phytophthora nicotianae*. The genotypes like *Poncirus trifoliata* and its hybrids like 'Swingle citrumelo', 'X-639' and 'Sour orange' are the promising sources of resistance to develop rootstock hybrids resistant to *Phytophthora* (Savita et al 2012, Dhakad et al 2014, Lima et al 2018). Of the above mentioned *Phytophthora* tolerant genotypes, 'Sour orange' (*C. aurantium* L.) also imparts high quality to the fruits of budded citrus varieties. It also confers tolerance to citrus blight, xyloporosis and exocortis (Castle et al 1993). In order to introgress the *Phytophthora* tolerance from 'Sour orange', the hybrids were developed in the cross of 'Jatti khatti' (a strain of 'Rough lemon', used as rootstock in Punjab, India) and 'Sour orange' and their hybridity was confirmed through polymorphic SSR markers (Kaur et al 2021). To quickly determine the tolerance of these hybrids to *P. nicotianae*, their rapid screening is required. Leaf inoculation is a rapid and reliable method to determine genotypic reaction to *Phytophthora* (Vawdrey et al 2005). In citrus, morphological traits hold importance for characterization of genotypes/ accessions and are also required for registration of most of the varieties (Castellana et al 2020). Various leaf types and petiole wings are particularly important for characterization of citrus at young plant stage (Ballve et al 1997). In this study, 21 'Jatti khatti' × 'Sour orange' hybrids were characterized for leaf based traits and their tolerance to *P. nicotianae* was determined using *in vitro* leaf inoculation method.

MATERIAL AND METHODS

Twenty one pre-developed 'Jatti khatti' × 'Sour orange' hybrids at Dr. J.C. Bakhshi RRS, Abohar were characterized for leaf based traits namely shape of leaf lamina, leaf apex, leaf margin and petiole wing as given in the IPGRI Descriptor for citrus (Anonymous 1999). Apart from it, different leaf variables were scored as 1 or 0 and the genetic relatedness of the parents and hybrids was estimated based on these variables, which was calculated using Jaccard coefficient of association. The cluster analysis was performed through Unweighted Neighbour-Joining Tree method in software package DARwin 6.0 (Perrier and Jacquemoud 2006). The *Phytophthora* tolerance of these hybrids was determined by leaf inoculation method as described by Dhakad et al (2014). To verify the validity of the method in differentiating the *Phytophthora* tolerance, alongside hybrids, the parents 'Jatti khatti' and 'Sour orange' were also included in the study. Healthy leaves were collected from parents and 21 hybrids. The circular discs were made from the leaves. These leaf discs were surface sterilized with 0.1% mercuric chloride for 10 seconds followed by washing with sterile double distilled water twice. The surface sterilized leaf discs were then punctured with a sterile needle. The pathogen (*Phytophthora nicotianae*) culture was obtained and maintained on a selective PARPH-CMA medium at 25±1ºC. Four days old culture of the pathogen was used for *in vitro* inoculation of citrus leaf discs. One leaf disc was placed in each petri plate containing inoculum under aseptic conditions. Three replications were kept for each parent and hybrids. The petri plates were incubated at 25±1ºC. After 48 hours of incubation, the data on lesion size was recorded. The statistical significance of the data was checked using one way analysis of variance (ANOVA) and differences among the genotypic means were determined using Tukey's HSD test in software SAS 9.1.

RESULTS AND DISCUSSION

Morphological variation: The data on variation of leaf attributes among parents and 21 hybrids is presented in Table 1. The parents 'Jatti khatti' and 'Sour orange' had ovate leaf shapes. The hybrids represented five different leaf shapes in descending order of abundance namely ovate (9), elliptic (5), obovate (4), lanceolate (2), round to orbicular (1) (Table 1, Plate 1). The leaf apex was acute to retuse in 'Jatti khatti' and acuminate in 'Sour orange'. The hybrids represented six different leaf apex types in descending order of frequency i.e. acute (9), acuminate (4), acute to obtuse (3), round to obtuse (3), obtuse to retuse (1), and retuse (1) (Table 1, Plate 2). The parents- 'Jatti khatti' and 'Sour orange' had sinuate leaf margins while hybrids had three different types of margins i.e. sinuate (10), dentate (7) and crenate (4) (Table 1, Plate 3). Petiole wing is one of the important morphological character, which has utility in genotypic identification (Ballve et al 1997). The parents 'Jatti khatti' and 'Sour orange' had linear and obdeltate type of petiole wings. Three different

Table 1. Characterization of parents and 21 hybrids based on leaf shape, leaf apex, leaf margin and petiole wing shape

Plant ID	Leaf attributes			
	Leaf shape	Leaf apex	Leaf margins	Petiole wing shape
Jatti khatti (♀)	Ovate	Acute to retuse	Sinuate	Linear
Sour orange (♂)	Ovate	Acuminate	Sinuate	Obdeltate
H52	Elliptic	Acute	Sinuate	Obdeltate
H13-2	Elliptic	Acute	Dentate	Obdeltate
H120-1804	Elliptic	Acute	Sinuate	Linear
H88-2	Elliptic	Acute	Dentate	Obdeltate
H97-2	Elliptic	Acuminate	Dentate	Obdeltate
H74-1	Lanceolate	Acuminate	Sinuate	Obdeltate
H78-1	Lanceolate	Acuminate	Dentate	Obdeltate
H750	Obovate	Obtuse to retuse	Crenate	Obdeltate
H134-1	Obovate	Round to obtuse	Sinuate	Linear
H79-2	Obovate	Retuse	Sinuate	Obdeltate
H58	Ovate	Acute	Sinuate	Linear
H76	Ovate	Acute to obtuse	Dentate	Obdeltate
H558	Ovate	Round to obtuse	Crenate	Obcordate
H575	Ovate	Acute to obtuse	Crenate	Obcordate
H3-1	Ovate	Acute to obtuse	Sinuate	Linear
H255-3	Ovate	Acute	Dentate	Linear
H307-3	Ovate	Acute	Crenate	Obdeltate
H32-6	Ovate	Acute	Dentate	Obcordate
H83-3	Ovate	Acuminate	Dentate	Obdeltate
H90-1	Ovate	Acute to obtuse	Sinuate	Linear
H294	Round to orbicular	Round to obtuse	Sinuate	Obdeltate

petiole wing types namely obdeltate (11), linear (7) and obcordate (3) were observed in the hybrids (Table 1, Plate 4).

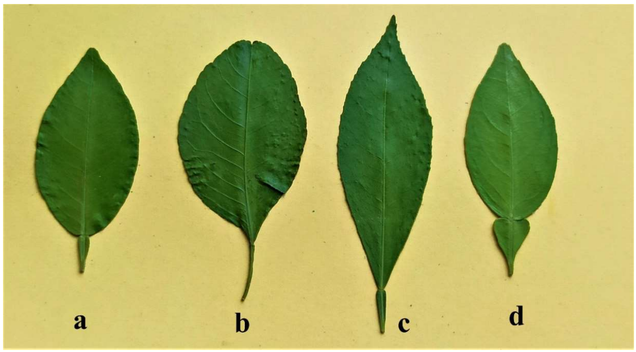

Plate 1. Hybrids displaying different leaf shapes. Ovate (**a**), Obovate (**b**), Lanceolate (**c**) and Elliptic (**d**)

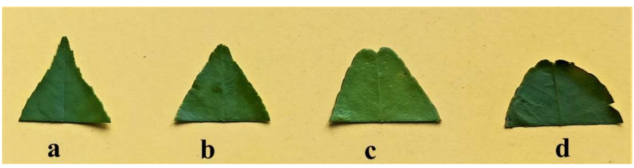

Plate 2. Illustration of different leaf apex of hybrids- acuminate (**a**), acute (**b**), obtuse to retuse (**c**) and retuse (**d**)

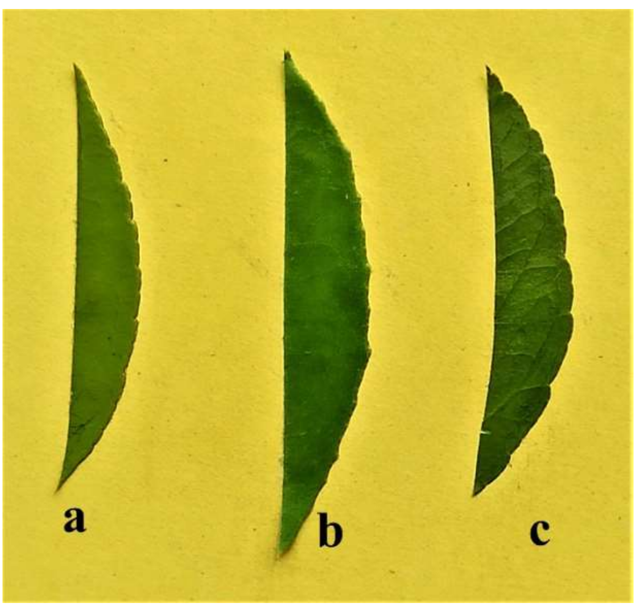

Plate 3. Illustration of the leaf margin types of hybrids- crenate (**a**), dentate (**b**) and sinuate (**c**)

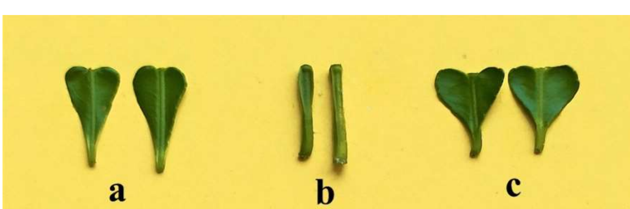

Plate 4. Illustration of petiole wing shapes of hybrids- obdeltate (**a**), linear (**b**) and obcordate (**c**)

The leaf variables data was also used for drawing an Unweighted Neighbor Joining Tree. In the tree, the parents and hybrids became arranged into three major clusters (Fig. 1). The cluster- I contained 'Sour orange' and 13 hybrids and was further branched into three sub-clusters: IA, IB and IC with 5 ('Sour orange' and 4 hybrids), 5 and 4 hybrids. The cluster II contained two sub-clusters with 4 ('Jatti khatti' and three hybrids) and two hybrids, respectively. The cluster III contained three hybrids. Two of the hybrids in sub-cluster IB (H13-2 and H88-2) and IIA (H03-1 and H90-1) were inseparable for the studied traits. Thus, the cluster analysis also revealed closeness of few hybrids to parent 'Jatti khatti', few to 'Sour orange' while the arrangement of remaining three hybrids into a separate cluster indicated the higher variability present in them over the two parents.

The appearance of higher magnitude of variation of leaf based traits in hybrid progeny than the parents indicates quantitative inheritance of the leaf traits (Iwata *et al.* 2002). Both of the parents come from a hybrid pedigree. 'Jatti khatti' ('Rough lemon') is a hybrid between acidic mandarin and citron

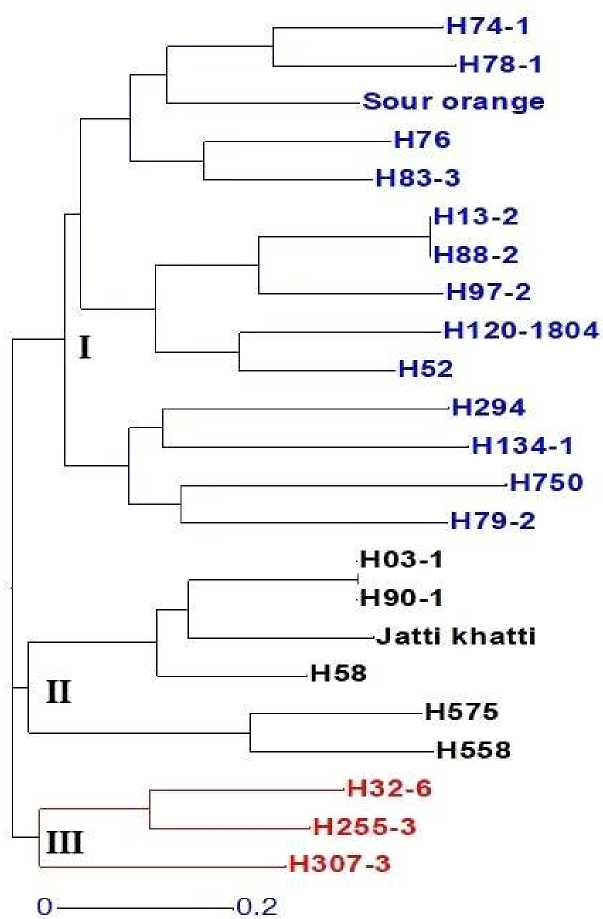

Fig. 1. Association of parents and hybrids as inferred through Unweighted Neighbour-Joining Tree in DARwin 6.0

while 'Sour orange', is a natural hybrid of mandarin and pummelo (Nicolosi et al 2000, Curk et al 2015). Thus, the possibility of segregation and recombination in gametes during meiosis is very high. The emergence of shapes different from the parents might be a consequence of genetic recombination by virtue of crossing over between the homologues chromosomal segments during meiosis (Jiguang et al 1995)

The morphological features are important for the purpose of identification and conservation of germplasm. In citrus, leaf type (monofoliate, trifoliate and multifoliate) and broadness of petiole wing are two useful traits for distinguishing various citrus types at vegetative stage (Ballve et al 1997, Tan et al 2007). 'Sour orange' exhibit broad petiole wing (Ballve et al 1997, Kaur et al 2021). The shape of 'Sour orange' petiole wing in this study was found to be obdeltate. In this study, 11 hybrids (>50%) had obdeltate type petiole wings. Thus, the shape of petiole wing can give a clue about the male parent pedigree of the hybrids.

Assessment of tolerance to *Phytophthora nicotianae*: After 48 hours of incubation of the leaf discs on *Phytophthora* culture, the reaction was observed in parents and hybrids. *Phytophthora* infection caused lesions on leaf discs and the response of the two parents was statistically different at $P \leq 0.05$. The susceptible parent 'Jatti khatti' exhibited leaf lesion size of 2.6 cm while in 'Sour orange', the lesion size was limited to 1.3 cm (Table 2). In response to *Phytophthora* infection, the hybrids responded differently. The H83-3 recorded lesion of size (1.0 cm) even statistically smaller than that of 'Sour orange'. The reaction of another six hybrids (H120-1804, H3-1, H97-2, H13-2, H134-1 and H307-3) for lesion size was statistically similar to the tolerant parent 'Sour orange', indicating that these hybrids possessed *Phytophthora* tolerance similar to 'Sour orange'. Another two hybrids (H558 and H79-2) developed lesion size of about 2.0 cm, which might exhibit moderately tolerant response to the pathogen. Based on lesion size, three hybrids namely H58, H88-2 and H575 could be categorized as susceptible as their lesion size was equal to the susceptible parent 'Jatti khatti'. The response of the remaining nine hybrids was intermediate of moderately tolerant and susceptible categories of hybrids. Hence, these hybrids can be considered as moderately susceptible to *Phytophthora* (Table 2). The appearance of different sized leaf lesions in parents and also their differentiation into hybrids verified the utility of *in vitro* leaf inoculation method in authentically determining the *Phytophthora* tolerance in citrus. The leaf inoculation method is a quick and reliable method to identify the *Phytophthora* resistance (Harada and Kondo 2009). The results of differential susceptibility of parents using *in vitro* leaf inoculation method were in agreement with the findings of Dhakad et al (2014) that the reaction of genotypes to *Phytophthora* under leaf bait assays corroborated well with the results of seedling inoculation method. The result of the study has helped in preliminary determining the tolerance of 'Jatti khatti' ('Rough lemon') × 'Sour orange' hybrids to *P. nicotianae*. The tolerance of seven tolerant hybrids can be further verified by screening under natural field conditions followed by evaluating them for other stresses.

Table 2. Size of *Phytophthora* induced leaf lesion in parents and 21 hybrids

Plant ID	Lesion size on leaf discs (cm)
Jatti khatti (♀)	2.6 ± 0.03 [a]
Sour orange (♂)	1.3 ± 0.03 [gh]
H83-3	1.0 ± 0.03 [i]
H120-1804	1.1 ± 0.06 [hi]
H3-1	1.2 ± 0.06 [hi]
H97-2	1.2 ± 0.07 [hi]
H13-2	1.3 ± 0.03 [ghi]
H134-1	1.3 ± 0.07 [ghi]
H307-3	1.5 ± 0.07 [g]
H558	2.0 ± 0.06 [f]
H79-2	2.0 ± 0.03 [ef]
H32-6	2.2 ± 0.03 [def]
H78-1	2.2 ± 0.03 [def]
H255-3	2.2 ± 0.07 [def]
H750	2.2 ± 0.07 [def]
H90-1	2.2 ± 0.07 [def]
H52	2.3 ± 0.03 [cdef]
H294	2.3 ± 0.06 [bcde]
H76	2.3 ± 0.06 [bcde]
H74-1	2.3 ± 0.07 [bcd]
H88-2	2.4 ± 0.07 [abcd]
H575	2.5 ± 0.03 [abc]
H58	2.6 ± 0.03 [ab]

The ± values represent standard error (SE). The genotypic means not sharing common superscript letters are statistically different as per Tukey's HSD test at $P \leq 0.05$

CONCLUSIONS

The hybrids displayed a great amount of variation for traits leaf lamina shape and leaf apex. The shape of petiole wing can help in demarcating the pedigree of more than 50% of the characterized hybrids. The verification of the *Phytophthora* tolerance of seven putatively tolerant hybrids under field conditions and their evaluation against other stresses could provide a rootstock that combines *Phytophthora* tolerance alongside the desirable features of 'Jatti khatti' (Rough lemon).

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Resource use Efficiency of Agricultural Farms in Mid Hills of Indian North-Western Himalayas

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Abstract: North-west Himalayas of India has been facing the problems of food and feed shortages and nutritional scarcity during winter months, so watershed has been considered to be an effective approach to raise agricultural productivity, conserve natural resources and reduce poverty particularly in rainfed regions. HP Mid-Himalayan Watershed Development Project - an integrated multi-sectoral watershed development project has been operative in Mid Hills of Himachal Pradesh in 10 districts of the state since October 2005. This study has been carried out in order to determine resource utilization on beneficiary farms and to analyse the problems faced by beneficiaries. The project has helped the beneficiaries for sustainable utilization of land and labour through different land development programmes, workshops, trainings and exposure visits. Demand for labour required for irrigation increased due to increase in irrigation facility through construction of village ponds, makowal structures, masonry dams, water harvesting structures and earthen run off dams on 16.66, 10.00, 6.67, 25.00 and 2.78 percent of the total number of beneficiaries. Inputs such as seed, plant protection and irrigation man-days underutilised, so recommendations from the study have been made to increase their respective marginal value productivities. In spite, of above benefits of the project, the beneficiaries have encountered some major problems viz. stray/wild animal menace (72.38 %), lack of technical knowledge of input use (63.27 %) and ineffectiveness of working of gram panchayats (60.56 %) which in case solved may lead to enhancement of efficiency levels of different resources.

Keywords: Watershed, Command area, Input use pattern, Resource use efficiency, Productivity

Agriculture has been playing an important role in overall growth of the Indian economy despite its structural shift towards the services sector during the recent decades. Although share of agriculture in GDP has declined from 51.8 percent in 1950-51 (to 17.8 percent in 2019-20, yet this sector has been a major source of employment for rural workers. North-West Himalayas comprise of states of Himachal Pradesh and Uttarakhand and union territory of Jammu and Kashmir; and Ladhakh with mountainous regions transacted by a number of mountain ranges, rivers and rivulets originating from the region. Its physiography is highly undulating with steep slopes and erodible but fertile soils spread over sub-tropical, temperate-valleys and high hills, very high hills and cold arid regions. Severe and prolonged winter with sub-zero temperature bringing agriculture to almost standstill, fruit trees shedding their leaves and going under dormant phase and livestock experiencing severe morbidity and mortality. There has been an acute food and feed shortages and nutritional scarcity during winter months. The varied agro-ecological situations ranging from sub-tropical to temperate have been enabling vast scope of production of variety of food-grains, fruits, vegetables, flowers, medicinal and aromatic plants, livestock, animal husbandry and fishery. The region as a whole has been reported to be food deficit in terms of cereals, pulses and oilseed, and the average productivity has been reported to be lower than the national average (Anonymous 2015). However, sufficiency in agricultural production has been considered possible through sustainable utilization of land and labour, high yielding varieties, increasing the cropping intensity, irrigation facility and plant protection measures in the command area of the project. Watershed development has been considered an effective approach to raise agricultural productivity, conserve natural resources and reduce poverty, particularly in the rainfed regions. Several useful studies have been conducted in the past to assess the impact of watershed programmes (Reddy 2000, Mondal et al 2012) with respect to various bio-physical and environmental indicators; and have provided useful insights on the performance of numerous watersheds. The Government of Himachal Pradesh has also launched many watershed development projects financed by national and international donor agencies with a view to rehabilitate the degraded environment and improve the economy of the state (Anonymous 2006). In spite of its economic importance sufficient attention has not been given to increase the gross income of the beneficiaries. Specifically, there has been an information gap concerning optimal levels of resource utilization in agricultural farms. This study has been carried out in order to estimate the resource use efficiency of the sampled households and to identify the problems faced by beneficiaries and providing remedial solutions.

MATERIAL AND METHODS

Selection of the study area: For the present study, three districts namely Solan, Sirmaur and Mandi were selected out of 10 districts covered under Mid Himalayan Watershed Development Project. The three districts selected represents 17 development blocks out of 42, comprising 40.4 percent of the total command area.

Sampling procedure: Primary data have been obtained through the use of pre-tested structured schedule administered to beneficiaries and non-beneficiaries selected by multistage stratified random sampling. At the first stage, two development blocks from each three selected districts, therefore six blocks comprising of 35.3 percent of the total number of development blocks have been selected. At the second stage, three gram-panchayats from each block, thus 18 gram panchayats have been selected from six blocks. At the third stage, a sample of 10 farmers from each gram-panchayat by adopting probability proportion to size method have been selected, thereby a sample of 180 beneficiaries has been selected for the study. Simultaneously, a sample of 90 non-beneficiaries has also been selected from the adjacent villages assumed to be unaffected by the project interventions by adopting probability proportion to size method.

Collection of data: Data was collected on the input used in agricultural farms viz. gross return from major crops, area (bighas), labour (man-days), manure and fertilizer (Rs.), seed (Rs.), plant protection (Rs.) and irrigation labour (man-days). The data have been analysed using descriptive and inferential statistics. Cobb-douglus production function has been selected in conformity with priority economic criteria of the magnitude of the coefficients, signs and significance of the adjusted coefficient of multiple determination (R^2), F-ratio and t-ratio. The simple and linear logarithmic form of the specified Cobb-Douglas function is given as;

$$Y=aX_1^{b1}X_2^{b2}X_3^{b3}X_4^{b4}u$$

Where:

Y= Gross return

X_1, X_2, X_3, X_4, X_5 and X_6 have been area, labour, manure and fertilizer, seed, plant protection and irrigation respectively.

a = intercept

u = error term

The coefficients are the marginal productivities of the corresponding inputs with respect to output. To ensure maximum profit and efficiency of resource, a farmer must utilize resources at the level where their marginal value product (MVP) is equal to their marginal factor cost (MFC). The efficiency ratio of a resource (r) has been determined by the ratio of MVP of inputs (based on the estimated regression coefficients) and the MFC. The efficiency ratio has been given as;

r = MVP/MFC

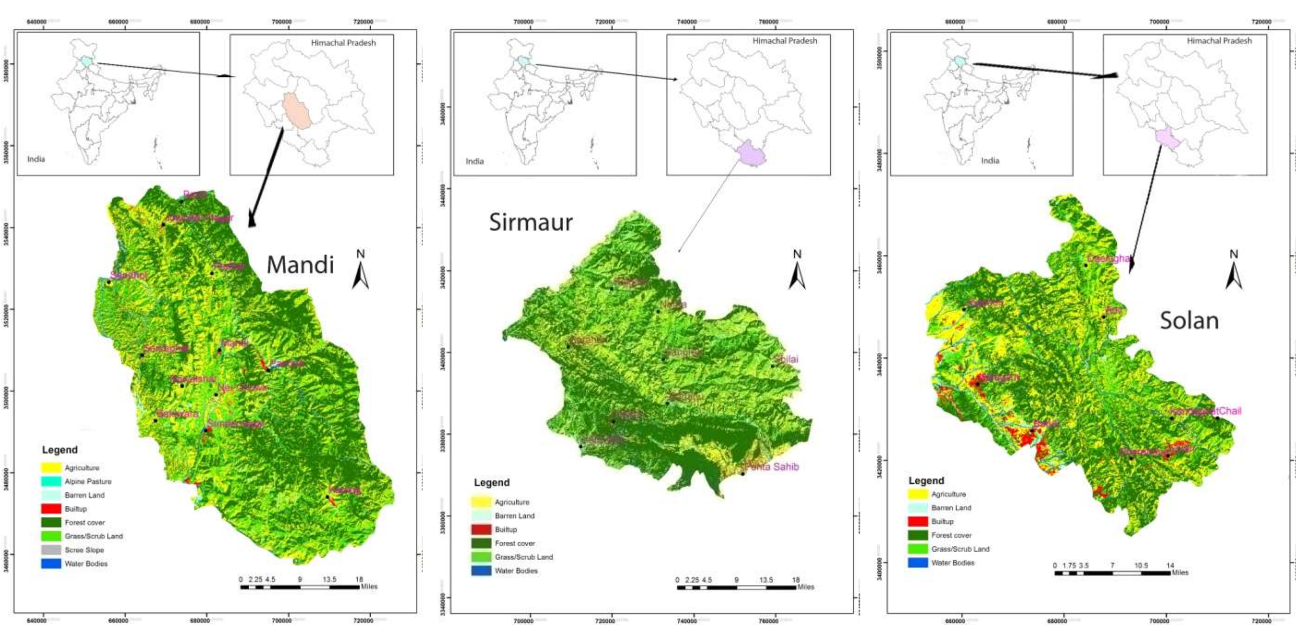

Fig. 1. Location map of the study area

The decision rule for the efficiency analysis is if:

r = 1; resource used efficiently

r >1; resource was underutilized and increased utilization will increase output.

r <1; resource was over utilized and reduction in its usage will lead to maximization of profit.

The absolute value of the percentage change (D) in the MVP of each input used has been calculated as:

$$D = \left(1 - \frac{MIC}{MVP}\right) \times 100$$

Where, D is the absolute value (Iheanacho et al 2000).

Garrett's ranking technique: The problems encountered by beneficiaries have been analysed using Garrett's ranking technique. The ranks given by respondents have been converted into percent position by using following formula:

$$\text{Percent position} = \frac{100 \times (R_{ij} - 0.5)}{N_j}$$

Where,

R_{ij} = Rank given to i^{th} problem by the j^{th} individual and

N_j = Number of problems ranked by j^{th} individual.

The estimated percent positions have been converted into scores using Garrett's table. The mean score values have been estimated for each factor and have been arranged in the descending order. The constraint with the highest mean value has been considered as the most important one and the other followed that order (Karthick et al 2013).

RESULTS AND DISCUSSION

Farm specific characteristics: The beneficiary farms in spite of having lesser land holding (1.29 ha) put more land under cultivation and orchards by 7.82 cent and 0.99 percent due to increase in irrigated area by 17.99 percent as compared to non-beneficiary farms. Dev et al (2017) and Kulshrestha et al (2014) also observed hat with the interventions of the project, there has been a significant change in the area of major crops.

Input use pattern: Average operational holding was higher in case of main vegetables grown on beneficiaries farms like tomato (74.98 %), capsicum (52.50 %), pea (87.32 %), garlic (75.05 %) and ginger (99.14 %) as compared to non-beneficiary farms (Table 2). The scientific use of land promoting higher value vegetables crops, due to increase in land development programme (4.44 %) and irrigation facility, through construction of village ponds, *Makowal* structures, masonry dams, water harvesting structure, and earthen run off dams. The area wheat and vegetable crops have increased by 5.88 and 53.42 percent, respectively (Kushwah et al 2016, Ankita et al 2021). Segar et al (2008) has observed that area under maize increased by 4.43 percent due to project interventions among tribals of Chhattisgarh. The strength of active workforce (between ages of 14 to 65 years) has been considered to be directly proportional to the use of resource structure available on agricultural farms. The average utilization of labour has found to be lower in case of main vegetables grown on beneficiaries farms ranges between 9.91 and 3.56 percent as compared to non-beneficiary farms. This significant decrease in labour force in farming activity, was due to increase in the technical efficiency through workshops (28.89 %), trainings (19.44 %) and exposure visits (12.22 %). Project Interventions has also helped in creation of diverse source of non-farm activities such as knitting (26.67 %), swing (6.67 %), *khadi* (3.89 %), cutting and tailoring (3.33 %) and coal making through pine needles (2.78 %). These project interventions decreasing the disguised unemployment on beneficiary farms and to increase the marginal productivity of labour.

Expenditure on manure and fertilizers has been evaluated by multiplying the physical quantities of different manures and fertilizers used on the farms by their respective prices. The per hectare utilization of manure and fertilizers for beneficiary farms was lower for tomato, capsicum, pea, cauliflower, beans and garlic by 0.96 to 6.28 percent, respectively as compared to non-beneficiary farms. This significant decrease in the utilization of fertilizer has been due to assistance provided for construction of vermi compost pit, distribution of biozyme fertilizers and azolla on 22.22, 11.11 and 5.56 percent of total number of beneficiary farms, respectively, which have made the beneficiaries self-dependent for preparation of fertilizers at lower cost than non-beneficiary farms. Different livestock improvement programmes like, manger construction on 30.56 percent beneficiary farms, supply of chaff cutter to 33.33 percent beneficiary farms and distribution of goats and poultry birds to 5.56 percent (each) beneficiary farms; dissemination of technology on farm fodder cultivation and crop residue treatment to 2.78 percent (each) and health cover and breeding methods (e.g. artificial insemination) to 5.56 percent of total number of beneficiary farms; along-with up-gradation of livestock management skill through veterinary camps and

Table 1. Farm specific characteristics of the study area

Particulars	Beneficiaries	Non-beneficiaries	Change (%)
Land use			
Total land holding (ha)	1.29	1.34	-3.73
Cultivated land (%)	41.62	33.80	7.82
Orchard (%)	1.65	0.66	0.99
Forest (%)	3.85	4.89	-1.04
Irrigated area (%)	28.00	10.01	17.99

breeding centres to 3.33 percent (each) have led to overall improvement in the livestock sector and also increase in the supply of manures to be used in the beneficiaries farms. Utilization of seed was lower in case of main vegetables grown on beneficiaries farms by 2.29 to 9.58 percent while in cereals it ranged between 7.01 to 10.77 percent (Table 2). This significant decrease in the expenditure of seed has been due to distribution of seed of high yielding varieties to 55.56 percent of the beneficiaries and assistance provided for seed driers (2.22 %). The per hectare utilization of plant protection measures for beneficiary farms was 0.67 to 8.76 percent lower as compared to non-beneficiary farms (Table 2). This significant decrease in the expenditure of plant protection has been due to workshops (28.89 %), followed by trainings and exposure visits (organized by the project and distribution of spray pumps.

The number of labour required for irrigation for main vegetables like tomato, capsicum, pea, cauliflower, beans, garlic and ginger on per hectare basis has been 15.00 and 12.52, 3.76 and 3.42, 3.27 and 2, 13.21 and 12.17, 8.30 and 6.69, 7.38 and 6.73 and 7.95 and 6.38 man-days, on beneficiary and non-beneficiary farms, respectively (Table 2). Increase in the irrigation facility on beneficiary farms through project due to construction of village ponds, makowal structures, masonry dams, water harvesting structure and earthen run off dams on 16.66, 10.00, 6.67, 25.00 and 2.78 percent respectively of the total beneficiary farms along with emphasis given to roof rain harvesting, rejuvenation of village ponds, tanks and land development programme on 11.11, 1.67, 14.44 and 4.44 percent of total number of beneficiary farms have led to increase in number of man-days required for irrigating on beneficiary farms compared to non-beneficiary farms.

Table 2. Input use pattern on beneficiary and non-beneficiary farms in case of major crops

Crops		Percent	Area (Big ha)	Labour (MD ha^{-1})	Manure + Fertilizer (Rs. ha^{-1})	Seed (Rs. ha^{-1})	Plant protection (Rs. ha^{-1})	Irrigation (MD ha^{-1})
Tomato	B	68.89	2.79	94.45	28077.26	7089.17	15620.94	15.00
	NB	80.00	1.60	103.53	29192.41	7255.08	15440.20	12.52
			(74.98)	(-8.78)	(-3.82)	(-2.29)	(1.17)	(19.85)
Capsicum	B	64.44	2.32	111.92	7371.30	7621.79	9159.32	3.76
	NB	58.89	1.52	109.63	7443.07	7805.19	9568.31	3.42
			(52.50)	(2.08)	(-0.96)	(-2.35)	(-4.27)	(9.86)
Pea	B	81.11	3.00	220.80	7461.96	10159.93	3843.89	3.27
	NB	71.11	1.60	233.17	7946.50	10690.55	4212.96	2.78
			(87.32)	(-5.30)	(-6.10)	(-4.96)	(-8.76)	(17.59)
Cauliflower	B	15.56	1.22	160.07	9282.72	8683.41	9381.02	13.21
	NB	32.22	1.35	171.66	9904.53	9602.89	9444.71	12.17
			(-9.66)	(-6.75)	(-6.28)	(-9.58)	(-0.67)	(8.52)
Beans	B	20.56	0.94	172.90	9753.34	14644.84	11188.80	8.30
	NB	26.67	1.04	179.33	10290.27	15836.82	11757.05	6.69
			(-9.91)	(-3.58)	(-5.22)	(-7.53)	(-4.83)	(23.97)
Garlic	B	63.89	2.13	118.34	46947.39	43867.55	21857.39	7.38
	NB	71.11	1.22	117.00	48833.52	45471.83	22365.36	6.73
			(75.05)	(1.15)	(-3.86)	(-3.53)	(-2.27)	(9.75)
Ginger	B	22.22	2.27	119.20	53670.74	137420.24	24203.78	7.95
	NB	22.22	1.14	123.60	53611.81	142232.14	25259.22	6.38
			(99.14)	(-3.56)	(0.11)	(-3.38)	(-4.18)	(24.55)
Wheat	B	75.00	3.15	38.96	17944.79	3475.77	290.62	-
	NB	87.78	2.01	38.82	19148.48	3737.66	288.33	
			(57.15)	(0.35)	(-6.29)	(-7.01)	(0.79)	
Maize	B	77.78	2.28	38.90	13218.66	4097.57	281.93	-
	NB	87.78	2.06	40.89	13895.64	4592.33	281.81	
			(11.04)	(-4.86)	(-4.87)	(-10.77)	(0.04)	

MD-Man-days, B-beneficiaries and NB-Non-beneficiaries, Figure under parentheses indicate percent change

Productivity of main crops: Productivity of various important cash crops on agricultural farms has been shown in (Table 3). The maximum yield level has been obtained in tomato (298 and 333 q/ha) followed by garlic, cauliflower, ginger, beans, capsicum, pea, maize and wheat, respectively for non-beneficiaries and beneficiaries. Thus, major crops have shown about 7 to 30 percent enhancement in physical productivities levels on beneficiary farms as compared to non-beneficiary farms. The changes in crop productivity levels have been found to be statistically significant on beneficiaries as compared to non-beneficiaries (Table 4). The respondents have observed that enhancement in physical productivities levels was due to creation of water resources, soil conservation structures, assistance for vermi composting, distribution of farm implements and high yielding seeds. Jat et al (2008) and Kushwah et al (2016) have also observed that productivity of different crops increased due to watershed development project interventions.

Resource use efficiency on agricultural farms: The included variables in model were explained 95 percent of variation in main vegetables and cereals for beneficiary and 98.0 percent for non-beneficiary farms (Table 5).

The regression coefficients of area, seed, plant protection chemicals and irrigation was positive, 0.46, 0.36, 0.31 and 0.42 respectively, beneficiary farms, whereas, found to be negative (-0.27) in case of fertilizer. The regression coefficients of area, seed, plant protection chemicals and irrigation have been positive, 0.31, 0.09, 0.54 and 0.29 for non-beneficiary farms. Beneficiaries and non-beneficiaries have been operating in increasing return to scale have been found to be 1.28 and 1.23, significant indicating sub optimal use of most of the inputs on both types of farms which need to be increased for achieving higher levels of input efficiency that will further leads to enhanced production level of respective crops grown in the study area (Table. 5). Economic adjustment of resources has been examined with the help of the ratios of marginal value product (MVP) of inputs and their marginal input cost (MIC). The marginal value products for area, seed, plant protection and irrigation was higher than their marginal factor costs implying underutilization of inputs, whereas, the marginal value products for fertilizers applied have found to be lower than their marginal factor cost implying over utilization of the inputs by beneficiaries. The area, seed, plant protection and irrigation inputs have been under-utilized, required 91.04, 85.69, 91.43 and 98.92 percent addition, respectively of these inputs for optimal production to be achieved. Similarly, in non-beneficiaries, all inputs have been found to be underutilized. This optimal use of area, seed, plant protection and irrigation MVP has to be increased by 85.80, 34.84, 94.28 and 97.92 percent, respectively (Table 6).

Table 3. Crop productivity of major crops (in q ha^{-1})

Crops	Beneficiaries	Non-beneficiaries
Wheat	19.96	17.45
Maize	28.8	22.14
Tomato	332.86	297.94
Capsicum	115.99	104.13
Beans	117.37	106.44
Ginger	128.6	114.67
Pea	112.79	99.65
Garlic	185.11	171.44
Cauliflower	179.38	167.24

Table 4. Percent change of crop productivity and its significance between beneficiaries and non-beneficiaries

Crops	Percent change	t value
Wheat	13.64	8.68*
Maize	30.08	26.23*
Tomato	11.72	24.22*
Capsicum	11.39	13.67*
Ginger	12.15	6.89*
Beans	10.27	14.27*
Pea	13.19	12.89*
Garlic	7.97	12.11*
Cauliflower	7.26	5.20*

*p value <0.01

Table 5. Regression coefficients on agricultural farms based on main vegetables and cereals

Parameters	Beneficiary farms	Non-beneficiary farms
Intercept	3.22* (0.20)	2.50* (0.11)
Area (bigha)	0.46* (0.07)	0.31* (0.07)
Labour (MD)	-	-
Fertilizer (Rs.)	-0.27* (0.08)	-
Seed (Rs.)	0.36* (0.04)	0.09** (0.04)
Plant protection (Rs.)	0.31* (0.02)	0.54* (0.03)
Irrigation (MD)	0.42* (0.03)	0.29* (0.06)
Adjusted R^2	0.95*	0.98*
F	736.67	972.94
∑bi	1.28*	1.23*

**p<0.05 and *p<0.1, Figure under parentheses indicates standard error

Problem encountered by beneficiaries: The most significant production problem was stray or wild animal menace (72.38 %) followed by lack of knowledge about seed treatment (63.27 %). Although, different project interventions have been made for irrigation but lack of irrigation facility has been perceived as production problem by 27.91 percent of beneficiary farms. Karthick et al (2013) has also found the water scarcity as one of the production problem encountered by 39.60 percent of sampled households. Similar type of production problems had also been reported by earlier workers (Sisodia et al 2007, Thomas et al 2009),

The major marketing problems viz. price fluctuations in perishable crops (76.75 %), inadequate post-harvest technologies (48.31 %) and lack of transport facilities (40.98 %) have been faced by beneficiaries. Ineffectiveness of working of gram panchayats in supplying inputs including credit facility and weak advisory and extension services have been reported as a problem by 60.56 and 46.31 percent respectively, of the respondents. Similar results had also been reported by Dev et al (2019). The range of production, marketing and financial problems has been found within about 25 to 77 percent, in case solved (Table 7) within budgetary constraints of the input supplying agencies may lead to enhanced resource use efficiency on agricultural

Table 6. Marginal analysis of input used by beneficiaries and non-beneficiaries

Inputs	Beneficiaries					Non-beneficiaries				
	Geometric mean	MVP	MIC	Efficiency ratio (r)	MVP adjustment required	Geometric mean	MVP	MIC	Efficiency ratio (r)	MVP adjustment required
Area	8.87	8927.10	800.00	11.16	91.04	6.21	5634.03	800.00	7.04	85.80
Labour	62.07	-	300.00	-	-	54.56	-	300.00	-	-
Fertilizer	13516.64	-3.44	1.00	-3.44	129.09	10650.58	-	1.00	-	-
Seed	8734.68	6.99	1.00	6.99	85.69	6316.88	1.53	1.00	1.53	34.84
Plant protection	4494.99	11.67	1.00	11.67	91.43	3431.17	17.47	1.00	17.47	94.28
Irrigation	2.61	27823.56	300.00	92.75	98.92	2.25	14422.69	300.00	48.08	97.92

*Underutilized and **Overutilized

Table 7. Problem encountered by beneficiaries during implementation of project

Problem	Mean score (%)	Rank
Production problem		
Stray wild animal menace	72.38	II
Lack of knowledge about seed treatment	63.27	III
Lack of knowledge about the management of common properties resources	55.35	V
Technology is capital and labour intensive	54.23	VI
Fragmented holding	53.61	VII
Lack of coordination among the beneficiaries	44.79	X
Lack of outside field visits for successful implementation of watershed areas	42.31	XI
Lack of irrigation facility	27.91	XIV
Marketing Problem		
Price fluctuations in perishable crops	76.75	I
Inadequate post-harvest technologies	48.31	VIII
Lack of transport facilities	40.98	XII
Unfavourable climatic conditions	37.61	XIII
High marketing cost	25.63	XV
Financial Problem		
Ineffectiveness of working of gram panchayat	60.56	IV
Weak advisory and extension services	46.31	IX
Chi square value	59.65*	

*p<0.01

farms in the study area that can further lead enhanced crops/livestock production levels and to overall social welfare.

CONCLUSIONS

Project interventions have assisted beneficiaries to bring shift to their cropping pattern through high value cash crops and that has brought changes in area under cultivation and decreased the expenditure on various inputs. Resource use efficiency of agricultural farms has shown that inputs such as seed, plant protection and irrigation have more positive and significant influence on resource use efficiency and crops productivities on beneficiary farms as compared to non-beneficiary farms. Crops' productivities on beneficiary farms have been found to be increased within a range of about 7 to 30 percent as compared to non-beneficiary farms, due to increased levels of irrigation infrastructure. The beneficiaries have been found facing major problems like perishable nature of the produce, stray/wild animal menace and ineffectiveness of gram panchayats. The study has suggested to bring in increase in cold storage facility; frame policy for wild animal menace specially monkey; provide good extension services and stream line working of gram panchayats to readily overcome the problems faced by farmers in the study area.

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Determinants of Livelihood Diversification: A Case Study of Tribal Households in Kinnaur District of Himachal Pradesh

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Abstract: Livelihood is a multifarious concept referring to what people do to manage revenue for living with the assets at their disposal and what they achieve by doing it in a particular context. In the past decades, livelihood diversification has received much attention from researchers and policy makers with high hopes that promoting it can offer a pathway for poverty reduction and economic growth. Therefore, an attempt has been made in this paper to identify the determinants of livelihood diversification of the tribal people using primary data collected based on multistage random sampling from 120 households of Kinnaur, one of the remote districts of Himachal Pradesh. The Simpson livelihood diversification index was found higher for salaried group as well as Agriculture+ Services group. Out of the 9 determinants of diversification of livelihoods identified, level of education, access to irrigation, membership and training have positive and significant effect on livelihood diversification activities. However, land-man ratio has negative and significant correlation with livelihood diversification sources. Therefore, the findings of this study implies that development policies in the region should consider education, skill generation, membership of formal organization and better irrigation facilities as the key areas for the better development and diversification of tribal households.

Keywords: Livelihood diversification, Tribal households, Simpson index, Determinants, Multiple regression analysis

In present era, the problem of livelihood has become a major concern among tribal communities. The inability to meet basic needs and goals forces many rural households to pursue a strategy of diversifying their economic activities. A surfeit of studies from developing countries have underscored the importance of diversification strategies from farm to non-farm activities which have immense potential to enhance farmers' income and alleviate conditions of poverty and inequality (de Janvry et al 2005, Reardon et al 2007). The livelihood among tribal communities in India is complex, dynamic and multidimensional phenomenon, perception of which varies with geographic location, type of community, age, gender, education, infrastructure, social, economic, cultural, ecological and political determinants (Kumar 2009). Agriculture constitutes main sources of livelihood among tribes in India playing a vital role in national economy, rural development, employment and occupation, agro-industries, food and nutritional security, growth and survival, social, economic and cultural conditions and poverty alleviation (Surayya et al 2008). About 70 per cent of the population mainly depends on rain fed agriculture characterized by low productivity, un-predictive weather and calamities, degraded soil with low fertility, un- protective irrigation and degraded natural resources (Chakraborty et al 2009). These factors aggravated the problems of poverty, migration, unemployment, underemployment, food insecurity and malnutrition for millions of tribal people in India. The linkages between tribal people, livelihood dependence on different resources and poverty are complex and require locally-specific analysis. Kinnaur is among the remote and high altitude districts of the state. On account of the high altitude and resultant cold-arid climate, it is among the environmentally very difficult regions to live in. Kinnaur was a restricted area till early 1990s this resulted in stepped up initiatives for socio economic development with the objective to broaden their social horizon and bring economic contentment among the people who till then were backward and formed a closed society. In order to understand the contribution and potential of different resources/assets to tribal livelihoods, poverty reduction, socio-economic upliftment, nutritional security, environmental conservation and rural development, it's changing pattern and reasons for changes, it is imperative to design a research plan based on multi- disciplinary approaches. Keeping the above facts in view, the present study was undertaken in Kinnaur District of Himachal Pradesh.

MATERIAL AND METHODS

This study was conducted in the Kinnaur district of North- Western Himalayan region of Himachal Pradesh stretching from N latitude 31°05′50″ and 32°05′15″ and E longitude 77°45′00″ and 79°00′35″. The sample of respondents for the study was drawn using a multistage random sampling procedure. Kinnaur district is divided into three developmental blocks, two of which were chosen at random for this study. A comprehensive list of panchayats was compiled, and three panchayats were chosen at random from each block. Following the selection of three panchayats, a comprehensive list of villages was compiled with the assistance of the panchayat secretary, and two villages from each panchayat were chosen at random. As a result, six villages from each block were chosen for the current study. A comprehensive list of the households in the selected villages was compiled, and 10 households were chosen at random from each village. Thus, a total of 120 households were chosen for the current study, and these households were then divided into four livelihood groups depending on their source of income: Agriculture, Salaried, Agriculture + Business, and Agriculture + Services.

Analytical Tools

Livelihood diversification index: There are a variety of indicators, and indices to measure livelihood diversification like number of income sources and their share, Simpson index, Herfindahl index, Ogive index, Entropy index, Modified Entropy index, Composite Entropy index (Shiyani and Pandya 1998, Khatun and Roy 2012). The Simpson index was chosen for this investigation because of its computational simplicity, robustness, and wide applicability.

$$S.I. = 1 - \sum_{i=1}^{N} Pi^2$$

Where, N is the total number of income sources and P_i represents income proportion of the i-th income source. Its value lies between 0 and 1. The value of the index is zero when there is a complete specialization and approaches one as the level of diversification increases.

Determinants of livelihood diversification: The livelihood diversification index was hypothesized to be a function of number of factors including age, education, family size, dependency ratio, land-man ratio, asset value, irrigation facility, training/ skill development and social organization membership. Among these determinants of livelihood diversification, educational level, dependency ratio, family size, asset value, irrigation, membership and training were hypothesized to be positively correlated with livelihood diversification. The households with higher level of education, high dependency ratio, larger family size, stronger asset base and well access to irrigation facilities, better cooperative participation and better access to skill development programmes in the study area are expected to have more diversified livelihood. The age of household heads was inversely related with livelihood diversification, implying that households with a younger head will have more desire and access to non-farm activities. Furthermore, land-man ratio was also hypothesised to be negatively correlated with livelihood diversification, implying that lower the value of land-man ratio, more will be the pressure on land, which leads to disguised unemployment in agriculture, forcing surplus labour to seek work in the non-farm sector thereby diversifying their livelihood (Table 1).

Regression analysis: Multiple regression analysis was used to determine the primary factors of livelihood diversification using Equation (1):

$$D = \beta_0 + \beta_i X_i + \mu \qquad \ldots(1)$$

Where, D is the dependent variable representing Livelihood Diversification Index, explained by β_i which represents a vector of parameters, and X_i is a vector of exogenous explanatory variables. Descriptions of the explanatory variables are given in Table 1.

Table 1. Description of explanatory variables used in regression analysis

Variable name	Definition	Expected sign of coefficients
LDI	Livelihood diversification index (Simpson *100)	
Age	Actual age of household-head in years	-
Dependency ratio	Percentage of household members below 14 and above 65 years	+
Education	Literacy rate of each household	+
Family size	A household's total number of members	+
Land-man ratio	Cultivable land per working member in a household (ha)	-
Asset value	A household's estimated worth of all physical assets (excluding land) and livestock worth (in rupees)	+
Irrigation	Percentage area irrigated	+
Membership	Dummy, if a household belongs to a formal social organisation such as a SHG/Co-operative/Village Committee, and so on.	+
Training	Dummy, has a family member received any official training in the development of livelihood skills?	+

RESULTS AND DISCUSSION

The main livelihood groups, their level of livelihood diversification, and the contribution of various sources of income in the research region indicates the highest level of diversification is in the Salaried and Agriculture+ Services groups (Table 2). The Agricultural Groups' livelihoods are less diverse in general. Agriculture+ Services and Agriculture+ Business are in a better position, perhaps due to their stronger asset base.

Regression analysis: The result of the multiple regression revealed that education, land man ratio, irrigation, membership and training are significant determinants of livelihood diversification in the study area, whereas the rest four explanatory variables are insignificant i.e. they have no significant impact on livelihood diversification in the study area (Table 3).

In contrary to research hypothesis, the co-efficient for age is positive and statistically insignificant. Furthermore, the dependency ratio is positively related with the level of diversification, but the co-efficient was statistically non-significant. Educational level was one of the most important predictors of livelihood diversification, with a positive correlation and significance. Education is a significant barrier to participation in the non-farm economy in Kinnaur for salaried positions and petty business. This shows that highly educated people diversify their livelihood alternatives by choosing salaried jobs, self-employment, and other activities, whereas low-educated and illiterate people rely solely on wage labour. Investing in education and increasing access to higher education will assist tribal households in obtaining alternate sources of income. Increased educational level will increase the likelihood of participation in non-farm activities in rural areas and diversification of livelihoods. The findings of this investigation are in line with previous findings (Nghiem 2010, Khatun and Roy 2012, Agyeman et al 2014 and Khan et al 2017).

Family size was positively associated to the level of livelihood diversification, which was in line with our expectations, but the co-efficient was not statistically significant. But land-man ratio was an important and statistically significant factor of livelihood diversification and the relationship between the land-man ratio and diversification level was found to be negative as per the hypothesis. This implies that a drop in its value puts undue pressure on land, resulting in disguised unemployment in agriculture (i.e., workers having very low or zero marginal productivities). The surplus labour will seek employment in the non-farm sector. The co-efficient of irrigation was significant determinant and positively related to livelihood diversification in the study area. Majority of people in the study area are involved in production and sale of various vegetable and fruit crops such as peas, cauliflower, potato, cabbage apple. Therefore availability of proper irrigating facilities boosts up the production and increase returns from sale of these crops there by generating more income which can be diverted to other non-farm activities leading to increase in livelihood diversification. The results of the study are consistent with the findings of Khatun and Roy (2012) and Ambachew and Ermiyas (2016).

The relationship between livelihood diversification and

Table 3. Parameter estimates of multiple regression result

Parameters	Coefficients	Standard Error	t Stat
Intercept	0.609	0.165	3.698
Age	0.001	0.001	0.094
Dependency ratio	0.017	0.069	0.245
Education	0.002*	0.001	1.768
Family size	0.009	0.009	1.081
Land man ratio	-0.042**	0.021	1.996
Irrigation	0.001*	0.001	1.683
Membership	0.078***	0.024	3.223
Training	0.088***	0.024	3.742
Assets	0.001	0.000	1.250
R^2		0.33	
F		6.18	
No. of observations		120	

Note: *, ** and *** denote significance at 10, 5 and 1% level of significance

Table 2. Level of livelihood diversification and income sources for different livelihood groups in Kinnaur district

Livelihood groups	Simpson index	Average income (Rupees)/HH/year	Share of different activities in household income (%)					
			Agriculture (including horticulture, forestry)	Livestock rearing	Business	Handicrafts	Salaried	Others
Agriculture	0.15	357612	92.77	6.34	0.04	0.86	0.00	0.00
Salaried	0.54	509808	32.08	5.03	1.72	1.96	58.85	0.37
Agriculture + Business	0.32	539897	80.49	4.38	15.13	0.00	0.00	0.00
Agriculture + services	0.52	789921	57.33	3.32	1.13	0.00	38.51	0.00
All occupations	0.23	433775	83.65	5.71	2.14	0.74	7.77	0.02

Source: Field survey

membership of a cooperative society was positive and statistically significant. Membership in multiple self-help groups (SHGs) boosts a person's social status and allows them access to common property resources as well as a variety of government and non-governmental organisation (NGO) programmes in the studied region. The outcome of the study is in line with Khatun and Roy findings (2012). The relation between skill enhancing training and level of diversification are positive and significant. Strong influence of this factor on livelihood diversification might be contributed to the various training programmes/schemes undergoing in the study area like industrial awareness workshops, Entrepreneurship Development Programme, Poultry Development Schemes, Integrated Handloom Trainings, and Horticulture Development Scheme etc. This implies that human capital in terms of capacity building through skill development help in diversifying livelihoods in rural area. Assets were found to be positively related to the extent of livelihood diversification, but the co-efficient was not significant.

CONCLUSION

Maximum level of diversification was for Salaried and Agriculture +Service Group and least for Agriculture Group as obtained from Simpson diversification index. This implies that combining different services can help people diversify their income. The multiple regression analysis revealed that among the nine determinants of household livelihood diversification, education level, land-man ratio, irrigation availability, household membership, and training were statistically significant predictors of household livelihood diversification. Therefore, in order to improve the livelihoods and make it more sustainable so as to empowering the tribal households through participatory methods and lift the standard of living of farmers through diversified activities, the implementation of multidimensional policies particularly related to skill generation, irrigation, education, membership through bottom up approach that will develop the capacities, choice, and diversity of livelihoods is deemed vital.

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Mammalian Diversity of Ghatigaon Bustard Sanctuary, Gwalior Madhya Pradesh, India

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Abstract: During the study 18 mammalian species were found in the Ghatigaon Bustard Sanctuary, belonging to 6 orders, 12 families and 18 genera. The maximum number of 4mammalian species belongs to family Bovidea (22.22%), followed by family Cervidea (16.67%) and Canidea (11.11%). The family Cercopithecidae, Manidae, Felidae, Hyaeniudae, Herpestidae, Sciuridae, Muridae, Leporidae and Suidae represented by one species each with a share of 5.56%. The highest diversity was in the Site IV, while the Site II has lowest diversity. Species evenness has shown variation in the first four sites with values of 0.861 (Site IV), 0.247 (Site I), 0.202 (Site III) and 0.102 (Site II). Conservation status of mammals reveals that among 18 species of mammals two species are vulnerable, three species are near-threatened, one specie is included in CITES Appendix II and another two species includes in CITES Appendix III, and rest of the mammalian species are of least concern.

Keywords: Ghatigaon Bustard Sanctuary, Mammalian diversity, Diversity index

India harbours a total of 417 species of mammals belonging to 48 families (Nameer 2000, 2008). Many studies have been carried out on the mammals of India. The study of available literature on mammals of Madhya Pradesh reveals that work on mammals of central India was started in late nineteenth century. William Thomas Blandford published the first Indian edition of *Fauna of British India- Mammalia* in two parts in 1888 and 1891. His work was mainly restricted to southern and central India. The most authentic and modern work on mammals of central provinces/central India was done during mammal survey of India conducted by Bombay Natural History Society (Wrougton 1912-1929). During this period, collections of samples were made from Gwalior, Guna, Nimar, Hoshangabad and Sagarin Madhya Pradesh.Harshey and Chandra (2001) annotated the list of mammals of Madhya Pradesh and Chhattisgarh with current district-wise distribution in these two states. Much scientific study on the ecology, vegetation pattern, ungulate and livestock densities and rehabilitation of villages from the core area of Kuno Wildlife Sanctuary, Madhya Pradesh has been done by Khudsar et al (2008). They used both line and road transect for estimating ungulate density. The present study revealed the mammalian diversity of Ghatigaon Bustard Sanctuary, Gwalior Madhya Pradesh India.

MATERIAL AND METHODS

Study area: The present study was carried out in the Ghatigaon Bustard Sanctuary (GBS) Madhya Pradesh (Fig. 1). This is the only sanctuary located in Gwalior district.GBS was established in 1981 with the primary aim to protect the Great Indian Bustard (GIB). Total area of the Sanctuary is 512 sq. km of which 307 sq. km are protected forest area, 19.84 sq. km are reserve forest area and 185.16 sq. km are revenue area (Bhat and Rao 2020). To preserve and propagate Indian Bustard the Madhya Pradesh Government has declared Ghatigaon Wildlife Sanctuary vide Gazette Notification No. 15-16-75/Das/2 Wildlife Protection Act, 1972 dated 21st May 1981.

Study sites: For the present study four study sites were selected on the basis of different habitats such as: Aquatic, Grassland, Scrubland and Woodland habitat (Fig. 2).

Site I: Tighra reservoir, constructed on Sank River in the year 1917 near Tighra village. Geographically, the Tighra reservoir lies on $78^0$01' 24" E longitude and 26^0 12' 59" N latitude.

Site II: Pawta Military Grass Bir, geographically it lies on 77^0 57' 14" E longitude and 26^0 10' 37" N latitude. It is the grassland habitat having certain species of grasses as; Kans (*Saccharum spontaneum*), Bhanjura (*Apluda mutica*), Lapurse (*Aristida hysterix*) etc.

Site III: This study site is located near Ghatigaon and geographically lies on 77^0 57' 41" E longitude and 26^0 9' 5" N latitude. It is a scrubland habitat with certain thorny bushes as; Babul (*Acacia Arabica*), Reunja (*Acacia leucophloea*), Karonda (*Carissa spinarum*) etc.

Site IV: This study site is located near Lakan Pura village and geographically lies on 77^0 54' 37" E longitude and $26^0$12' 9" N latitude. It is a woodland habitat with certain species as; Tendu (*Diospyros melanoxylon*), Palash (*Butea frondosa*) and Khair (*Acacia catechu*) forms the climax.

The study was carried out from May 2017 to October 2017. During the study the Ghatigaon Bustard Sanctuary was visited at regular intervals so as to collect data on Mammals. Theline transect method was used, by which various transects of lengths 200 and 300 meters were laid randomly. The mammals were observed on either side of transect by walking silently along the transect and were recorded by direct sightings. The identification of the species recorded was done with the help of standard literature (Menon 2003).Different research instruments were used for the study are field Binocular (8x40X), Global Positioning System (GPS) (Garmin 60), Nikkon Digital Camera (D60, 70-300 mm) etc. Species diversity and evenness were calculated by using Shannon-Weiner Index.

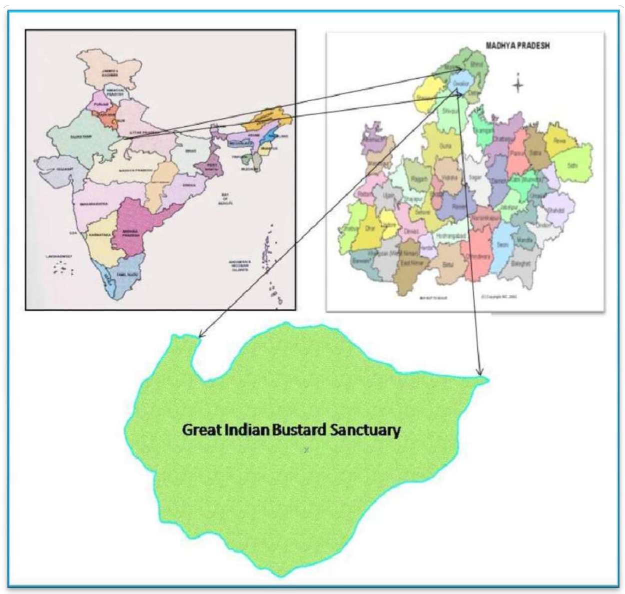

Fig. 1. Map showing study area, Ghatigaon Bustard Sanctuary

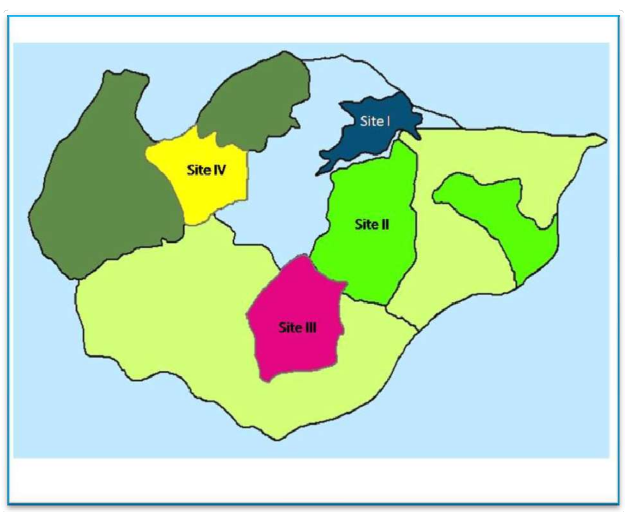

Fig. 2. Map showing study sites

RESULTS AND DISCUSSION

In the present study 18 mammalian species belonging to 6 orders, 12 families and 18 genera were recorded (Table 1). two species are vulnerable (*Tetracerus quadricornis, Rusa unicolor*) one specie *Tetracerus quadricornis* also included in CITES Appendix III, 3 species are near-threatned (*Manis crassicaudata, Hyaena hyaena, Antilope cervicapra*) one species *Manis crassicaudata*is included in cites Appendix II and *Antilope cervicapra* includes in cites Appendix III, and rest of the mammalian species are least concern. Prakash and Singh (2001) identified 15 species of small mammals, 1 insectivore and 14 rodents, from 35 habitats at 11 localities in the hilly tracts of South-eastern Rajasthan. Shrinivaslu and Nagulu (2001) reported 74 species of mammal belonging to 9 orders and 28 families, from the Nallamala Hills, Andhra Pradesh. Mishra et al (2006) reported a total of 35 mammal species, of which 13 are of high conservation importance globally, categorized as endangered or vulnerable on the IUCN Red list (IUCN 2001) from the high altitudes of western Arunachal Pradesh. A total of 16 species of mammals were reported from Kalatop-Khajjiar Wildlife Sanctuary Himachal Pradesh, out of 16 species of mammals 9 species has been listed as threatened in cites under different schedules (Singh and Banyal 2012).

The large herbivores, nilgai, chital and chinkara were abundant, while Sambar, four-horned antelope, barking deer and black buck were rare. Wild boar and Indian porcupine were mostly found in woodland and grassland areas. Five stripped palm squirrel and Indian Bush Rat are very abundant. Common grey mangoose is fairly common and sighted many times. Indian fox and jackal were sighted in the evening hours. Though jungle cat, Indian pangolin and stripped hyena are reported in the Sanctuary, they are not seen during the present study. Rhesus monkey was found in woodland area, while Indian Hare was sighted mostly in the grasslands and scrublands and was present in a good number (Table 2).

The family wise proportion of mammalian species richness varies from site to site respectively, with Bovidae family having 4 species (22.22%), followed by Cervidae represented by 3 species (16.67%), Canidae familywith 2 species (11.11%) and family Cercopithecidae, Manidae, Felidae, Hyaeniudae, Herpestidae, Sciuridae, Muridae, Leporidae and Suidae with one species each (5.56%) (Table 3).

The species diversity index fluctuates from 0.602 (Site IV) to 0.114 (Site II) respectively. The highest diversity was in

Table 1. Checklist of mammals found in Ghatigaon Bustard Sanctuary

Order	Family	Common name	Scientific name	IUCN status
Primates	Cercopithecidae	Rhesus Monkey	*Macaca mulatta*	LC
Pholidota	Manidae	Indian Pangolin	*Manis crassicaudata*	NT
Carnivora	Felidae	Jungle Cat	*Felis chaus*	LC
	Hyaenidae	Stripped Hyaena	*Hyaena hyaena*	NT
	Herpestidae	Indian Grey Mangoose	*Herpestes edwardsii*	LC
	Canidae	Indian Fox	*Vulpes bengalensis*	LC
		Common Jackal	*Canis aureus*	LC
Rodentia	Sciuridae	Five Stripped Palm Squirrel	*Funambulus pennantii*	LC
	Muridae	Indian Bush Rat	*Golunda ellioti*	LC
Lagomorpha	Leporidae	Indian Hare	*Lepus migricollis*	LC
Cetartiodactyla	Suidae	Wild Boar	*Sus scrofa*	LC
	Bovidae	Black Buck	*Antilope cervicapra*	NT
		Chinkara	*Gazelle bennettii*	LC
		Nilgai	*Boselaphus tragocamelus*	LC
		Four Horned Antelope	*Tetracerus quadricornis*	VU
	Cervidae	Barking Deer	*Mantiacus vaginalis*	LC
		Sambar	*Rusa unicolor*	VU
		Chital	*Axis axis*	LC

LC = Least concern, VU = Vulnerable, NT = Near-threatened

Table 2. Abundance of mammalian species in Ghatigaon Bustard Sanctuary

Group	Common name	Site I	Site II	Site III	Site IV	Total
Carnivore	Indian Fox	-	2	4	-	6
	Jackal	-	1	1	-	2
	Grey Mangoose	2	8	14	12	36
Herbivore	Five Stripped Palm Squirrel	-	8	12	36	56
	Indian Bush Rat	-	-	16	2	18
	Indian Hare	-	18	10	-	28
	Wild Boar	-	14	-	21	35
	Black Buck	-	2	-	-	2
	Chinkara	4	12	-	-	16
	Blue Bull (Nilgai)	3	8	-	-	11
	Four Horned Antelope	-	2	-	-	2
	Barking Deer	-	1	-	-	1
	Sambar	-	1	-	-	1
	Chital	1	9	-	-	10
	Rhesus Monkey	-	-	-	18	18
	Total	10	86	57	89	242

Table 3. Total number and percentage of Mammalian species of different families

Family	No. of genera	No. of species	Percentage contribution of families
Cercopithecidae	1	1	5.56
Manidae	1	1	5.56
Felidae	1	1	5.56
Hyaeniudae	1	1	5.56
Herpestidae	1	1	5.56
Canidae	2	2	11.11
Sciuridae	1	1	5.56
Muridae	1	1	5.56
Leporidae	1	1	5.56
Suidae	1	1	5.56
Bovidae	4	4	22.22
Cervidae	3	3	16.67
Total	18	18	

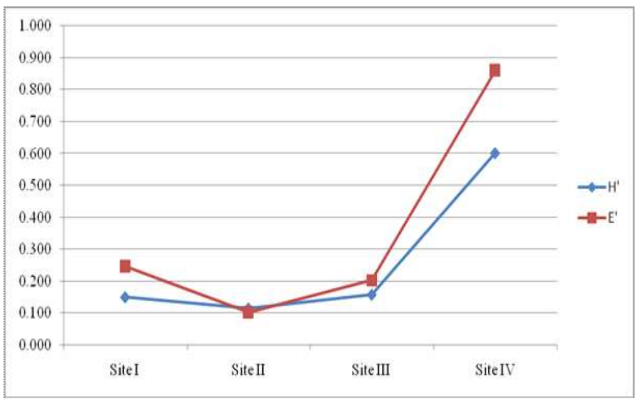

Fig. 3. Shannon-Weiner diversity index and evenness of mammals of Ghatigaon Bustard Sanctuary

the Site IV, while the Site II has the lowest diversity. This fluctuation of the mammalian species diversity index may be due to the habitat type, availability of food, water and shelter etc. Apart from diversity, species evenness has shown variation in the first four sites with values of 0.861 (Site IV), 0.247 (Site I), 0.202 (Site III) and 0.102 (Site II) with respect to each other (Fig. 3). The mammalian species diversity and richness vary from site to site due to the type of habitat.

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CONCLUSION

Though the great Indian Bustards form the chief attraction of the sanctuary, Ghatigaon Wildlife Sanctuary is also home to a number of other wild creatures due to its great beauty and rarity. The Sanctuary consists of different types of habitats as aquatic, grassland, scrubland and woodland. Due to this habitat diversity within the sanctuary a good diversity of wild animals was being reported from the sanctuary. During this study 18 mammalian species has been reported. These species were also showing the variation of their species richness from site to site respectively. This fluctuation of their species richness may be due to the habitat type, availability of food, water and shelter etc.

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Bird Diversity in Riverscapes of Ayodhya District, Uttar Pradesh

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Abstract: The bird diversity using line transect method along the 45 km stretch of Saryu river between Aharauli and Pitapur in eastern Uttar Pradesh was assessed. A total of sixty eight bird species, belonging to 56 genera, 35 families and 12 orders were recorded from the study area. Passeriformes (24) had the maximum number of bird species. The maximum encounter rate was for Indian Silverbill (2.685) and the minimum for Blue-tailed Bee-eater (0.054). Out of 68 bird species recorded, 56 bird species (82%) were resident, 11 bird species (16%) were winter visitors and only 1 bird species (1%) was summer visitor. A large number of Carnivores (29 species, 43%) were recorded in the area. Of the recorded species, nine were in the threatened category of IUCN Red List and eighteen species (26%) of birds had a declining population trend globally highlighting the conservation value of riverscapes of Saryu river. This study has helped in generating a baseline information on the bird diversity of the Saryu river and emphasis on carrying out long-term monitoring of birds in such threatened ecosystem.

Keywords: Avian, Freshwater ecosystems, Feeding guild, Ayodhya, Saryu river

Freshwater is a natural resource which is important in terms of economy, culture, science and education (Dudgeon et al 2006). Freshwater habitats including rivers, streams, lakes, oxbows, wetlands and estuaries etc. and their adjacent areas called riparian zones alone support around 6% of world known species (Hawksworth and Kalin-Arroyo 1995). Birds are an important constituent of the riverscape. A riverscape is a landscape constituting of the streams, floodplains and riparian zones along a river channel (Wiens 2002). The riverscapes provide essential dispersal pathways, shelter, breeding and nesting sites for the birds, thus supporting high bird species diversity (Sinha et al 2019). But as these riverscapes are exposed to anthropogenic pressure due to its productivity and developmental activities, these areas are the most threatened ecosystems of the world (Revenga et al 2005). Thus, leading to loss of the ecosystem and their associated bird diversity. These riverscapes are meagerly managed from conservation point of view. In addition, the existing knowledge on bird diversity in these ecosystems is incomplete and insufficient to assess the impacts of anthropogenic pressures on bird diversity loss.

The river Ganga is one of the largest rivers with many tributaries flowing through 2510 km from north to east India (Adel 2001). This river supports 8% of the world's population living in its catchment (Newby 1998). Understanding the bird diversity, abundance and habitat preferences are necessary baseline parameters for planning conservation activities, but such information is meagre from certain tributaries of Ganga. Studies have been conducted on the faunal diversity of some segments along the stretch of Ganga (Behera 1995, Bashir et al 2012). Ghaghra river is one of the principal tributaries of river Ganga. The Ghaghra joins its sub-tributary, the Sharda river and flows through the district of Ayodhya where it is locally known as Saryu river (Dhar and Nandargi 2002, Singh et al 2016). There have been no bird diversity studies done on the Saryu river flowing through Ayodhya district, Uttar Pradesh. Therefore, in this study, an attempt was made to document the bird diversity in the catchment area of river Saryu.

MATERIAL AND METHODS

The study was conducted in a 45 km stretch of Saryu river flowing between Aharauli 26.858°N and 81.814°E and Pitapur 26.782°N and 82.256°E in Ayodhya district, Uttar Pradesh (Fig. 1). The banks of this river are sandy or muddy; the floodplains are mosaic of agriculture, orchards, forests, grasslands etc. The climate of the district is tropical monsoon. The average temperature varies from 32°C in summers to 16°C in winters and the average annual rainfall is 1067 mm (Anonymous 2021). There are three distinct seasons – summer (March to June), rainy (July to October) and winter (November to February). Hundreds of pilgrims visit the river banks of Saryu during Hindu festivals to perform religious ceremonies.

The entire 45 km stretch of the Saryu river in Ayodhya district was divided into nine segments of 5 km each. Bird survey was done using line transect method (Gregory et al 2004) in five segments (selected based on their accessibility and feasibility of sampling), so in all covering a stretch of 25 km. Five transects (5 km each) were laid parallel to the river and without any overlap in the selected 25 km segment of river. The bird sampling was done from October 2020 to May 2021, each month to record birds in winter and summer season. Two replications of each transect were made in both the seasons, making a total field effort of 400 km for the study. The transect was walked on foot at a speed of 1 to 2 km/hr from early morning (30 minutes after sunrise to 11 am). For each direct sighting, the GPS location, time and habitat were recorded. A standard field guide was used for identification (Grimmett et al 2011). Every species recorded was assigned the taxonomic position, common and scientific names by referring to Praveen et al (2020). The assessment of threat status of the recorded bird species was based on IUCN Red List (2021). Torre-Cuadros et al (2007) was followed to calculate the relative diversity of bird families. The formula is given below:

$$RDi = \frac{\text{Number of bird species in a family}}{\text{Total number of species}} \times 100$$

The sightings obtained from each transect walk was pooled to report encounter rates of species for the entire river stretch. The encounter rate for each species was calculated using the formula 'number detected per km' (Datta and Goyal 2008).

RESULTS AND DISCUSSION

A total of 68 bird species belonging to 56 genera, 35 families and 12 orders were recorded from the study area (Table 1). Similar studies in riverine areas of Ganga indicate that the present study has yielded fewer species of birds in contrast to 86 bird species reported by Behera (1995), but higher species of birds when compared to study done by Bashir et al (2012) which yielded 55 bird species. The high bird diversity in the riverscape may be attributed to the mosaic nature of the area which consists of agricultural fields, mango and guava orchards, marshlands, forest patches which may have provided diverse habitat to meet the different requirements of birds. Amongst the order, Passeriformes (24) had the maximum number of species, followed by Pelecaniformes (11) (Fig. 2). The order of Caprimulgiformes, Galliformes and Psittaciformes (1 each) had the lowest number of species (Fig. 2). The order of Passeriformes (13) had the maximum number of families, followed by Charadriiformes (6) (Fig. 2). The family Ardeidae (6) had the highest number of species, followed by Accipitridae, Columbidae, Motacillidae and Sturnidae (4 each) (Table 2). In India, Passeriformes are known to be the most dominant order (Praveen et al 2016).

The maximum encounter rate was for Indian Silverbill (*Euodice malabarica*) (2.685) and the minimum for Blue-tailed Bee-eater (*Merops philippinus*) (0.054) (Table 1). This result is dissimilar to the result of Bashir et al (2012) who have reported highest encounter rate of Little Cormorant and the least of Indian White-rumped vulture. Out of 68 bird species recorded, 56 bird species (82%) were resident, 11 bird species (16%) were winter visitors and only 1 bird species (1%) was summer visitor (Fig. 3). The study area is a part of

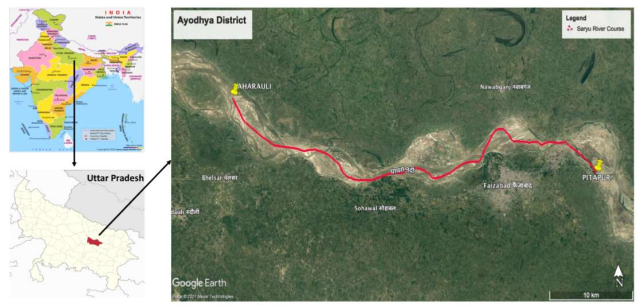

Fig. 1. Location map of study area

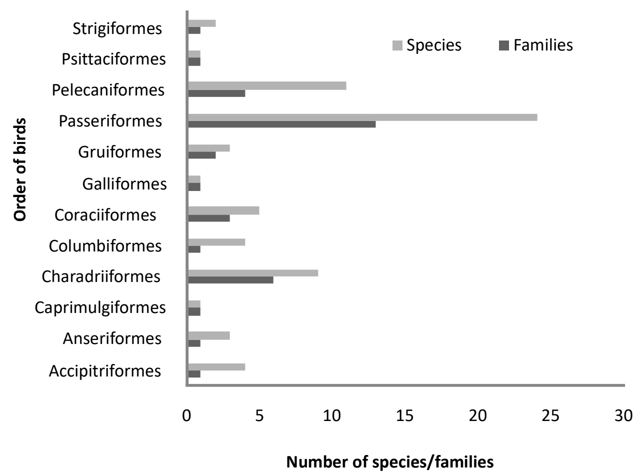

Fig. 2. Order wise bird community composition in riverscapes of Ayodhya district, Uttar Pradesh

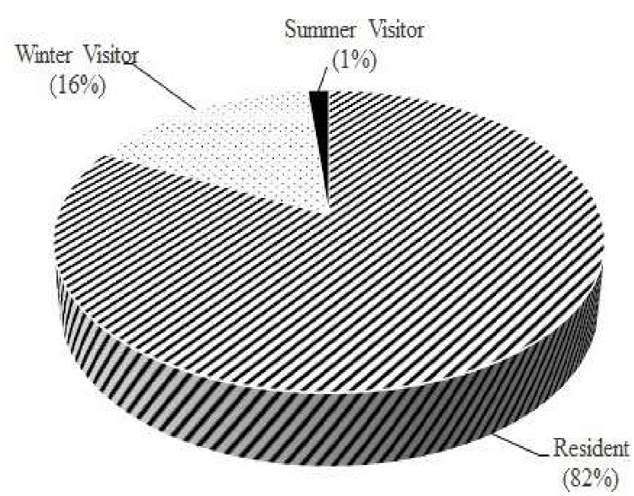

Fig. 3. Seasonal status of bird species in riverscapes of Ayodhya district, Uttar Pradesh

Table 1. Checklist and encounter rate of avifauna recorded in riverine areas of Ayodhya district, Uttar Pradesh, India

Order/Family/ Common name	Scientific name	Residential status	Feeding guild	Conservation status				Habitat (s)	Encounter rate
				IUCN list (2021)	CITES (2012)	IWPA (1972)	Global status		
Accipitriformes Accipitridae (4)									
Black Kite	*Milvus migrans* (Boddaert, 1783)	R	C	LC	II	I	→	RB, A, F, M	0.21
Black-winged Kite	*Elanus caeruleus* (Desfontaines, 1789)	R	C	LC	II	I	→	A	0.092
Egyptian Vulture	*Neophron percnopterus* (Linnaeus, 1758)	R	C	EN	-	I	↓	A, M	0.082
Shikra	*Accipiter badius* (Gmelin, 1788)	R	C	LC	II	I	→	A, F	0.338
Anseriformes Anatidae (3)									
Common Pochard	*Aythya ferina* (Linnaeus, 1758)	WV	O	VU	-	IV	↓	RC, M	0.432
Indian Spot-billed Duck	*Anas poecilorhyncha* (Forster, 1781)	R	O	LC	-	IV	↓	RC, M	0.974
Ruddy Shelduck	*Tadorna ferruginea* (Pallas, 1764)	WV	O	LC	-	IV	?	RC	0.56
Caprimulgiformes Upupidae (1)									
Common Hoopoe	*Upupa epops* (Linnaeus, 1758)	R	O	LC	-	IV	↓	RB, A, F	0.609
Charadriiformes Burhinidae (1)									
Great Thick-knee	*Esacus recurvirostris* (Cuvier, 1829)	R	C	NT	-	IV	↓	RB, M	0.38
Charadriidae (2)									
Little Ringed Plover	*Charadrius dubius* (Scopoli, 1786)	R	O	LC	-	IV	→	RB, M	1.842
Red-wattled Lapwing	*Vanellus indicus* (Boddaert, 1783)	R	O	LC	-	IV	?	RB, M, A	1.837
Jacanidae (1)									
Bronze-winged Jacana	*Metopidius indicus* (Latham, 1790)	R	O	LC	-	IV	?	A	0.268
Laridae (3)									
Black-bellied Tern	*Sterna acuticauda* (Gray, 1832)	R	C	EN	-	IV	↓	RB	0.17
Brown-headed Gull	*Larus brunnicephalus* (Jerdon, 1840)	R	C	LC	-	IV	→	RC	0.935
River Tern	*Sterna aurantia* (Gray, 1831)	R	C	VU	-	IV	↓	M	0.533
Recurvirostridae (1)									
Black-winged Stilt	*Himantopus himantopus* (Linnaeus, 1758)	WV	C	LC	-	IV	↑	RB, M	0.592
Scolopacidae (1)									
Common Sandpiper	*Actitis hypoleucos* (Linnaeus, 1758)	WV	C	LC	-	IV	↓	RB, M	0.632
Columbiformes Columbidae (4)									
Eurasian Collared Dove	*Streptopelia decaocto* (Frivaldszky, 1838)	R	G	LC	-	IV	↑	RB, A, F	0.661
Red Collared Dove	*Streptopelia tranquebarica* (Hermann, 1804)	R	G	LC	-	IV	↓	RB, A, F	0.632
Rock Pigeon	*Columba livia* (Gmelin, 1789)	R	G	LC	-	IV	↓	RB, A, F	0.555

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Table 1. Checklist and encounter rate of avifauna recorded in riverine areas of Ayodhya district, Uttar Pradesh, India

Order/Family/ Common name	Scientific name	Residential status	Feeding guild	Conservation status				Habitat (s)	Encounter rate
				IUCN list (2021)	CITES (2012)	IWPA (1972)	Global status		
Yellow-footed Green-pigeon	*Treron phoenicopterus* (Latham, 1790)	R	F	LC	-	IV	↑	F	0.84
Coraciiformes Alcedinidae (2)									
Pied Kingfisher	*Ceryle rudis* (Linnaeus, 1758)	R	C	LC	-	IV	?	RB, M	0.679
White-throated Kingfisher	*Halcyon smyrnensis* (Linnaeus, 1758)	R	C	LC	-	IV	↑	RB, M, A	0.546
Coraciidae (1)									
Indian Roller	*Coracias benghalensis* (Linnaeus, 1758)	R	C	LC	-	IV	↑	A, F	1.177
Meropidae (2)									
Blue-tailed Bee-eater	*Merops philippinus* (Linnaeus, 1767)	SV	I	LC	-	IV	→	A, F	0.054
Green Bee-eater	*Merops orientalis* (Latham, 1801)	R	I	LC	-	IV	↑	A, F	0.764
Galliformes Phasianidae (1)									
Indian Peafowl	*Pavo cristatus* (Linnaeus, 1758)	R	O	LC	III	I	→	A, F	0.872
Gruiformes Gruidae (1)									
Sarus Crane	*Antigone antigone* (Linnaeus, 1758)	R	O	VU	-	IV	↓	RB, M, A	0.39
Rallidae (2)									
Common Moorhen	*Gallinula chloropus* (Linnaeus, 1758)	R	O	LC	-	IV	→	RC, M	0.924
White-breasted Waterhen	*Amaurornis phoenicurus* (Pennant, 1769)	R	O	LC	-	IV	?	RC, RB, M, A	0.962
Passeriformes Alaudidae (1)									
Sand Lark	*Alaudala raytal* (Blyth, 1845)	R	O	LC	-	IV	→	A	0.446
Cisticolidae (2)									
Ashy Prinia	*Prinia socialis* (Sykes, 1832)	R	I	LC	-	IV	→	A, F	0.592
Plain Prinia	*Prinia inornata* (Sykes, 1832)	R	I	LC	-	IV	→	A, F	0.857
Corvidae (3)									
House Crow	*Corvus splendens* (Vieillot, 1817)	R	O	LC	-	V	→	RB, M, A, F	1.787
Large-billed Crow	*Corvus macrorhynchos* (Wagler, 1827)	R	O	LC	-	IV	→	RB, M, A, F	2.125
Rufous Treepie	*Dendrocitta vagabunda* (Latham, 1790)	R	O	LC	-	IV	↓	A, F	0.549
Dicruridae (1)									
Black Drongo	*Dicrurus macrocercus* (Vieillot, 1817)	R	C	LC	-	IV	?	A, F	0.36
Estrildidae (2)									
Indian Silverbill	*Euodice malabarica* (Linnaeus, 1758)	R	G	LC	-	IV	→	A	2.685
Scaly-breasted Munia	*Lonchura punctulata* (Linaeus, 1758)	R	O	LC	-	IV	→	A	0.979

Cont...

Table 1. Checklist and encounter rate of avifauna recorded in riverine areas of Ayodhya district, Uttar Pradesh, India

Order/Family/ Common name	Scientific name	Residential status	Feeding guild	Conservation status				Habitat (s)	Encounter rate
				IUCN list (2021)	CITES (2012)	IWPA (1972)	Global status		
Hirundinidae (1)									
Barn Swallow	*Hirundo rustica* (Linnaeus, 1758)	WV	I	LC	-	IV	↓	RB, A, M	0.839
Laniidae (1)									
Long-tailed Shrike	*Lanius schach* (Linnaeus, 1758)	R	C	LC	-	IV	?	M, A	0.644
Leiothrichidae (1)									
Common Babbler	*Argya caudata* (Dumont, 1823)	R	O	LC	-	IV	→	M, A, F	2.113
Motacillidae (4)									
Citrine Wagtail	*Motacilla citreola* (Pallas, 1776)	WV	I	LC	-	IV	↑	RB, M	1.499
Grey Wagtail	*Motacilla cinerea* (Tunstall, 1771)	WV	I	LC	-	IV	→	RB, M	0.725
White Wagtail	*Motacilla alba* (Linnaeus, 1758)	WV	I	LC	-	IV	→	RB	1.482
White-browed Wagtail	*Motacilla maderaspatensis* (Gmelin, 1789)	R	I	LC	-	IV	→	RB, M	1.161
Muscicapidae (2)									
Indian Robin	*Copsychus fulicatus* (Linnaeus, 1766)	R	C	LC	-	IV	→	A, F	1.766
Oriental Magpie Robin	*Copsychus saularis* (Linnaeus, 1758)	R	C	LC	-	IV	→	M, A, F	0.754
Passeridae (1)									
House Sparrow	*Passer domesticus* (Linnaeus, 1758)	R	O	LC	-	IV	↓	RB, A, F	2.44
Pycnonotidae (1)									
Red-vented Bulbul	*Pycnonotus cafer* (Linnaeus, 1766)	R	O	LC	-	IV	↑	M, A, F	2.471
Sturnidae (4)									
Asian Pied Starling	*Gracupica contra* (Linnaeus, 1758)	R	O	LC	-	IV	↑	RB, A, F	1.477
Bank Myna	*Acridotheres ginginianus* (Latham, 1790)	R	O	LC	-	IV	↑	RB, M	0.931
Brahminy Starling	*Sturnia pagodarum* (Gmelin, 1789)	R	O	LC	-	IV	?	A, F	0.536
Common Myna	*Acridotheres tristis* (Linnaeus, 1766)	R	O	LC	-	IV	↑	M, A, F	1.187
Pelecaniformes Anhingidae (1)									
Oriental Darter	*Anhinga melanogaster* (Pennant, 1769)	WV	O	NT	-	IV	↓	RB, M	0.695
Ardeidae (6)									
Cattle Egret	*Bubulcus ibis* (Linnaeus, 1758)	R	C	LC	-	IV	↑	RB, M, A	2.12
Great Egret	*Ardea alba* (Linnaeus, 1758)	R	C	LC	-	IV	?	M, A	0.333
Grey Heron	*Ardea cinerea* (Linnaeus, 1758)	WV	C	LC	-	IV	?	RB, M	0.453
Indian Pond Heron	*Ardeola grayii* (Sykes, 1832)	R	C	LC	-	IV	?	RB, M	1.392
Intermediate Egret	*Ardea intermedia* (Wagler, 1829)	R	C	LC	-	IV	↓	RB, M	2.086
Little Egret	*Egretta garzetta* (Linnaeus, 1766)	R	C	LC	-	IV	↑	RB, M, A	2.595

Cont...

Table 1. Checklist and encounter rate of avifauna recorded in riverine areas of Ayodhya district, Uttar Pradesh, India

Order/Family/ Common name	Scientific name	Residential status	Feeding guild	Conservation status				Habitat (s)	Encounter rate
				IUCN list (2021)	CITES (2012)	IWPA (1972)	Global status		
Ciconiidae (3)									
Asian Openbill	*Anastomus oscitans* (Boddaert, 1783)	R	C	LC	-	IV	?	RC	1.77
Painted Stork	*Mycteria leucocephala* (Pennant, 1769)	WV	C	NT	-	IV	↓	RC, RB, M	0.582
Woolly-necked Stork	*Ciconia episcopus* (Boddaert, 1783)	R	C	NT	-	IV	↓	A	1.126
Phalacrocoracidae (1)									
Little Cormorant	*Microcarbo niger* (Vieillot, 1817)	R	C	LC	-	IV	?	RB	2.569
Psittaciformes Psittaculidae (1)									
Rose-ringed Parakeet	*Psittacula krameri* (Scopoli, 1769)	R	F	LC	-	IV	↑	A, F	0.691
Strigiformes Strigidae (2)									
Jungle Owlet	*Glaucidium radiatum* (Tickell, 1833)	R	C	LC	-	IV	→	A, F	0.198
Spotted Owlet	*Athene brama* (Temminck, 1821)	R	C	LC	II	IV	→	A, F	0.316

IUCN: International Union for Conservation of Nature and Natural Resources; CITES: Convention on International Trade in Endangered Species of Wild Fauna and Flora; IPWA: Indian Wildlife Protection Act; R: Resident, WV: Winter Visitor, SV: Summer Visitor; C: Carnivorous; O: Omnivorous; I: Insectivorous; F: Frugivorous; G: Granivorous; LC: Least Concern; EN: Endangered; VU: Vulnerable; NT: Near Threatened; CITES II: Schedule-II species of CITES are the ones that are not necessarily threatened now with extinction but may become so unless trade is closely controlled; IWPA I: Schedule - I species of IWPA (high priority species); IV: Schedule - IV species of IWPA (relatively low priority species); ?: Unknown; —: Stable; ↑: Increasing; ↓: Decreasing; RB: River Bank; A: Agricultural field, F: Forested area, M: Marshland; RC: River Course

the Central Asian Flyway and thus might be supporting high diversity of migratory birds. The resident as well as migratory birds preferring this area indicates the good habitat quality of the riverscape. The birds recorded in this study were observed to be well distributed among different habitats of the riverscapes suggesting that not only the river but also the banks are equally rich in biodiversity and provide the basic requirements of the birds.

According to the feeding guilds, the 68 bird species recorded were classified into five foraging guilds. The maximum number of species recorded were Carnivores (29 species, 43%), followed by omnivores (24 species, 35%) and the least number of species were frugivores (2 species, 3%)

Fig. 4. Foraging guild-based classification of bird species in riverscapes of Ayodhya district, Uttar Pradesh

(Fig. 4). This result again suggests that the area provides the birds with diverse food items. According to the IUCN Red List (2021), out of the 68 bird species recorded, two species (3%) were 'Endangered', three species (4%) were 'Vulnerable', four species (6%) were 'Near Threatened' and the rest 59 species (87%) were 'Least Concern' (Table 1). Moreover, four species were included in the Appendix-II and one species

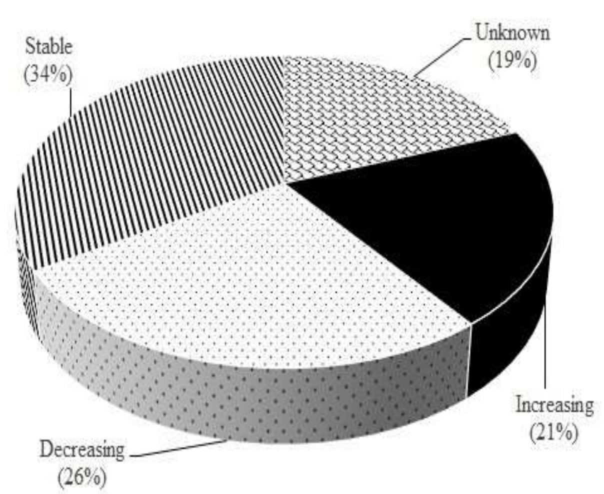

Fig. 5. Global population status of bird species recorded in riverscapes of Ayodhya district, Uttar Pradesh

Table 2. Relative diversity (Rdi) of various avian families in riverscapes of Ayodhya district, Uttar Pradesh

Avian family	Number of species recorded	Rdi value
Ardeidae	6	8.82
Accipitridae	4	5.88
Columbidae	4	5.88
Motacillidae	4	5.88
Sturnidae	4	5.88
Anatidae	3	4.41
Ciconiidae	3	4.41
Corvidae	3	4.41
Laridae	3	4.41
Alcedinidae	2	2.94
Charadriidae	2	2.94
Cisticolidae	2	2.94
Estrildidae	2	2.94
Meropidae	2	2.94
Muscicapidae	2	2.94
Rallidae	2	2.94
Strigidae	2	2.94
Alaudidae	1	1.47
Anhingidae	1	1.47
Burhinidae	1	1.47
Coraciidae	1	1.47
Dicruridae	1	1.47
Gruidae	1	1.47
Hirundinidae	1	1.47
Jacanidae	1	1.47
Laniidae	1	1.47
Leiothrichidae	1	1.47
Passeridae	1	1.47
Phalacrocoracidae	1	1.47
Phasianidae	1	1.47
Psittaculidae	1	1.47
Pycnonotidae	1	1.47
Recurvirostridae	1	1.47
Scolopacidae	1	1.47
Upupidae	1	1.47

was included in Appendix-III of CITES (CITES 2012) (Table 1). Five species came under Schedule I of the Indian Wildlife (Protection) Act (1972) (Table 1). In addition to this, the riverscape supported 18 species (26%) of birds having a declining population trend globally (Fig. 5). This work thus, highlights the conservation value of the riverscape of Saryu river.

CONCLUSION

The high species richness and presence of species of conservation importance along the riverscape of Saryu river indicates the ecological importance of the area. This result also lays emphasis on the need for proper management and conservation of this river and its surrounding landscapes. But threats like intensification and expansion of agriculture and developmental activities loom over this biodiversity rich area. Therefore, there is an urgent need to assess the level of biodiversity and health of this ecosystem all along its stretch. Future in-depth studies must be conducted in this riverscape using a multi-organismal approach. In addition to this, awareness programs at local level are necessary.

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Seasonal and Spatial Variations of Particulate Matter and CO_2 Concentration in Srinagar City, Jammu and Kashmir

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Abstract: This study was undertaken to monitor the seasonal variation of particulate matter (PM) and CO_2 of some selected tourist sites in Srinagar city, Kashmir valley, and to spatially interpolate them using the inverse distance weighting (IDW) technique in the QGIS software. The study/tourist sites include Harwan Garden, Shalimar Garden, Naseem Bagh, Nishat Garden, and Chesmashahi Botanical Garden, Sher-e-Kashmir University of Agricultural Sciences and Technology of Kashmir (SKUAST-K) Shalimar campus, and Lal Chowk. The air sampling was carried out every fortnight using Aerocet 831-Aerosol Mass Monitor and CDM 901-CO_2 Monitor three times during the day viz., morning, afternoon, and evening with three replications. The data proved that there was a statistically significant variation ($p \leq 0.05$) between the seasonal (winter and spring) average mean and locational mean concentrations of the monitored pollutants. Also, meteorological parameters like average temperature, wind speed, and sunshine hours were negatively correlated with the pollutants' levels at all the sampling sites. Indicating an increase in pollutants' levels as these meteorological parameters decrease. Whereas, relative humidity showed a positive correlation with all the monitored pollutants. Which shows a higher concentration of all monitored pollutants as relative humidity increases.

Keywords: Carbon dioxide, Particulate matter, Monitored pollutants, Meteorological parameters, Spatial interpolation.

Srinagar city in the Kashmir valley is the largest city and the summer capital of the Indian union territory of Jammu and Kashmir. The quality of the ambient air of Srinagar has been deteriorating due to the high number of vehicles most of which use diesel, the domestic and commercial (including industries) burning of coal and fuelwood, road dust, and dust emitted from other developmental activities like construction and demolition of buildings, construction of flyovers, bridges and repairing of roads (Anonymous, n.d.). The IQ*Air* (2021) noted that at the beginning of 2021, Srinagar was experiencing air quality which was categorised as unhealthy for sensitive groups' with a United States' Air Quality Index (AQI) reading of 110. This classification falls in line with recommendations by the World Health Organisation (WHO). Iqbal (2018) mentioned that the data of the state pollution control board of Jammu and Kashmir on the air quality of Kashmir pointed out that “Respirable Suspended Particulate Matter (RSPM), also known as PM_{10}, and Fine Particulate Matter ($PM_{2.5}$), are present in Kashmir air above permissible limits.” As of 2010, Jehangir et al (2010) pointed out that air quality assessment has not received much attention in Srinagar city. With the continuous increase in population, as per the 2011 census, Jammu and Kashmir have a total population of 12,541,302 out of which 1,273,312 people reside in the district Srinagar. This rise in population is bringing in more anthropogenic causes for increasing air pollution due to the build-up of vehicular population, increased biomass burning, lack of proper traffic management, lack of disposal of old vehicles, etc. In the Statistical Year Book India 2017 on motor vehicles, the total number of registered vehicles in Srinagar city as of the 31st March 2015 is 2.36 Lakh. Therefore, this study was conducted to estimate the seasonal (winter and spring) variation of carbon dioxide (CO_2) and particulate matter (PM_1, $PM_{2.5}$, PM_4, PM_{10}, and TSP).

In order to estimate the spatial variation of the monitored pollutants, the inverse distance weighting (IDW) technique was used to map out the pollutant concentrations in nearby unsampled areas. The IDW hypothesizes that areas closer to the sampling points ought to have a high concentration of pollutants than those in remote places. This means that the areas closer to the prediction location are expected to have more influence on the predicted value than those further away (Goutham and Jayalakshmi 2018). This interpolation method has proven to be best for monitoring the ambient air quality of urban sensitive areas (Fontes and Barros 2010) and has also been used for estimating the spatial disparity in pollutant concentrations over widespread urban environments (Lipsett et al 2011). It can therefore be considered a reliable technique in spatially interpolating the air quality data of the selected tourists' sites in Srinagar city as influenced by their seasonal variations.

MATERIAL AND METHODS

Study area: Srinagar is the summer city of Jammu and Kashmir State of India located at coordinate 34°5'24" N and 74°47'24" E and altitude of 5200 feet. It has a very humid and subtropical climatic condition with four seasons (viz. winter, spring, summer, and autumn). The air sampling sites shown in Figure 1 were selected based on the most visited tourist sites in the city with Lal Chowk (N 34.07268°, E 076.81310°) and SKUAST-K Shalimar (N 34.14674°, E 074.87832°) viewed as control sites. These tourist sites are famous gardens, which includes Shalimar Garden (N 34.13518°, E 074.87045°), Harwan garden (N 34.15808°, E 074. 90237°), Naseem Bagh (N 34.13805°, E 074.84006°), Nishat Garden (N 34.12431°, E 074.87881°), and Chesmashahi Botanical Garden (N 34.09262°, E 074.87740°).

Air sampling method: The air sampling was done in the winter and spring seasons from November 2019 to April 2020 on the second and fourth week of each month. Each morning (9:00 am-10:30 am), afternoon (1:00 pm-2:30 pm), and evening (4:30 pm- 6:00 pm) sampling of particulate matter (PM) of sizes 1, 2.5, 4, 10, total suspended particles (TSP) and monitoring of CO_2 were conducted at each sampling point to take three replicate readings. Aerosol Mass Monitor (AEROCET 831, Met One Inc. Washington, USA) which uses

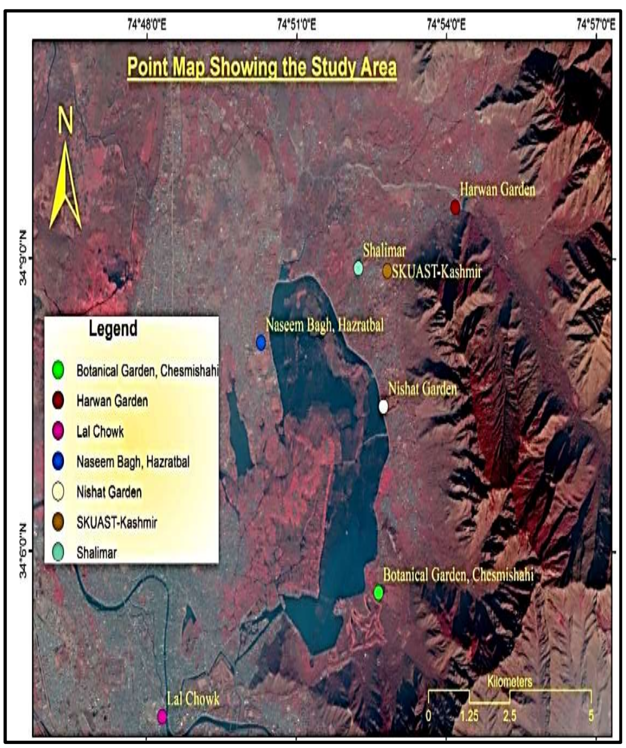


Fig. 1. Digital map showing the air monitoring sites

the operating principle of particle count to mass conversion using scattered laser light (Remer et al 2005) was held at some height for about 1 minute and then the data was recorded. The CO_2 analyser (CDM 901, Rave Innovations, India) which works with the principle of NDIR (Non-Dispersive Infrared Radiation) and the NDIR sensors operate on the principle of IR radiation being absorbed by a target gas (Baschant and Stahl 2004) was used for monitoring CO_2 concentration in the ambient air. The instruments were held at a point away from disturbances from vehicular movements etc. so that the right concentrations of particulate matter and CO_2 could be estimated. Meteorological data from November 2019 to April 2020 for maximum and minimum temperatures, relative humidity, wind speed, and sunshine hours respectively were obtained from the Agro-meteorological cell of the Sher-e-Kashmir University of Agricultural Sciences and Technology of Kashmir. The daily meteorological data obtained were brought down to a monthly basis for the prerequisite analysis. The data were then correlated with the air sampling data and a relationship was established with all the pollutants sampled (PM_1, $PM_{2.5}$, PM_4, PM_{10}, TSP, and CO_2).

Inverse distance weighting spatial interpolation technique: The average mean of the results obtained for particulate matter (PM_1, $PM_{2.5}$, PM_4, $PM_{10,}$ and TSP) and carbon dioxide (CO_2) in both winter and spring at the seven sampling sites were interpolated by the inverse distance weighting (IDW) technique available in the QGIS software (version 3.16.3). The IDW interpolation is computed as a function of the distance between the sampling sites and the sites at which sampling has not been done to make predictions of the unsampled sites (Wong and Lu 2008; Arif et al 2015). It is a very flexible interpolation method in executing decent and special interpolation based on the sample size and the spatial distribution of samples.

Statistical analysis: The triplicate data obtained during the sampling period (winter and spring) for the seven locations were analysed by a two-factor analysis.

RESULTS AND DISCUSSION

Variation of particulate matter (PM) and carbon dioxide (CO_2): The winter season recorded a higher concentration of all the monitored pollutants at all the sampling sites than in the spring season (Table 1). These variations of pollutants in both seasons were statistically significant. The quality of air in Srinagar city was worst during the winter than the spring with respect to the monitored pollutants. During the winter months the air quality deteriorates in Srinagar city as the air carries five times more tiny particles than the permissible limit (Savio 2020, IQ*Air* 2021). The higher concentration of particulate

Table 1. Estimation of the levels of particulate matter and carbon dioxide (CO_2) at different tourist sites, of Srinagar city, J&K.

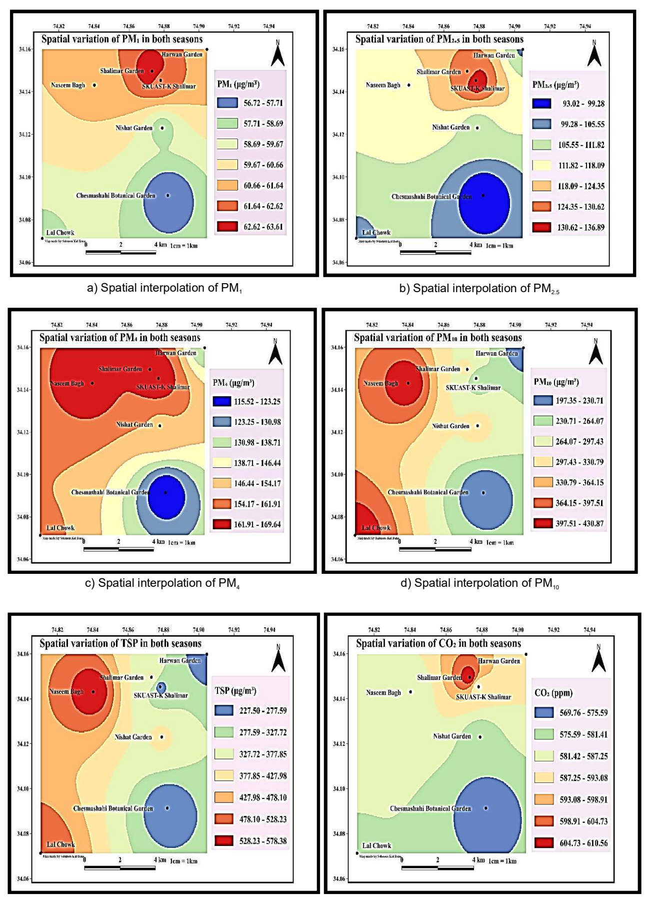
Parameters	Seasons	Monitoring sites										
		Harwan garden	Shalimar garden	Naseem bagh	Nishat garden	Chesmashahi botanical garden	SKUAST-K Shalimar	Lal chowk	Mean (S)	Factors	C.D.	SE(d)
PM_1 (µg m^{-3})	Winter	75.78	78.86	78.06	73.80	73.64	78.97	72.72	75.98	Season (S)	0.65	0.31
	Spring	46.70	48.35	43.70	42.62	39.81	45.41	44.18	44.40	Location (L)	1.21	0.59
	Mean (L)	61.24	63.61	60.88	58.21	56.72	62.19	58.45		S x L	1.71	0.83
$PM_{2.5}$ (µg m^{-3})	Winter	137.68	169.80	158.53	142.53	122.77	192.97	139.22	151.93	Season (S)	1.89	0.64
	Spring	72.10	79.09	73.95	71.77	63.28	80.80	70.56	73.08	Location (L)	3.51	1.20
	Mean (L)	104.89	124.45	116.24	107.15	93.02	136.89	104.89		S x L	4.97	1.70
PM_4 (µg m^{-3})	Winter	167.88	217.40	223.46	187.43	145.20	222.03	195.14	194.08	Season (S)	2.89	1.40
	Spring	94.96	111.24	113.08	118.56	85.83	117.25	116.10	108.15	Location (L)	5.41	2.62
	Mean (L)	131.42	164.32	168.27	153.00	115.52	169.64	155.62		S x L	7.65	3.70
PM_{10} (µg m^{-3})	Winter	253.37	356.98	514.13	313.51	207.98	260.44	474.14	340.08	Season (S)	6.25	3.03
	Spring	155.59	261.47	347.60	304.78	186.71	208.20	367.01	261.62	Location (L)	11.70	5.66
	Mean (L)	204.48	309.22	430.87	309.14	197.35	234.32	420.57		S x L	16.54	8.00
TSP (µg m^{-3})	Winter	277.76	431.95	668.45	375.33	232.03	271.02	589.07	406.52	Season (S)	9.69	4.69
	Spring	177.13	339.85	488.30	404.31	231.02	247.22	467.75	336.51	Location (L)	18.13	8.77
	Mean (L)	227.5	385.90	578.38	389.82	231.53	259.12	528.41		S x L	25.64	12.40
CO_2 (ppm)	Winter	627.98	639.07	590.71	601.05	611.96	585.62	598.67	607.86	Season (S)	3.86	1.87
	Spring	549.48	582.06	573.55	550.65	527.56	585.62	562.95	561.70	Location (L)	7.23	3.50
	Mean (L)	588.73	610.56	582.13	575.85	569.76	585.62	580.81		S x L	10.22	4.95

[*] Critical Difference (CD) significant at $p \leq 0.05$

matter in the winter might be due to lower temperatures and therefore very cold and cloudy weather which can reduce the dispersion and dilution of pollutants. The stagnation of air caused by temperature inversion and low wind speed causes the pollutants level to worsen the air quality of an area (Kakoli et al 2006, Kgabi and Mokgwetsi 2009, Cichowicz et al 2017). Exposure during short-term episodes of pollution to high levels of particulate matter can aggravate heart and lung conditions, distressing life's quality, and upsurging hospital admissions and deaths (Anonymous 2020; Mehrad 2020).

The variation in CO_2 between winter and spring seasons could be attributed to the temperature variation and plants' photosynthetic processes. During winter, plants are mostly dormant, in other words, their photosynthetic activities are dormant, and respiration is active, and therefore they make less/no use of CO_2. For this reason, CO_2 concentrations were very high during the winter season. But, during the spring season when temperatures are increasing, plants start getting active again; as they start budding, photosynthesis dominates respiration, and therefore they make much use of CO_2 thereby decreasing the atmospheric CO_2 concentration (Jawad and Ahmed 2021). Due to reduced dispersion and dilution of CO_2, caused by low temperatures, high humidity, and low wind speed, CO_2 concentration increased during the winter than in the spring. Furthermore, during winter, engines of any kind use more fuel as compared to spring. This is because, during winter, engines take a much longer time to reach their maximum operating temperature. Therefore, they emit more carbon monoxide (CO) which further reacts with atmospheric oxygen (O_2) forming high volumes of CO_2 which remain stagnated in an area over a long period. Other causes of increased CO_2 in winter as well in spring are burning of fossil fuels and other hydrocarbons using generators, animal respiration, and smokes from households, hotels, roadside confectionaries, etc.

Inverse distance weighting maps of the spatial interpolation of particulate matter and carbon dioxide: Figure 2 shows the inverse distance weighting (IDW) interpolation maps of the locational average means of each of the seven (7) sampling sites for both seasons with respect to particulate matter and carbon dioxide. On each map, the red and blue shaded portions indicate the location that recorded the highest and lowest concentration of each pollutant (Table 1, Fig. 2). The legend on each map in a descending and ascending order shows an increasing and decreasing trend of each monitored pollutant respectively. The prediction of the concentration of each pollutant in the nearby locations of the sampling sites can be determined by the coverage distance of the scaling area on the coordinates on the maps. These maps can be used to make predictive estimates of the pollutant's coverage at the different sites and in Srinagar city as a whole due to the homogeneousness in topography. The data Figure 2 (a, b & c) shows from the spatial interpolation that the concentrations of PM_1, $PM_{2.5}$ and PM_4 respectively were highest at Shalimar Garden, SKUAST-K Shalimar, and Naseem Bagh and the areas surrounding them. Figure 2 (d & e) shows from the spatial interpolation that the concentrations of PM_{10} and TSP were highest at Naseem Bagh and Lal Chowk and the areas surrounding them. The highest concentrations of these pollutants at these sites could be because these sites are located in areas that experience high traffic flow, burning of coal and agricultural residues in the surrounding houses; construction and demolition of buildings, flyovers, bridges, and repairing of roads (Anonymous n.d.) especially at Naseem Bagh and Lal Chowk which are the business hub of the city. Carbon dioxide concentration was high especially at Shalimar Garden and its surrounding areas. This can be attributed to the high traffic flow and burning of biomass especially in the winter season at Shalimar. The lowest



a) Spatial interpolation of PM_1 b) Spatial interpolation of $PM_{2.5}$

c) Spatial interpolation of PM_4 d) Spatial interpolation of PM_{10}

e) Spatial interpolation of TSP f) Spatial interpolation of CO_2

Fig. 2. Inverse distance weighting (IDW) maps of the average mean winter and spring concentrations of particulate matter and Carbon dioxide

Table 2. Correlation of pollutants with the considered meteorological parameters

Weather parameters	Pollutants					
	PM_1	$PM_{2.5}$	PM_4	PM_{10}	TSP	CO_2
Average temperature	-0.764^{NS}	-0.591^{NS}	-0.508^{NS}	-0.220^{NS}	-0.108^{NS}	-0.919^{**}
Relative humidity	0.911^{*}	0.920^{**}	0.864^{*}	0.545^{NS}	0.419^{NS}	0.695^{NS}
Wind speed	-0.803^{NS}	-0.700^{NS}	-0.627^{NS}	-0.345^{NS}	-0.241^{NS}	-0.940^{**}
Sunshine hours	-0.889^{*}	-0.849^{*}	-0.810^{NS}	-0.592^{NS}	-0.495^{NS}	-0.866^{*}

* Significant at $p \leq 0.05$; ** Significant at $p \leq 0.01$

concentration of all pollutants was mostly observed at Chesmashahi Botanical Garden which is located at a very secluded location away from traffic flow and human habitations. The data (Table 1) shows that there was a significant spatial variation between most of the sampling sites shown in the spatial interpolation maps and could be attributed to their different location, different traffic flow in the daytime, the different activities that are carried out temporarily in and around them, and the seasonal (winter and spring) effects on the pollutants.

Pollutants correlation with some meteorological parameters: The data on the correlation of the pollutants and the meteorological/weather parameters presented in Table 2 shows that all monitored pollutants were negatively correlated with average temperature, wind speed, and sunshine hours. The correlation of CO_2 was significantly negative with the above weather parameters, and so were PM_1 and $PM_{2.5}$ with sunshine hours. Thus, indicating that the increase or decrease of these weather parameters had an inverse effect on pollutants level most especially CO_2. Conversely, relative humidity was positively correlated with all the monitored pollutants with a significant correlation with PM_1, $PM_{2.5}$, and PM_4. This shows that relative humidity increases/decreases simultaneously with the monitored pollutants with significant effect on PM_1, $PM_{2.5}$, and PM_4. The correlation analysis thus shows that during winter when temperatures, wind speed, and sunshine hours were very low, and relative humidity very high, there was an increase in the concentration of all the pollutants. This is due to the reduced dispersion and dilution of pollutants caused by low temperatures, cold and cloudy weather; and also, the increased consumption of fuel by vehicles during winter enhanced the emission of pollutants. During spring when temperatures, wind speed, and sunshine hours start increasing and relative humidity starts reducing a decrease in the pollutants level was observed.

Owoade et al (2012) observed that in March (dry season) due to atmospheric haze there was an increase in the concentration of particulate matter and in July (rainy season) the lowest concentration of PM was observed. Therefore, meteorological parameters such as rainfall, global radiation, air temperature, and relative humidity play a significant role in day-to-day variations of the mass concentration of PM. Biglari et al (2017) studied the relationship between air particulate matter and meteorological parameters in Qom city of Iran and observed that rainfall, dryness of the air, insufficiency of humidity, high temperature, sources of air pollutants such as lime and plaster factories, brick baking, a large number of industrial cities, and the city proximity to the desert are the potential factors that increased Qom's air pollution.

CONCLUSION

The winter season recorded higher concentrations of pollutants at all the sampling sites and there was a statistically significant variation between the winter and the spring seasonal average mean concentrations of all the monitored pollutants respectively. This might be attributed to the meteorological influence on pollutants concentrations in the ambient air. Thus, lower temperatures and sunshine hours, higher humidity, less wind flow causes less/no dilution of pollutants leading to the stagnancy of pollutants in the atmosphere for a long time in the winter season. The locational average mean of each sampling site and the IDW maps show a very significant variation between most of the sampling sites in both seasons. This might be due to locational distances, variation in spatiotemporal activities, and traffic flow at the monitoring sites.

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An Analysis of Income and Consumption Pattern among Agricultural Labourer Households in Rural Punjab

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Abstract: Pattern of income and consumption is an important parameter to study the economic conditions of people living in any society. The present analysis is based upon primary data which collected from three different agro-climate regions of Punjab (South-west, Central plain and Shivalik foot-hill). Income from casual activities in agricultural accounts more than 40 per cent of the total income for an average agricultural labourer household followed by permanent agricultural labour and non-farm employment in rural Punjab. South-west region has recorded the highest share of permanent agricultural labour income, while Central plain and Shivalik foot-hill region has recorded the highest share of casual agricultural labour income. The per capita income is the highest in South-west region of Punjab. In all regions, an average household spends higher proportion of total consumption on non-durable items followed by marriages & other socio-religious ceremonies, services and durable items. There are slightly a few point differences between the expenditure on education and intoxicants among the sampled households.

Keywords: Agricultural labourer, Consumption, Income, Per capita income, Rural Punjab

Punjab is one of those Indian states which experienced technological transformation in agriculture during the mid-sixties. This transformation had been in terms of increased the use of high yielding seed varieties, assured irrigation, fertilisers, insecticides, pesticides and new package of farm machinery. This technological transformation has successfully helped to increase the food grains production in the country. The total food grains production was 55 million tons at the very beginning of the planning era, which increased to 308.65 million tons in 2020-21 (GOI 2021). This new technology has completely replaced traditional mode of production and traditional agriculture was successfully given way to modern and commercial agriculture which result after a short time Punjab became the role model for other states in the country (Singh et al 2016). This leads to change in state's agrarian structure. However, it must be admitted that agrarian structure of Punjab would not have been what it is today if the country had not adopted technological change in encouragement to solve the food grains shortage which it was faced in late 1950's and early 1960's (Sidhu 2005). The agricultural labourers is a large rural worker category, accounting for 30.50 per cent of the total workers, marginally lower than that of India as a whole which is 31.80 per cent (Singh 2000). The share of agricultural labourers in total workforce of the Punjab state has increased from 20.10 per cent in 1971 to 22.16 per cent in 1981 and then to 23.82 per cent in 1991. However, in 2011, this proportion of workers has recorded decline in their percentage to 16.32 (Singh and Singh 2015). Agricultural labourers constitute an important section of the rural community. But they are backward, illiterate, unorganised, and heavily indebted for insufficiency of non-agricultural occupations in villages and find seasonal employment in agriculture. Although agricultural labourers have contributed to Green Revolution, yet they have not benefited, at least in terms of betterment of their conditions (Singh and Toor 2018). Still after the seven decades of adaption of planning for economic development, the position of agricultural labourers and their economic conditions remains unchanged (Singh and Singh 2015). They are unable to fulfill their consumption requirements because of low income level. The social and economic status of agricultural labourers is weak as compared to the other workers and their economic condition has deteriorated remarkably (Chopra 2005). The debt trap is so vicious that more than 80 per cent of agricultural labourers of Punjab are indebted (Kaur et al 2021). The present study is an important attempt to empirically study the economic conditions of agricultural labourer households in rural Punjab.

MATERIAL AND METHODS

The present study is an empirical analysis of income and consumption pattern among agricultural labourer households in rural Punjab. For the analysis purpose the primary data has collected through a detailed schedule of

145 sampled households of agricultural labourer category from 6 villages two from each district belonging to three districts (Mansa, Fathegarh Sahib and Hoshiarpur) situated in three well defined agro-climate regions namely South-west region, Central plain region and Shivalik foot-hill region. District Mansa (29.9995° N, 75.3937° E) selected from South-west region, Fathegarh Sahib district (30.6435° N, 76.3970° E) from Central Plain region and Hoshiarpur district (31.6479° N, 75.8069° E) from Shivalik foot-hill region. To carry out the analysis, standard statistical tools like mean values and proportions have been used.

RESULTS AND DISCUSSION

Region-wise level of household income: In South-west region, an average agricultural labour household earns Rs. 53508, in Shivalik foot-hill region and Central Plain region are Rs. 51744 and Rs. 50845 respectively. The main source of income among agricultural labour households is hiring out casual labour in agricultural, followed by hiring out permanent labour in agricultural, hiring out labour in non-agricultural activities. Income from milk & milk product rank at fourth positioning, while job salary appears at the fifth position, followed by other sources, self-employment, farm income, sale of livestock and live poultry/egg production in rural Punjab (Table 1).

The region wise comparison shows that the main source of income in South-west region is hiring out permanent labour in agriculture, while in Central plain and Shivalik foot-hill region, the main source of households income from hiring out casual labour in agriculture. In Central plain region and Shivalik foot-hill region hiring out permanent labour in agriculture appears at second place, but in South-west region second place goes to hiring out casual labour in agricultural activities. It is also important to mention here that salary income accounts very small part of household total income across the three regions. The analysis indicates that an average agricultural labour household from South-west region has higher income as compared to Shivalik foot-hill region and Central plain region of rural Punjab.

Pattern of household income: Average household from agricultural labour category earns 41.13 per cent of the total income by hiring out casual labour in agricultural followed by hiring out permanent labour in agricultural (36.76 per cent) and hiring out labour in non-agricultural activities (7.87 per cent). Only 2.57 per cent of the total income comes from job salary. The analysis further reveals that there is variation in the relative share of total income across the three sampled regions. In South-west region, it has recorded the highest share of hiring out permanent labour is agriculture (60.04 per cent), but in Shivalik foot-hill and Central plain region the highest share of the total income comes from hiring out casual labour in agriculture (51.06 and 43.56 per cent) respectively. An average household from agriculture labour category in South-west region gets 29.18 per cent of total income from hiring out casual labour in agriculture, while in Central plain region and Shivalik foot-hill region the relative share of hiring out permanent labour in agriculture are 36.34 per cent and 13.10 per cent respectively. In Shivalik foot-hill region, the relative share of hiring out labour in non-farm activities is the highest (11.87 per cent) as compare to Central plain region and South-west region (10.04 and 1.91 per cent only). The income from job salary is the highest in Shivalik foot-hill region and the lowest in South-west region. There is only Shivalik foot-hill region where an average household earns 3.38 per cent of total income from farm business activity (Table 2). The proportion share of self-employment source is the highest is Shivalik foot-hill region followed by Central plain region and South-west region. The

Table 1. Region-wise level of mean household income (Rs. per annum)

Source of income	Central plain region	Shivalik foot-hill region	South-west region	All sampled households
Farm business	0	1752	0	584
Milk and milk products	1560	2107	1757	1808
Live poultry/eggs production	276	314	127	239
Livestock/ livestock products	384	569	281	411
Hiring out permanent labour in agriculture	18474	6780	32129	19127
Hiring out casual labour in agriculture	22149	26421	15614	21395
Hiring out labour in non-agricultural activities	5134	6144	1018	4098
Salaries	769	2613	641	1341
Self-employment	531	1499	419	816
Other sources	1568	3545	1522	2212
Total	50845	51744	53508	52031

Source: Primary field survey

relative share of other sources, pensions, sale of manure, live poultry/ livestock get very low proportion of the total household income among the agricultural households in rural Punjab. The analysis reveals that an agricultural labourer household in three regions of rural Punjab supplements their income with different activities.

Region-wise per capita income: Per capita income among an average household of agricultural labourer category is Rs. 12125 in rural Punjab (Table 3). An agricultural labour household in South-west region earns the highest (Rs. 12588) per capita annually and the lowest in Central plain region (Rs. 10314) of rural Punjab.

Region-wise household consumption expenditure: An average household from agricultural labourer category spends the highest amount on non-durables items (Rs. 43454) of consumption expenditure, followed by marriages & other socio religious ceremonies (Rs. 8824), services (Rs. 6002) and durable items (Rs. 4060). The study reveals that out of total consumption expenditure on non-durables, an average household spends higher amount on food grain (Rs. 16949), followed by milk& milk products (Rs. 8220) and intoxicant & drugs (Rs. 3842). The other important components of non-durables items include teas leaves, fuel & light, clothing & bedding, footwear, LPG, edible oils etc. As far as consumption expenditure on durable items is concerned, the highest amount spends on house construction/major repair (Rs. 1764). Out of total consumption expenditure on different kinds of services, an average household spends the highest amount on healthcare, followed by conveyance, education, telephone communication, entertainment and so on. The analysis reveals that an average household spends less on education as compare to telephone communication services (Table 4).

An average household from agricultural labourer household category in South-west region spends the highest amount (Rs. 67804) on consumption expenditure, followed by Central plain region (Rs. 61474) and Shivalik foot-hill region (Rs. 60644). In South-west region an average households spends the highest amount on non-durable items (Rs. 48572), followed by Central plain region (Rs. 46655) and Shivalik foot-hill region (Rs. 42625). In case of durable items of consumption expenditure, an average household from South-

Table 2. Region-wise pattern of household income (Percentage)

Source of income	Central plain region	Shivalik foot-hill region	South-west region	All sampled households
Farm business	0.00	3.38	0.00	1.12
Milk and milk products	3.06	4.08	3.28	3.47
Live poultry/eggs production	0.55	0.61	0.24	0.46
Livestock/ livestock products	0.76	1.09	0.53	0.78
Hiring out permanent labour in agriculture	36.34	13.10	60.04	36.76
Hiring out casual labour in agriculture	43.56	51.06	29.18	41.13
Hiring out labour in non-agricultural activities	10.09	11.87	1.91	7.87
Salaries	1.51	5.05	1.19	2.57
Self-employment	1.04	2.89	0.78	1.57
Other sources	3.09	6.87	2.85	4.26
Total	100.00	100.00	100.00	100.00

Source: Primary field survey

Table 3. Region-wise per capita value of household income (Rs. per annum)

Source of income	Central plain region	Shivalik foot-hill region	South-west region	All sampled households
Farm business	0	404	0	136
Milk and milk products	316	486	416	421
Live poultry/eggs production	56	72	30	55
Livestock/ livestock products	78	131	66	96
Hiring out permanent labour in agriculture	3748	1564	7620	4459
Hiring out casual labour in agriculture	4494	6097	3703	4987
Hiring out labour in non-agricultural activities	1041	1418	241	955
Salaries	156	603	0	312
Pensions	94	197	152	126
Self-employment	107	346	73	190
Other sources	318	816	439	514
Total	10314	11937	12588	12125

Source: Primary field survey

Table 4. Region-wise level of household consumption expenditure (Rs. per annum)

Items of consumption	Central plain region	Shivalik foot-hill region	South-west region	All sampled households
Non-Durables				
Food grains	17329	16458	17084	16949
i. Cereals	15842	15191	15755	15539
ii. Pulses	1487	1267	1329	1410
Condiments and spices	987	770	997	940
Fruits	326	412	210	279
Vegetables	1418	1310	1363	1259
Milk and Milk products	8816	8135	9196	8220
Edible oils	1289	976	1512	1042
Sugarcane products	3016	2663	3519	3071
Meat, fish and eggs	289	175	122	197
Tea leaves	1708	1243	2041	1664
Biscuits/bread and sweets	672	503	515	563
Pickles	228	127	278	211
Intoxicants and Drugs	4065	4289	6171	3842
Fuel and Light	783	727	590	700
Clothing and Bedding	2985	2529	2651	2168
Soaps and Detergents	937	794	874	869
Footwear	1536	1273	1336	1272
LPG	148	66	33	82
Others	123	175	81	126
Sub-total	46655	42625	48572	43454
Durables				
House construction/repairs	1363	1772	1743	1764
Radio/TV/VCR/Tape records/CD	623	266	271	387
Watches/Clocks	80	6	474	187
Electric fans/cooler	349	370	447	388
Sewing machine	104	84	88	92
Furniture	24	30	47	34
Utensils	135	97	122	118
Scooter/Motorcycles	252	333	420	410
Bicycles	351	297	535	405
Others	116	374	297	275
Sub-total	3397	3629	4444	4060
Services				
Education	573	527	379	565
Healthcare	2443	2014	4123	3093
Conveyance	980	1049	1322	1126
Telephone/ mobile	808	736	902	823
Entertainment	111	248	135	165
Others	24	37	175	230
Sub-total	4939	4611	7036	6002
Marriages and other Socio-religious ceremonies	6483	9779	7752	8824
Total	61474	60644	67804	62340

Source: Primary field survey

Table 5. Region-wise pattern of household consumption expenditure (Percentage)

Items of consumption	Central plain region	Shivalik foot-hill region	South-west region	All sampled households
Non-Durables				
Food grains	28.19	27.13	25.19	27.18
i. Cereals	25.77	25.04	23.23	24.92
ii. Pulses	2.42	2.09	1.96	2.26
Condiments and spices	1.60	1.27	1.47	1.51
Fruits	0.54	0.68	0.31	0.45
Vegetables	2.30	2.16	2.01	2.02
Milk and Milk products	14.29	13.41	13.56	13.18
Edible oils	2.09	1.61	2.23	1.67
Sugarcane products	4.89	4.39	5.19	4.92
Meat, fish and eggs	0.48	0.29	0.18	0.32
Tea leaves	2.78	2.05	3.01	2.67
Biscuits/bread and sweets	1.09	0.83	0.76	0.90
Pickles	0.38	0.21	0.41	0.34
Intoxicants and Drugs	6.59	7.07	9.10	6.16
Fuel and Light	1.27	1.20	0.87	1.13
Clothing and Bedding	4.87	4.17	3.91	3.48
Soaps and Detergents	1.58	1.32	1.29	1.39
Footwear	2.49	2.10	1.97	2.05
LPG	0.25	0.11	0.05	0.13
Others	0.21	0.29	0.12	0.20
Sub-total	75.89	70.29	71.64	69.70
Durables				
House construction/repairs	2.21	2.92	2.57	2.83
Radio/TV/VCR/Tape records/CD	1.01	0.44	0.40	0.62
Watches/Clocks	0.13	0.01	0.70	0.30
Electric fans/cooler	0.89	0.61	0.66	0.62
Sewing machine	0.17	0.14	0.13	0.15
Furniture	0.04	0.05	0.07	0.05
Utensils	0.22	0.16	0.18	0.19
Scooter/Motorcycles	0.41	0.55	0.62	0.66
Bicycles	0.57	0.49	0.79	0.65
Others	0.19	0.62	0.44	0.44
Sub-total	5.82	5.98	6.55	6.52
Services				
Education	0.93	0.87	0.56	0.91
Healthcare	3.96	3.32	6.08	4.96
Conveyance	1.59	1.73	1.95	1.80
Telephone/ mobile	1.31	1.21	1.33	1.32
Entertainment	0.18	0.41	0.20	0.26
Others	0.04	0.06	0.26	0.38
Sub-total	8.04	7.61	10.38	9.63
Marriages and other Socio-religious ceremonies	10.55	16.12	11.43	14.15
Total	100.00	100.00	100.00	100.00

Source: Primary field survey

Table 6. Per capita value of household consumption expenditure (Rs. per Annum)

Items of consumption	Central plain region	Shivalik foot-hill region	South-west region	All sampled households
Non-Durables				
Food grains	3516	3798	4052	3951
i. Cereals	3214	3505	3736	3623
ii. Pulses	302	293	316	328
Condiments and spices	200	177	236	219
Fruits	66	95	49	65
Vegetables	287	302	323	293
Milk and Milk products	1788	1877	2181	1916
Edible oils	261	225	358	242
Sugarcane products	612	614	834	715
Meat, fish and eggs	58	40	28	46
Tea leaves	346	287	484	388
Biscuits/bread and sweets	136	116	122	131
Pickles	46	29	65	49
Intoxicants and drugs	824	989	1463	895
Fuel and light	158	168	139	163
Clothing and bedding	605	583	628	505
Soaps and detergents	190	183	207	202
Footwear	311	294	316	296
LPG	30	15	8	19
Others	25	40	19	29
Sub-total	9459	9832	11512	10124
Durables				
House construction/repairs	276	409	413	411
Radio/TV/VCR/Tape records/CD	126	61	64	90
Watches/Clocks	16	1	112	43
Electric fans/cooler	70	85	106	90
Sewing machine	21	19	20	21
Furniture	5	7	11	7
Utensils	27	22	28	27
Scooter/Motorcycles	51	77	99	95
Bicycles	71	68	127	94
Others	22	85	69	63
Sub-total	685	834	1049	941
Services				
Education	116	121	90	131
Healthcare	495	464	978	721
Conveyance	199	242	313	262
Telephone/ mobile	163	169	213	191
Entertainment	22	57	32	38
Others	4	8	41	53
Sub-total	999	1061	1669	1396
Marriages and other Socio-religious ceremonies	1315	2256	1838	2057
Total	12458	13983	16066	14518

Source: Primary field survey

west region spends the highest amount, followed by Shivalik foot-hill region and Central plain region. In South-west region, an average household from agricultural labourer category spends the highest amount on different types of services as compared to other two regions as Central plain and Shivalik foot-hill region. In Shivalik foot-hill region, an average household spends the highest (Rs.9779) on marriages & other socio-religious ceremonies, followed by South-west region (Rs. 7752) and Central plain region (Rs. 6483).

Region-wise pattern of household consumption expenditure: The relative share of household consumption expenditure has recorded the highest share of the total consumption expenditure spends on non-durable items of consumption expenditure (69.70 per cent). In Central plain region, the highest share (75.89 per cent) spends on non-durable items, while the lowest (70.29 per cent) in Shivalik foot-hill region spends on non-durable items of consumption. The analysis has found that the expenditure on marriages & other socio-religious ceremonies appears the second place where the relative share is the highest (16.12 per cent) in Shivalik foot-hill region, followed by South-west region (11.43 per cent) and Central plain region 10.55 per cent of the total consumption expenditure. An average household spends 14.15 per cent on marriages & other socio-religious ceremonies of consumption expenditure (Table 5).

The proportion of consumption expenditure on services is the highest (10.38 per cent) in South-west region, followed by Central plain region (8.04 per cent) and Shivalik foot-hill region (7.61 per cent) while in all sampled regions an average household spends 9.63 per cent on different kinds of services. The highest percentage consumption expenditure appears on healthcare services in three sampled regions under study. As far as consumption expenditure on durable items is concerned, it has recorded 6.52 per cent of the total consumption. In South-west region, an average household spends higher proportion on durable items, followed by Shivalik foot-hill region and Central plain region.

Per capita household consumption expenditure: The analysis has found that an average household from agricultural labourer household category in rural Punjab consumer annually Rs. 14518 per capita on different items of consumption. Further, the study reveals that an average household from South-west region has the highest per capita consumption, while the lowest in Central plain region (Table 6).

CONCLUSIONS

The present study analysed that the main source of income among agricultural labourer households is hiring out causal labour in agriculture. But region-wise analysis reveals that an average household in South-west region earns the highest proportion of total income from hiring out permanent labour in agriculture, while in Shivalik foot-hill region and Central plain region, the higher relative share of total incomes comes from hiring out casual labour in agriculture. An average household spends large proportion of their income on non-durables items of consumption expenditure, followed by marriages & other socio-religious ceremonies, services and durables. The present level of income of agricultural labourer households in rural Punjab is not enough to support their daily consumption requirements. The foregoing analysis shows that there is declining permanent labour and rise in casualization of labour in agricultural activities in rural Punjab. To meet their basis needs, they are forced to borrow from non-institutional agencies and they fell in debt trap and their debt continued to increase day by day. The government should make a strong policy regarding subsidiary occupations and provide financial support at reasonable interest rate. The analysis has found the dairying is one of the main sources of household's income in rural Punjab, but the price of milk is very low. So the Government should come forward with appropriate policy in this regard to increase their level of income. To uplift the poor non-farming households in rural areas, there is a strong need to establish agro-based industries in rural areas. These households can get employment in these industries for a reasonable number of days and at decent wage rate. The proper implementation of MGNREGA would be milestone helpful to overcome the problems of agricultural labourer households.

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Paddy Straw Management in Punjab: An Economic Analysis of Different Techniques

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Abstract: The study has been conducted to undertake economic analysis of paddy straw management in Ludhiana and Mansa districts of the Punjab state during the year 2019-20. A sample of 80 farmers growing paddy and using various methods of paddy straw management viz. in-situ complete burning, partial burning and non-burning using different technologies was taken for the study. Happy seeder revealed to be the most economic approach for handling paddy straw without burning it before sowing of wheat crop. Other techniques of straw management (Straw baling technology, Straw incorporation with M B Plough and Super seeder technology) increased the burden of Rs 2000 to 5100 per hectare on the farmers. The returns from wheat crop grown using happy seeder were almost same as that of wheat grown after burning paddy straw. For wheat crop grown using other paddy straw management methods showed relatively lesser returns due to increase in variable cost. However, rodents attack, higher disease/pest incidence and expensive implements were some constraints faced by the farmers in the adoption of this technique. These issues can be addressed by using appropriate crop production strategies, short duration varieties of paddy and making these machines available to farmers on a custom-hire basis. Compensation to farmers by including the cost of paddy residue management in the MSP, ensuring the availability of residue management machines at subsidised rates, and better custom hiring services could all be the options for addressing the state's paddy straw management problems.

Keywords: Paddy straw, Economic analysis, Punjab, Straw baler, Super seeder

India has gone from a food shortage to a surplus food economy as result of green revolution. Enormous public investment decisions in modern agricultural practice and research were decided to make in the northern peninsular belt of Punjab, Haryana, and Western UP in the 1960s to substantially improve rice, wheat, and other cereal yields. Agriculture focused on high-yielding crops, chemical-based processing and protection technology, and increased food grain productivity and output, increasing farmers' income and substantially contributing to national food security. Punjab and Haryana transitioned from their traditional crops (pulses, pearl millet, maize, and oilseeds) to the rice-wheat cropping rotation in the late 1970s and early 1980s. The shift in cropping patterns was made to ensure that the country had enough food production; therefore there was no concern about resource sustainability. Punjab and Haryana now have a highly active rice-wheat region in the IGP, contributing roughly 69% of the overall food production in the country (about 84% wheat and 54% rice). Despite its significance, there have been concerns about residue production and management of rice and wheat crops. Though paddy straw burning is an issue in many states, Punjab and Haryana have the most serious cases. Since most of the farmers in Punjab were dependent on fresh groundwater for irrigation in the crops. The rice-wheat cropping rotation resulted in the over-exploitation of groundwater supplies in Punjab. However, in 2009, Punjab became the first state in the country to pass a legislation prohibiting the transplantation of rice before the second fortnight of June (Punjab Preservation of Sub-Soil Water Act). The goal was to forestall the water table from declining. Most of the farmers growing long duration varieties faced the delay in the harvesting period of paddy crop by 10 to 15 days. While the regulation achieved its goal, it resulted into a short time window of merely 15 to 20 days for residue management between paddy harvesting and subsequent crop sowing. The high grain yield of paddy has also caused enormous straw production, which appears a severe problem to the farmers as its management practices are expensive and time-consuming. Around 75 to 80% of the area under paddy is machine-harvested, and approximately 95% of paddy straw is burnt annually in the state (Singh et al 2018). A study conducted at the Institute for Social and Economic Change, Bengaluru, by the Agricultural Development and Rural Transformation Centre reported that a vast cloud of smog resulted from residue burning gave rise to health hazards in rural Punjab amounting to the tune of Rs 76 million per year. Straw burning not only endangers human and animal health, but it also depletes essential nutrients like nitrogen, phosphorous, sulphur, and potassium from the top soil layer, making the land less productive and unsuitable for agriculture in the long term (Mandal et al 2004, Lohan et al 2018). Another study (Kumar et al 2019) examined the microbiological dynamics of soil in response to paddy straw burning. They found that after paddy straw burning, the population of significant microorganisms such as bacteria, actinomycetes, fungi, phosphate solubilizing microorganism (PSM), potassium solubilizing microorganism (KSM), and cellulose degraders was significantly reduced. Even after 60 days, the microbial population and enzyme activity involved in biomass recycling did not recover, probably due to a lack of substrates. In the long run, this could have negative consequences for soil health.

Punjab was recognized as most vibrant and progressive state for its success in green revolution. But Punjab farmers have been grappled with second-generation problems like stagnating production and profitability, excessive use of natural resources having adverse environmental effects, casting doubt on long-term viability of agriculture. As a result, the state's current primary issue is to increase crop production and profitability while successfully addressing the problem of agricultural biomass residual or crop residue burning and natural resource exploitation. Furthermore, an energy, water, and labour efficient alternative method is urgently needed to assist maintain soil and environmental quality while producing more at a lower cost (Jat et al 2011, Gathala et al 2011). Aside from the recently introduced early maturing rice varieties (PR121, PR126, and PR127), there are also other technologies available to prevent farmers from burning leftovers. The major technologies for straw management developed by the Punjab Agricultural University, Ludhiana are happy seeder, tractor operated paddy straw chopper-cum-spreader, straw collector and baler etc. These have markedly supported farmers to manage paddy residue on the farm. From the last few years, the National Green Tribunal has strictly forced the Punjab Govt. for the proper implementation of the ban with legal actions for residue burning on the farms. Keeping this in view, there is a need to evaluate the cost of residue management for these machines and the constraints faced by farmers in their use. There is also a dearth of studies on economics of paddy straw management (Singh et al 2008, Sharma et al 2016). After the imposition of ban on stubble burning by the government, it has become very important to find out economically viable alternatives of paddy straw management. As a result, the current study has been carried out to examine the economics of various paddy straw management methods used by farmers prior to seeding the wheat crop in the year 2019-20. The study also emphasised the need of evaluating and comparing the costs and benefits of various resource conservation efforts used in wheat cultivation.

MATERIAL AND METHODS

The districts of Ludhiana and Mansa were selected purposively for the study. Ludhiana district was selected due to advanced technology adoption by farmers for managing paddy straw and location of the Punjab Agricultural University. On the other hand, Mansa district was selected on account of adoption of straw baler by larger number of farmers (Sharma et al 2016). Sample of 40 farmers was selected from each selected district making a total sample of 80 farmers for the study. Primary data pertaining to the agricultural year 2019-20 were obtained on the pre-tested interview schedule by personally visiting the respondents. The straw management techniques used on the farms of selected farmers are as follows:

Zero till drill post loose straw burning: The loose straw produced with combine harvesting was burnt directly and wheat was sown in the remaining standing stubbles using 'Tractor drawn zero till drill'. No preparatory tillage is required in this practice.

Rota seeder/super seeder post loose straw burning: The loose straw produced with combine harvesting was burnt directly and wheat was sown in the remaining standing stubbles using 'Tractor operated rota seeder/super seeder'. No separate preparatory tillage is required in this practice as the seed bed preparation and sowing along with straw management is done in a single operation.

Straw baler: After harvesting of paddy using combine harvester, straw was chopped with straw cutter cum spreader. Then the rotary rake run by tractor is used to collect straw into windrows which is next turned into straw bales by 'Tractor operated straw baler'. The straw bales are then collected from the field manually and transported/stored by the farmers.

Happy seeder: After harvesting of paddy with 'Super SMS fitted Combine harvester' and wheat was sown in the standing stubbles using 'Happy seeder' run by tractor. No preparatory tillage is required in this practice.

Straw incorporation with MB plough: After harvesting of paddy, 'Tractor operated Straw mulcher/Straw cutter cum spreader' is used for chopping of paddy straw and then straw incorporated into the soil with 'Tractor mounted Mould board plough'. After incorporation various tractor drafted implements like disc harrow, cultivator, rotavator, etc. were used for the tillage. The sowing was done with seed-cum-fertilizer drill.

Super seeder: After harvesting of paddy with 'Super SMS fitted Combine harvester' and wheat was sown in the standing stubbles using 'Super seeder' run by tractor. No separate preparatory tillage is required in this practice as the seed-bed preparation and sowing along with straw management is done in a single operation.

Burning (Control): After being cut using a straw cutter-cum-spreader, the paddy straw was burnt completely, as is a common practice. The field was then sown directly with zero till drill technique or prepared by ploughing with a tractor-mounted disc harrow, cultivator, and other implements, and wheat was sown with a seed-cum-fertilizer drill.

The data so collected were analysed using simple statistical tools such as percentages, averages, frequency etc. However, in order to know the statistical significance of various inputs used under different paddy straw management techniques as compared to burning of paddy straw, student's t-test was employed as sophisticated statistical approach. The independent t-test, also known as the two-sample t-test, independent-samples t-test, or student's t-test, is an inferential statistical test that evaluates if two unrelated groups' means significantly differ statistically. The pooled variance S^2 is an unbiased estimate of common variance of the two populations. For calculating pooled variance, following formula is used:

$$S^2 = \frac{(n_1 - 1)s_1^2 + (n_2 - 1)s_2^2}{n_1 + n_2 - 2}$$

Where,

$$s_1^2 = \frac{1}{n_1 - 1}(\Sigma x_i^2 - n_i^2 - n_1 \bar{x}^2) and$$

$$s_2^2 = \frac{1}{n_2 - 1}(\Sigma y_i^2 - n_i^2 - n_1 \bar{y}^2)$$

$$\bar{x} = \frac{1}{n_1} \sum_{i=1}^{n_1} xi \; and \; \bar{y} = \frac{1}{n_2} \sum_{j=1}^{n_1} yi$$

The null hypothesis (H_o) and alternative hypothesis (H_1) for the independent t-test can be stated as:

H_0: $_1 = {}_2$ or $_1 - {}_2 = 0$

$H_{1:1} \neq {}_2$ or $_1 - {}_2 \neq 0$ (two tailed)

$$t = \frac{(\bar{x} - \bar{y})}{\sqrt{S^2\left(\frac{1}{n_1} + \frac{1}{n_2}\right)}} \sim t_\alpha = (n_1 + n_2 - 2)$$

If $|t| \geq t_\alpha (n_1 + n_2 - 2)$ H_0 is rejected, otherwise If $|t| \geq t_\alpha (n_1 + n_2 - 2)$, fail to reject H_0 at a level of significance.

RESULTS AND DISCUSSION

Wheat cultivation using paddy straw management practices: The input use pattern in wheat cultivation revealed that seed rate was 5 to 10% higher among no-tillage and minimum tillage techniques under straw management techniques for seed sowing as compared to the traditional method of straw burning (Table 1). The seed rate was maximum (121.22 kg/ha) where crop was sown using rota seeder/super seeder followed by zero till drill, super seeder and happy seeder. Straw baler and straw incorporation with MB plough used lesser seed rate. In comparison, the seed rate used on farms using the traditional approach of straw burning was 109.05 kg/ha. Farmers' perceptions were the main reason for uneven seed rate use, as they believed that paddy straw management techniques caused germination issues, necessitating the use of higher seed rates to compensate for the poor germination problem. Use of urea was higher in straw incorporation with MB plough (366.88 kg/ha) and straw baler (364.54 kg/ha), while no-tillage techniques i.e., happy seeder (321.33 kg/ha) and zero till drill (336.03 kg/ha) used comparatively lesser quantity of urea as compared to other techniques and minimum tillage techniques i.e., rota seeder/super seeder and super seeder showed saving in urea consumption. Application of DAP was directly related to the seed rate where no-tillage and minimum tillage resulted into higher application of DAP.

The comparison of different straw management techniques used on the sampled farms with the control, almost each method showed saving in irrigation. The irrigation hours used in happy seeder were 12% lower. This not only saves water but also energy and reduces ecological impact. Tillage is a time-consuming and expensive process (Bhatia and Dhaliwal, 2001). In machine usage, no-tillage techniques i.e., zero till drill (9.81 hrs/ha) and happy seeder (12.97 hrs/ha) showed 35 and 14% saving as compared to the control. Minimum tillage techniques i.e., rota seeder/super seeder and super seeder also showed 20 and 14% saving in machine usage. Thus, straw management with no-tillage and minimum tillage results in time saving. The use of such non-burning techniques to manage straw can have a significantly larger impact on reducing carbon emissions. The one tonne of straw is burnt, 3 kg of particulate matter (PM), 1.46 tonnes of CO_2, 60 kg of CO, 2 kg of SO_2, and 0.199 tonnes of ash are released (Gupta et al 2004). Assuming an average straw yield of 9 t/ha, these non-burning methods can diminish 27 kg of particulate matter, 540 kg of Co, 13.14 tonnes of CO_2, 1.79 tonnes of ash, and 18 kg of SO_2 per ha.

Wheat yield under various paddy straw management techniques: There was not much difference in wheat yield under various straw management techniques as compared to control. However, super seeder and straw incorporation with MB plough showed 1 to 1.5% higher yield. The other techniques showed almost same yield around the control. The analysis of variable cost structure, indicate the cost of machine utilisation accounted for about 40 to 50% of the total variable cost (Table 2). Tractors and equipment were used for paddy straw management, wheat crop sowing, and crop harvesting with a combine harvester; tractors were also utilized for wheat crop transportation and marketing, and then for wheat straw management. The cost of equipment usage was calculated using custom hiring rates for all of these farm operations in the study area. In absolute terms, under non-burning techniques, the highest incurred cost for the use of machinery in wheat sowing was on farms, where whole paddy straw was incorporated into the soil (Rs 17050/ha) followed by straw baler (Rs 15418/ha) and superseeder (Rs 13987/ha). The lesser expense for non-burning techniques was in Happyseeder technology (Rs 11028/ha). In post loose straw burning techniques, the cost of machine labour use was Rs 9029 and Rs 10647 per ha in the case of zero till drill and rota seeder/super seeder. Therefore, compared to conventional straw burning methods, the operation of paddy straw was associated with an increase in machine costs to the tune of Rs 5067 per ha (42.28%) for straw incorporation with MB plough, Rs 3435 per ha (28.66%) for the straw removal with straw baler and Rs 2004 per ha (16.72%) for straw incorporation with super seeder. But the implementation of Zero till drill, Rota seeder/super seeder and Happy Seeder technology has, in comparison with conventional practises of straw burning, reduced the machinery costs by 24.65, 11.15 and 7.97%, respectively. Even though post loose straw burning techniques saved the cost of machine labour by 11 to 25% but due to ban on straw burning these techniques cannot be used for management of straw. In comparison to the control, the implementation of happy seeder, a legal non-burning method, has helped to reduce the cost of machinery by 7.97%. Although only marginally, this helps to reduce emissions from fuel combustion, in addition to cost savings. The gross returns did not significantly differ among different straw management practices, with the highest (Rs 115013/ha) on farms using the straw incorporation with MB plough followed by superseeder and the lowest on farms using the happy seeder. The rest of the technologies did not show any variability in the gross returns. Returns over variable cost (ROVC) were the highest in post loose straw burning techniques adopted on farms which was Rs 88003 and Rs 86716 per ha in case of zero till drill and rota seeder/super seeder. Among the non-burning techniques, happy seeder showed almost same returns over variable cost. But the rest of the techniques i.e., straw baler, straw incorporation with MB plough and super seeder showed 6.16, 3.76 and 1.57% lesser returns over variable cost as compared to the control., the cost components of different technologies fluctuate, notably in terms of variable

Table 1. Input use pattern and yield of wheat crop using different paddy straw management techniques in Punjab (2019-20)

(Per ha)

Particulars	Different paddy straw management techniques						Burning (Control)
	Loose straw burning techniques		Non-burning techniques				
	ZTD	RS/SST	SBT	HST	SI (MBP)	SST	
Seeds (Kg)	119.18* (3702.01)	121.22** (3822.91)	105.61** (3084.45)	115.25** (3584.91)	103.30** (3060.00)	116.30* (3766.32)	109.05 (3211.17)
Urea (Kg)	336.03* (1989.20)	352.57 (2087.42)	364.54** (2157.70)	321.33* (1902.44)	366.88** (2171.67)	352.08 (2084.40)	357.04 (2113.69)
DAP (Kg)	137.80* (3307.08)	134.23 (3221.84)	130.61 (3134.66)	135.70 (3256.98)	130.13 (3123.12)	134.96 (3239.06)	132.51 (3180.14)
Other fertilizers (Rs)	- (205.06)	- (335.53)	- (232.82)	- (185.84)	- (108.18)	- (134.39)	- (133.04)
Irrigation (Hrs)	26.11 (286.02)	27.19 (172.45)	27.10 (244.26)	24.59 (213.82)	26.35 (162.05)	26.32 (328.23)	27.57 (204.07)
Plant protection	- (2983.09)	- (3047.05)	- (3073.30)	- (3271.74)	- (3162.14)	- (3244.82)	- (2899.61)
Human Labour (Hrs)	63.07* (2838.12)	67.63 (3087.96)	104.85* (4872.20)	60.36* (2817.47)	69.48 (3277.31)	65.34* (3022.13)	69.42 (3246.23)
Machine Labour (Hrs)	9.81* (9029.23)	12.11* (10646.54)	21.77* (15418.06)	12.97* (11028.31)	16.16 (17050.02)	13.08* (13986.94)	15.15 (11983.19)
Yield (Kg)	5227 (100619.75)	5258 (101216.50)	5233 (100735.25)	5199 (100080.75)	5290 (101832.50)	5290 (101832.50)	5220 (100485.00)

Figures in the parenthesis represents the value in rupees

ZTD- Zero Till Drill, RS/SST- Roto Seeder/Super Seeder Technology, SBT- Straw Baling Technology, HST- Happy Seeder Technology, SI (MBP)- Straw Incorporation (Mould Board Plough), SST- Super Seeder Technology

Independent sample t-test (* and ** denote the difference between various inputs used in different straw management techniques and control significant at 1% and 5% level of significance) cost on paddy straw removal and incorporation, resulting in varied returns over variable cost in wheat cultivation under different straw management techniques.

Problems faced in paddy straw management: The constraints faced by farmers in the adoption of various paddy straw management techniques have been classified into three categories namely management constraints, post-management constraints and economic constraints (Table 3). In the case of management constraints, farmers adopting different technologies for straw management instead of burning it in the field (non-burning method) were facing more problems as compared to farmers adopting partial burning method of paddy straw management. Shortage of skilled labour was the major problem faced by all the farmers adopting MB plough for straw management. The corresponding figures for farmers adopting happy seeder technology, super seeder technology and straw baling technology were 77.78, 75 and 40%, respectively. Delayed sowing of proceeding crop was reported by 62.5 and 15% of the farmers adopting MB plough and straw baling technology, respectively. Moreover, shortage of hired machinery was another problem faced by 50 and 35% of the farmers adopting straw baling and super seeder technology, respectively. In case of partial burning, 100% farmers who adopted rota seeder /super seeder technology after burning of paddy loose straw felt the need of skilled labour for proper sowing of proceeding crop and management of standing stubbles. The 37.5% of the respondents who adopted zero tillage technology also reported the same problem. Further, 50% of the farmers adopting rota seeder /super seeder technology reported the shortage of hired machinery for the adoption.

In post-management constraints, 75% of the farmers adopting zero tillage technology after partial burning reported the difficulty in intercultural operation as a major problem in the adoption. The problem of difficulty in sowing of

Table 2. Cost-return structure of wheat cultivation under different methods of paddy straw management in Punjab (2019-20)

(Rs /ha)

Particulars	Different paddy straw management techniques						Burning (Control)
	Post loose straw burning techniques		Non-burning techniques				
	ZTD	RS/SST	SBT	HST	SI (MBP)	SST	
Cost of human Labour	2838 (11.40)	3088 (11.43)	4872 (14.79)	2817 (10.49)	3277 (9.98)	3022 (9.92)	3246 (11.77)
Cost of machine Labour	9029 (36.28)	10647 (39.41)	15418 (46.80)	11028 (41.07)	17050 (51.92)	13987 (45.89)	11983 (43.45)
Cost of seeds	3702 (14.88)	3823 (14.15)	3084 (9.36)	3585 (13.35)	3060 (9.32)	3766 (12.36)	3211 (11.64)
Cost of fertilizers	5501 (22.10)	5645 (20.90)	5526 (16.77)	5345 (19.91)	5403 (16.45)	5457 (17.91)	5427 (19.68)
Cost of plant protection	2983 (11.99)	3047 (11.28)	3073 (9.33)	3272 (12.19)	3162 (9.63)	3245 (10.65)	2900 (10.52)
Cost of irrigation	286 (1.15)	172 (0.64)	244 (0.74)	214 (0.80)	162 (0.49)	328 (1.08)	204 (0.74)
Interest @ 9 pa for half season of wheat crop	548 (2.20)	594 (2.20)	725 (2.20)	591 (2.20)	723 (2.20)	671 (2.20)	607 (2.20)
Total variable cost	24887 (100.00)	27016 (100.00)	32942 (100.00)	26852 (100.00)	32837 (100.00)	30477 (100.00)	27578 (100.00)
Value of main product	100620	101217	100735	100081	101833	101833	100485
Value of By-product	12270	12515	12333	12301	13181	12690	12477
Gross return	112890	113732	113068	112382	115013	114522	112962
ROVC	88003	86716	80126	85530	82176	84045	85384
Percentage difference of ROVC in comparison to Control	3.07	1.56	-6.16	0.17	-3.76	-1.57	-
I-O Ratio	4.54	4.21	3.43	4.19	3.5	3.76	4.1
Percentage difference of I-O Ratio in comparison to Control	10.74	2.78	-16.21	2.17	-14.49	-8.26	-

proceeding crop and rodent attack was informed by 50% of the farmers adopting this method. Around 25% farmers pointed out the risk of higher disease or pest incidence in this method. In the case of non-burning method, 77.78% of the farmers adopting happy seeder technology were facing rodent attack as the major problem. Higher disease or pest incidence and difficulty in sowing of proceeding crop was also faced by 44.44% of the farmers adopting this method. 37.5% of the farmers adopting MB plough pointed to the above-mentioned problem. Higher weed infestation was faced by 41.67% farmers adopting super seeder technology for paddy straw management. In economic constraints, majority of the farmers adopting partial burning method with zero till drill (87.5%) and rota seeder/super seeder technology (100%) complained about high cost of implements used for paddy straw management. All the farmers who adopted rotaseeder/superseeder and 75% of the farmers adopting zero till drill technology were worried about no market value of paddy straw. Further, 50% farmers who adopted rota seeder/super seeder technology were worried for high hiring charges of machinery. All the farmers adopting non-burning method observed that expensive implements were the major constraint for adoption of paddy straw management techniques. In addition to that 75 and 62.5% farmers adopting straw baler and MB plough for straw management were concerned about extra cost involved in paddy straw management. Around 66.67 and 45% farmers adopting super seeder and straw baler technology were facing problem of high hiring charges of machinery. Some farmers also reported no market value of paddy straw and delay in subsidy process as constraints in adoption of non-burning technologies of paddy straw management.

In order to resolve the constraints of paddy straw management, possible steps need to be undertaken. Farmers should use short duration varieties of paddy crop to widen the time window between harvesting of paddy crop and sowing of wheat crop. Selection of the straw management implements should be according to the availability of time. Government may focus on providing more field trainings, method demonstrations and extension contacts for the farmers to tackle the problem of lack of skilled labour and teach them about economic potential of paddy straw. Farmers' organizations at the village, district and state levels may also be developed and strengthened in order to promote location-specific paddy straw management. There is a need to promote custom-hiring services by co-operative societies, co-farmers, and other private organizations, so that small and marginal farmers can implement it quickly and economically. Compensating the farmers for not burning the rice residual in fields would result into additional income to farmers and at the same time reduces local pollution effects from straw burning.

Table 3. Various constraints reported by sampled farmers in the adoption of various paddy straw management techniques (%)

Particulars	Post loose straw burning		Non-burning techniques			
	ZTD	RS/SST	SBT	HST	SI (MBP)	SST
Management constraints						
It delays sowing of proceeding crop	0.00	0.00	15.00	0.00	62.50	0.00
Shortage of skilled labour	37.50	100.00	40.00	77.78	100.00	75.00
Shortage of hired machinery	0.00	50.00	35.00	0.00	0.00	50.00
Post-management constraints						
Difficulty in sowing	50.00	0.00	0.00	44.44	37.50	25.00
Difficulty in intercultural operation	75.00	0.00	0.00	22.22	0.00	0.00
Poor seed germination	0.00	0.00	0.00	33.33	0.00	8.33
Higher weed infestation	0.00	0.00	0.00	33.33	0.00	41.67
Rodent attack	50.00	0.00	0.00	77.78	12.50	16.67
Decreased yield of the proceeding crop	0.00	0.00	0.00	22.22	37.50	0.00
Higher disease/ pest incidence	25.00	0.00	0.00	44.44	0.00	0.00
Economic constraints						
Extra cost involved in paddy straw management	0.00	0.00	75.00	0.00	62.50	33.33
High hiring charges of machinery	0.00	50.00	45.00	0.00	0.00	66.67
No market value for paddy straw	75.00	100.00	50.00	33.33	62.50	75.00
Delay in the subsidy process	25.00	0.00	0.00	0.00	12.50	25.00
Implements are expensive	87.50	100.00	100.00	100.00	100.00	100.00

CONCLUSIONS

Straw baler, super seeder and straw incorporation with MB plough before wheat sowing, impose an economic strain on farmers to the range of Rs 2000 to Rs 5100 per ha. Straw incorporation with MB plough also delayed the wheat sowing since the soil took more time to reach the proper seed bed for sowing. Although Happy seeder is quite economical, but wheat crop sown using this method faced attack of pink stem borer and rodents. Some regulatory measures exist, such as impediments for paddy straw burning, and availability of subsidies on straw management implements but also paying farmers for ecosystem services is the need of the hour. Compensation for farmers by including the cost of paddy residue management in the MSP, ensuring the availability of residue management machines at subsidised rates, better custom hiring services and promoting the use of paddy straw in paper mills, energy generation plants, and other industries could all be options for addressing the state's paddy straw management problem.

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Effect of Deltamethrin on the Testicular Tissue of Albino Rats

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***Abstract*:** This experiment aimed to investigate effect of changes of deltamerthrin on the testicular tissues of adult males' rat. Twenty-four adult male rats after their acclimatization for three weeks divided randomly and equally into three groups (n=8 rats): The LD50 of deltamerthrin was 150 mg kg^{-1}. The experimental rats were inoculated orally with deltamerthrin 1/10 and 1/20 LD50 daily for 60 days. At the end of experiment animals were sacrificed post euthenization. For post mortem examination the testes were preserved in 10% formalin then processed with graduated concentrations of ethyl alcohol for impregnation in liquid paraffin then sectioned about 4-6 µm stained with hematoxylin and eosin staining for microscopic examination. Deltamethrin with have significant Histopathological effects on male'stestes of rats. Hyper chromatic germ cells with rounded cells inside the lumen of seminiferous tubules with apoptotic cells, decreased mature sperms inside the lumen (hypospermatogensis), severe necrosis, damage of spermatogonial layers, atrophy and shrinkage of seminiferous tubules, reflected marked reduction of spermatozoa and decreased Leydig cells.

Keywords: Deltamethrin, Histopathology, Tests of rats

Deltamethrin is among the most popular and widely used insecticides in the world but is toxic to aquatic life, particularly fish, and therefore must be used with extreme caution around water. Although generally considered safe to use against humans but still show neurotoxicity to humans. Deltamethrin is able to pass from a woman's skin through blood and into her breast milk (Bouwman et al 2006). It is an allergen and causes asthma in some people (Erdogan et al 2006). Deltamethrin prevent the spread of diseases carried by tick-infested prairie dogs, rodents and other burrowing animals. It is helpful in eliminating and preventing a wide variety of household pests, especially spiders, fleas, ticks, carpenter ants, carpenter bees, cockroaches and bed bugs. In rat deltamerthrin was poorly absorbed through the skinand left the body within 24 hours (Bradberry et al 2006). The objective of study is to evaluate the Histopathological changes occurred in testes post oral administration of deltamerthrin in rat.

MATERIAL AND METHODS

Twenty-four male albino rats aged about three months and body weight ranged between 150-200gm were raised and bred in the animal house of College of Veterinary Medicine, University of Baghdad. The animals were kept in cages of (20*30*50) cm^3 dimensions withaverage of three rats in each cage one month before study for acclimatization in optimum conditions of breeding at 22±3 ºC with a 14/10hours light/dark cycle .Commercial feed pellets and drinking water were given all the time of experiment (O'Malley 1997). LD50 was calculated as 150 mg kg^{-1}. The treatment included 1/10 LD50 and 1/20 LD50 dose of deltamerthrin was administered orally daily to three groups of rats along with control. The experimental animals were sacrificed after 60 days for pathology study including the gross and histopathology examination of the testis. The piece of testis were dissected free of connective tissues, then submitted to preservation in formalin 10%. Histopathological processing and staining with hematoxyline and eosin stain were performed according to Peterson et al (2011).

RESULTSAND DISCUSSION

Clinical observations: Most of significant clinical signs were obvious on rats treated 1/10 LD50 rats were neurobehavioral signs, emaciation and weakness which reflect the direct effect of toxin and damage the defense barriers of internal organs, like cross toxin blood-brain barriers and injured the endothelium lined blood vessels of meninges to cause severe neurodegenerative changes mainly 60days from experiment

Histopathological changes of the testes: The microscopic changes of the testes treated with deltamerthrin were summarized as degeneration and depletion of elongating spermatid, hyper chromatic germinal layer of spermatogonia, abnormal space between neighboring sertoli cells, also there was complete loss of spermatocytes lining-epithelium that sloughed into the lumen with rounded cells inside the lumen of seminiferous tubules left only base spermatic cells in the lumen of seminiferous tubule, thickening of the testicular capsule due to congestion of blood vessels sinuses and edema in the interstitial between tubules. Hyper chromic germ cells and some apoptotic figures showed with rounded cells inside the lumen of seminiferous tubule (Fig. 1). The Figure 2 showed hyper chromic germ cells with different degree of necrosis of spermatocytes accumulation of rounded cells in the lumen, the different degree of necrosis and some with severe destruction of germ cells and no spermatocytes found inside the lumen of the seminiferous tubules (Fig. 3). The different degrees of necrosis of germ cells and accumulation of the rounded cells inside the lumen of the seminiferous tubules with thickening of the testis wall due to congested blood vessels (Fig. 5). Finally increase in the rounded cells in the section (necrosis) with hypo spermatogenesis and leading cells decreased (Fig. 5). The study indicate that deltamerthrin caused damage of the defense barriers of

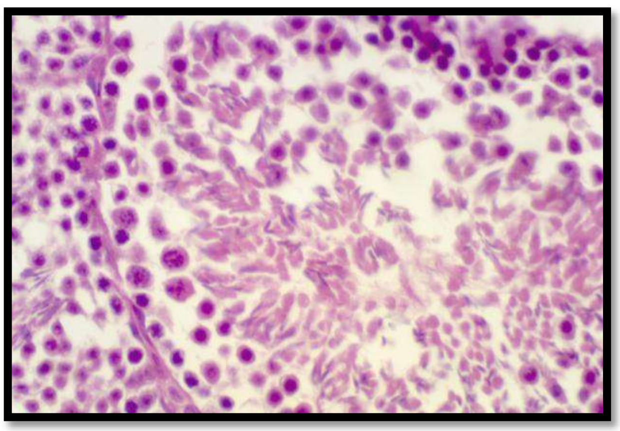

Fig. 1. Histopathological section of the testes shows; hyper chromic germ cells and some apoptotic figures showed with rounded cells inside the lumen of seminiferous tubules, (H&E stain, 400X)

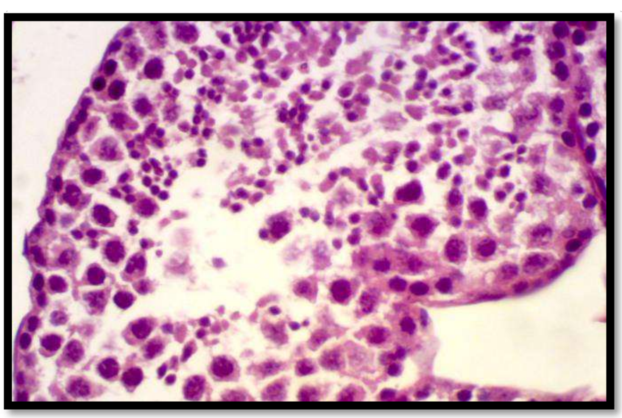

Fig. 2. Histopathological section of the testis shows; hyper chromic germ cells with different degree of necrosis of spermatocytes (accumulation of rounded cells in the lumen) (H&E stain, 400X).

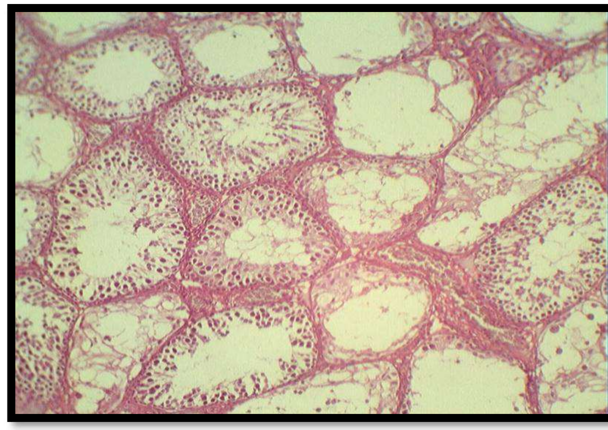

Fig. 3. Histopathological section of the testes shows: different degree of necrosis and some with severe destruction of germ cells and no spermatocytes found inside the lumen of the seminiferous tubules (H&E stain, 400X)

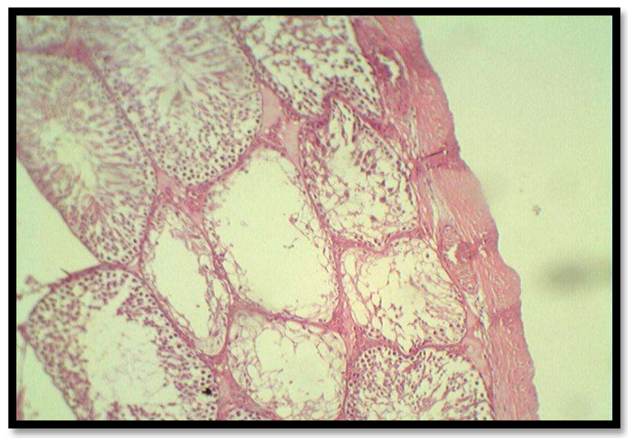

Fig. 4. Histopathological section of the testes shows: different degree of necrosis of germ cells and accumulation of the rounded cells inside the lumen of the seminiferous tubules with thickening of the testis wall due to congested blood vessels (H&E stain, 100X)

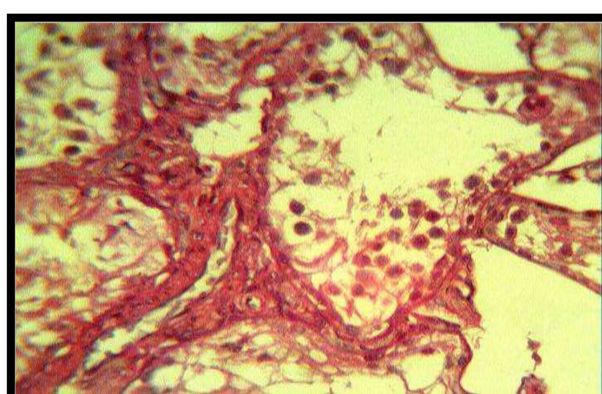

Fig. 5. Histopathological section of the testes showed: increase the rounded cells in the section (necrosis) with hypo-spermatogenesis, leydig cells decreased (H&E stain, 400X)

internal organs, like cross toxin blood-brain barriers and injured the endothelium lined blood vessels of meninges to caused severe neurodegenerative changes mainly at 4 and 6 weeks and also lead to congestion of the internal organs and also linked to the production of reactive oxygen species (ROS)resulting in oxidative stress in animals which could cause a damage to the mitochondria of the cells and then lead to death.

CONCLUSIONS

The oral administration of deltamerthrin15 mg kg^{-1} demonstrated the destruction of the spermatocytes with mild degeneration of seminiferous tubules and mild decrease of leydig cells with appearance of the rounded cells inside the lumen of it with decrease the mature sperms.

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