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Degradation of Western Algerian Steppes Lands: Monitoring and Assessment

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Abstract: The Algerian steppes are currently experiencing erosion of natural resources; the situation continues to grow and leads to an imbalance of local ecosystems. In this investigation, floristic surveys coupled with soil tests were carried out. The phytoecological study revealed a very strong degradation of the floristic richness and the phytomass with a predominance of the loamy-sand texture and a disturbance of the parameters studied from one site to another. The monitoring of ecological changes 60 years later shows a decrease in the number of species and families of 79 and 41% respectively with a disappearance of some facies that are replaced by other indicators of degradation with less forage value. This regressive dynamic is explained by two essential factors: land use changes and climatic aridity.

Keywords: Steppe, Degradation, Monitoring, Ecological changes

In Algeria, steppes have always been the development space for sheep farming. They play both an economic role linked to pastoral activity and an ecological role as a buffer zone between the Tell and the Sahara. Pastoralism was considered the most suitable system for steppe lands, which for a long time ensured the ecological balance in these environments. This balance has for a long time been assured by a very rigid harmony between human mobility and the environment in which he lives (Nedjimi et al 2012). However, this equilibrium is broken; due to the decrease in the area of rangelands and the fall in their yields as a result of the continuous increase in livestock numbers on the one hand and the extension of clearings at the expense of the best rangelands on the other hand, thus reducing the forage resources of the livestock (Nedjraoui 2004). The situation in these pastoral areas is worrying; the work of Bouazza et al (2004) on the watershed of El-Aouedj (south-west of Oran) show that the steppe plant formations are currently entering a phase of degradation that takes a worrying strong pace. The steppes at *Stipa tenacissima* were the most affected by these changes, they occupied 6.61 per cent of the territory in 1973 to decrease to 2.24 per cent in 1990 and in 2003 they disappeared completely from the zone. The strongest regression is recorded in the southern Oran, where in less than 10 years almost all alfa-nappes have disappeared (Aidoud et al 2006).

Various factors are mentioned by the authors to explain the causes of these transformations that have occurred in recent decades. The profound changes in the management policies adopted as well as the uses and farming practices have certainly modified the levels of anthropozoic impacts on vegetation and environment (Fikri Benbrahim et al 2004, Aidoud et al 2006, Benabadji et al 2009). However, Benabadji et al (2009) find that the last five decades have been marked by a decrease in the amount of rainfall leading to a recurring drought. Hirche et al (2007) suggest a two-month extension of the dry season while estimating a decrease in rainfall amount of 18 to 27 per cent per year on average. The combined action of man and climate creates a vulnerability of these ecosystems; the phytogenetic and edaphic resources are disrupted (Nedjraoui 2011). Any workers documented that changes that have occurred on the steppe of western Algeria (Slimani et al 2010, Bencherif 2011, Hasnaoui et al 2014, Hasnaoui and Bouazza 2015, Morsli et al 2016). These authors confirm the regressive dynamics of steppe plant formations. The aim of the present paper attempts to outline the current state of this steppe rangelands by a phytoecological study followed by a comparative diachronic analysis, to evaluate the natural resources available, to assess and monitor the degradation intensity of the study

area on the one hand, and discuss the probable causes of the changes that have occurred in the other hand. This analysis could thus highlight the dynamics of this ecosystem.

MATERIAL AND METHODS

Study area: Province of Saïda is located in the western part of the high plateaus (North -West) of Algeria. It decomposes respectively from the North to the South in three major areas: an agricultural area, an agro_pastoral area and a steppe area. The study area is located in South-eastern part of department combining two steppe municipalities: Maamora and Aïn Skhouna (from 34˚ 30′ to 34˚ 40′ North latitude and from 0˚ 30′ to 0˚ 50′ East longitude, with an elevation ranging from 995 to 1147m above sea level). The area is characterized by an annual rainfall relatively low; it is 286 mm year^{-1}. The rainfall pattern is AWSS (autumn, winter, spring, summer), favourable to vegetative activity despite the length of the drought period which extends from May to November, and the cold that extends from December to April. During the dry season, rainfall amounts do not exceed 90mm. Monthly average temperatures in winter reach 1 ˚ C (m) and 36 ˚ C (M) in summer. The evapotranspiration ETP is quite important in the period extending from May to September. The value of ETP recorded in July equals 173.3 mm and that of August is 163.4 mm (Moulay 2013). The rainfall quotient of Emberger (Q2) is 28. This allows us to classify the study area in the semi-arid bioclimatic stages with fresh winter. The soils are characterized by the presence of accumulation Limestone, the low organic matter content and high susceptibility to erosion and degradation D jbaili (1984).

Sampling: Out 90 phyto-ecological surveys with 10 repetitions for each station, executed during the optimum period of vegetation development, from mid-April to mid-June of 2012, 2013 and 2014; to obtain the maximum number of species (especially annuals), according to the Braun-Blanquet method (1951). The number of stations was quantified according to the variation in vegetation cover on a transect line: North-South, which is based on the use of the Emberger climate index (1955), which revealed large variations in the North-South direction. The execution of the surveys is accompanied by the recording of the stationary characters (Location, altitude, exposure, slope and recovery rate). The surveys are collected every 200 m depending on the variability of the vegetation and ecological conditions such as topography and exposure.

The surface of these surveys must be sufficient to understand the maximum of plant species (Guinochet 1973). The delimitation of the plots (sampling and measurement site) for each survey which characterizes a homoecological area is of 100 m² (Djebaili 1978) delimited with a rope. The determination of the taxa for the vegetation was made using the work of Quézel and Santa (1963) and that of Ozenda (1977). The biological types were attributed from the work of Raunkier (1905).

Choice of stations: The choice of stations was guided by our objective; the stations should best reflect the current state of the study area. To achieve our objectives we carried out various field trips which enabled us to characterize an ecological zoning and; identified three plants structures (facies): facies to Alfa (*Stipa tenacissima* L.), facies to white Wormwood (*Artemisia herba alba* Asso.) and facies to Sparte (*Lygeum spartum* L.). According to the state of vegetation cover, the facies have been selected to three types: good state (exclosure), moderately degraded and degraded.

Characterization of vegetation

Specific contribution calculation: To compare the floristic variation in point of view quantitative of the stations, the sum served to the calculations of the specific contribution of each species (Csi) which is defined as the report as a percentage of its specific frequency (Fsi) to the sum of the frequencies of all the listed species: $Csi = (Fsi/\Sigma Fsi) \times 100$ or $Fsi = (Ni/N) \times 100$ (Ni: The number of times where the species i is encountered; N: The total number of reading points, it is 100 in our case)

Aboveground biomass: The aboveground biomass measurements were made during the optimum period of vegetation development and determined by clipping the perennial and annual species which occupies 1m ^{x} 1m quadrats for each plots. The determination of the dry matter (DM) is done to the oven at 105˚C until to the constant weight (during 48h). The aboveground biomass production is expressed in kg of DM/ha.

Soil sampling and analysis: For the knowledge of the study area soil, conducted soil profiles (90 soil samples) at the level of the superficial horizon where the roots exist. The soil analysis has been devoted to the following parameters: the texture, according to the method of GRAS (1988) and the chemical analyzes are carried out using the methods described in AUBERT (1978), pH in distilled water, electrical conductivity (Ec), total limestone ($CaCO_3$), organic matter (OM) and the depth of the profile up to the calcareous crust.

Analysis of changes in steppic facies, diachronic study: For the monitoring of vegetation dynamics over the last sixty years, the comparative diachronic method was used. This method takes the oldest state as the starting point for the observation. The objective is to compare the situation of a site in an initial state and to assess the changes that occurred between the two observations. This diachronic study is based on the work of Dubuit and Simmoneau (1954). A phytoecological study was conducted on the same sampling

sites of the initial state (Fig.1). For that first by a calibration of the map of Dubuit and Simmoneau according to the projection Lembert (North Algerian) was done and then have georeference the surveys of the old map.

Statistical analysis: In order to confirm the results observed in the field. The specific contributions of species inter–facies was compered. The significance of changes between facies was tested using the nonparametric Friedman. To describe the both patternplant biomass and soil characteristics of each facies, the mean (± standard deviation) was calculated for each above-ground biomass and soil parameter based, on all observations. Analyzes were carried out using the XLSTAT software (version 2014 by Addinsoft). Significant differences for the statistical tests were evaluated at $p \leq 0.05$.

RESULTS AND DISCUSSION

Characterization of Vegetation

Analysis of the floristic composition: In the set of surveys studied, a floristic list of 33 perennial and annual species, belonging to 28 genera and 12 botanical families was identified. The 21, 18 and 12 percent belong to the families of the Asteraceae, Poaceae and Caryophylaceae with respectively. This order of magnitude is also obtained by several authors who have worked in this region (Hasnaoui et al 2015, Saidi et al 2017). The Amaranthaceae are present, particularly in the Ain Skhouna region with (12%); this is justified by location of this region near the Chott Echergui.

These plants are Therophytes with 54% and Chamaephytique with 21%. These results are in agreement with those obtained by Ghezlaoui et al (2011). These authors show that the Therophytes and the Chamaephytes are well adapted to steppe regions. Similarly Kadi-Hanifi et al (1998) have marked that the predominance of Therophytes is linked to the accentuation of the aridity outside the increase of Chamaephytes is linked to the anthropization of the environment. In addition, Quézel (2000) present the Therophyzation as a form of resistance to drought, as well as to the high temperatures of the arid environments and an ultimate stage of degradation. The geophytes are the less dominant, they are represented by three species which are: *Stipa tenacissima* L., *Stipa parviflora* Desf. and *Muscari comosum* (L.) Miller. Kadi-Hanifi et al (2003) have pointed out that the rate of Geophytes decreases with the anthropization. The arborescence stratum is represented by a single species *Atriplex halimus* L. (Nanophanerophyte). Kadi Hanifi et al (2003) confirms that the phanerophytes are always relegated to the last rank of the biological types in the steppe regions.

Specific Contribution Analysis

Facies to *Stipa tenacissima* L.: The number of species decreased from 17 in good state to 13 in moderately degraded, to only 8 in degraded facies (Fig. 2). More the palatable species regress more the number of species indicating degradation and overgrazing appear as *Noaea mucronata* (Forssk.) and *Peganum harmala* L. phenomenon confirmed by Nedjraoui (2004).

The statistical analysis shows that the difference is highly significant between facies in good state and the degraded. On the other hand, it is not significant between the good state and moderately degraded facies. However, the p-value between the facies in good state and the moderately

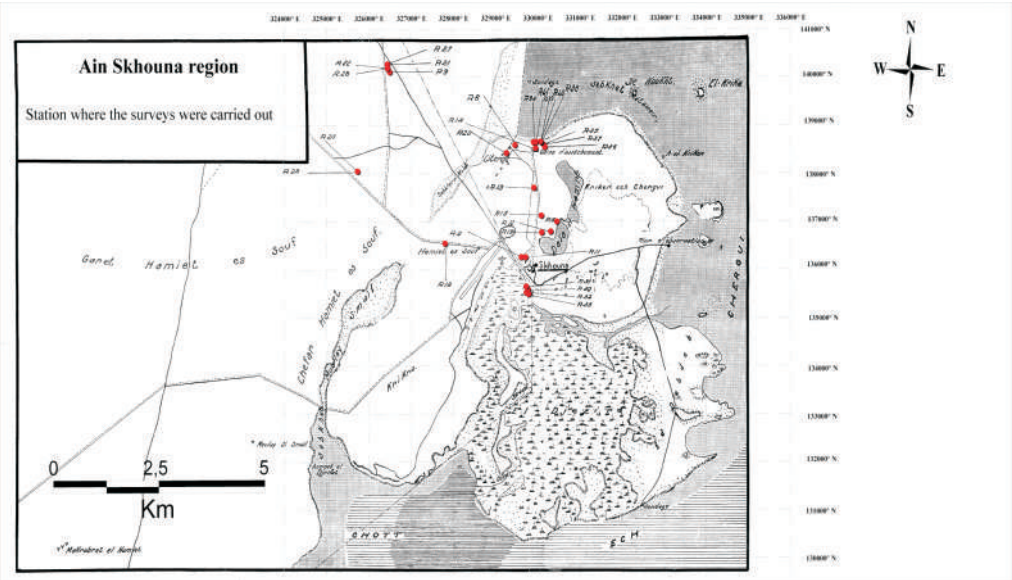

Fig. 1. Map presents the same sampling sites of the initial state

degraded is relatively high p= 0.7829 (Table 1). We can deduce that the courses seen in good state show a tendency to become moderately degraded. However, Slimani et al (2010) show that the regression of Alfa covers in western Algeria is mainly due to overgrazing.

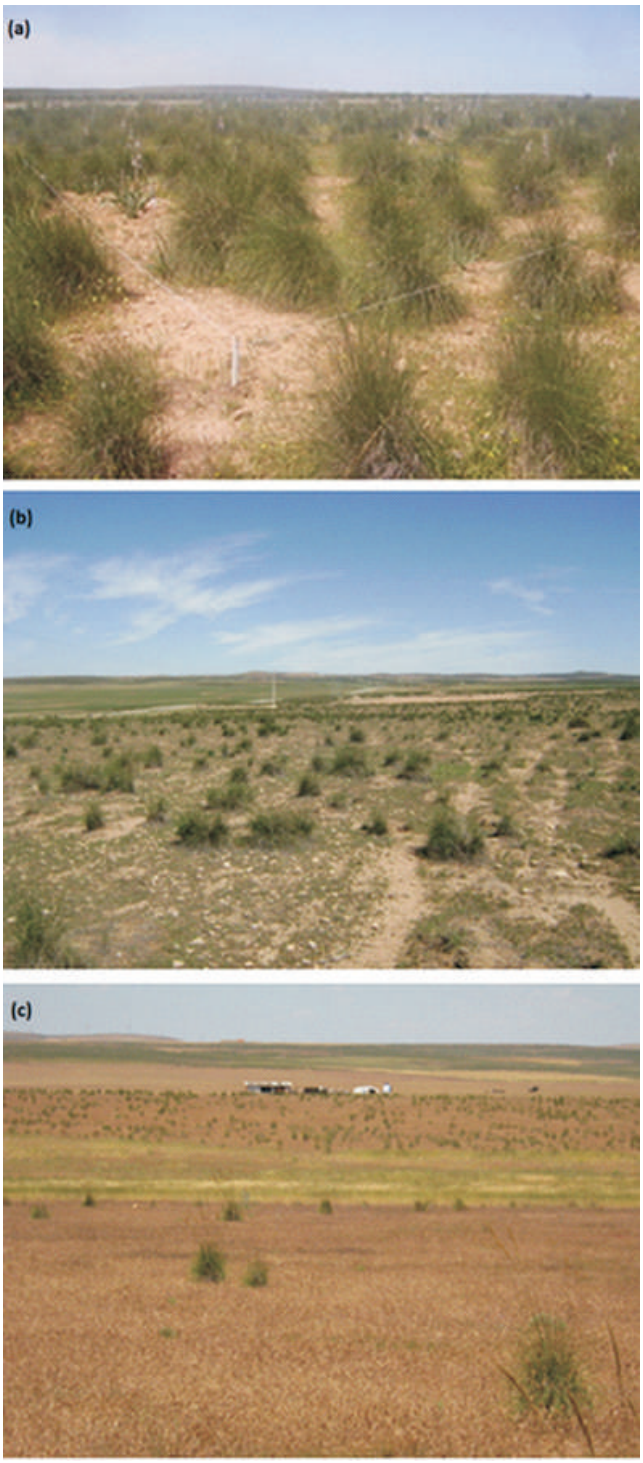

Fig. 2. Photographs showing different types of facies to *Stipa tenacissima* L: (a), facies to Alfa well growing; (b), facies to Alfa moderately degraded; (c), facies to Alfa degraded. Station of Maamora; province of Saïda; Western Algeria

Facies to *Artemisia herba alba* Asso.: The floristic diversity in the facies to white Wormwood more important than in the facies to Alfa. The comparative analysis of the specific contributions show a highly significant difference (Table 1) between the courses in good state and degraded with a decrease in Csi of the dominant specie; it′s from 70.85 to only 17.06%. It is significant between the good state and moderately degraded (p = 0.0397) with a decrease from 70.85 to 42.54%. This regression is explained by the anthropological action (overgrazing and land-use changes) exercised on the courses (Mahyou et al 2016).

The rise is important and progressive of the two species indicator of degradation (*Noaea mucronata*. and *Peganum harmala*), in the contributions reached respectively in the degraded facies 41.82 and 34.04%. The action of the herd on the courses considerably modifies the floristic composition. Permanent and uncontrolled pasture thus leads to the reduction of palatable species, which are replaced by other species little appetite, usually abandoned by livestock (Kadi Hanifi 2003). Most of the species are disappeared of the floral procession in the degraded facies (Figure 3).

Facies to *Lygeum spartum* L.: The comparative analysis of the specific contributions shows a very significant difference between facies in good condition and degraded and shows significant deference between facies in good condition and moderately degraded; the decrease in Sparta′s contribution from 70.30 to 38.48% to only 17.92 (Table 1).

A high contribution of *peganum harmala* was recorded in the degraded courses (Figure 4) with 63.24%. The occurrence of *P. harmala* [a toxic species that develops when soil nitrate levels are significant (Aimé 1988)] is an indicator of overgrazing in the area (Benabadjie et al 2009).

Aboveground biomass

Facies to *Stipa tenassicima* L.: The average of the above-ground biomass by facies shows that the courses to Alfa in good state offer a total biomass of 1251 for Alfa and 654 kg DM / ha for plants association. This result is similar to Bouchetata and Bouchetata (2005) who estimated that the above-ground biomass of Alfa is 1254 Kg DM/ha. However, in the courses moderately degraded and degraded the biomass present a considerable decline ranging respectively from 707 for Alfa and 242 kg DM/ ha for plants association to 237.8 for Alfa and 82.2 kg DM/ha for plants association (Figure 5). This decrease is explained by the result of several factors, including the irrational management of rangelands and the introduction of development means and techniques unsuited to steppe environments. Today, the biomass of the steppe is constantly decreasing; the comparative analysis of the

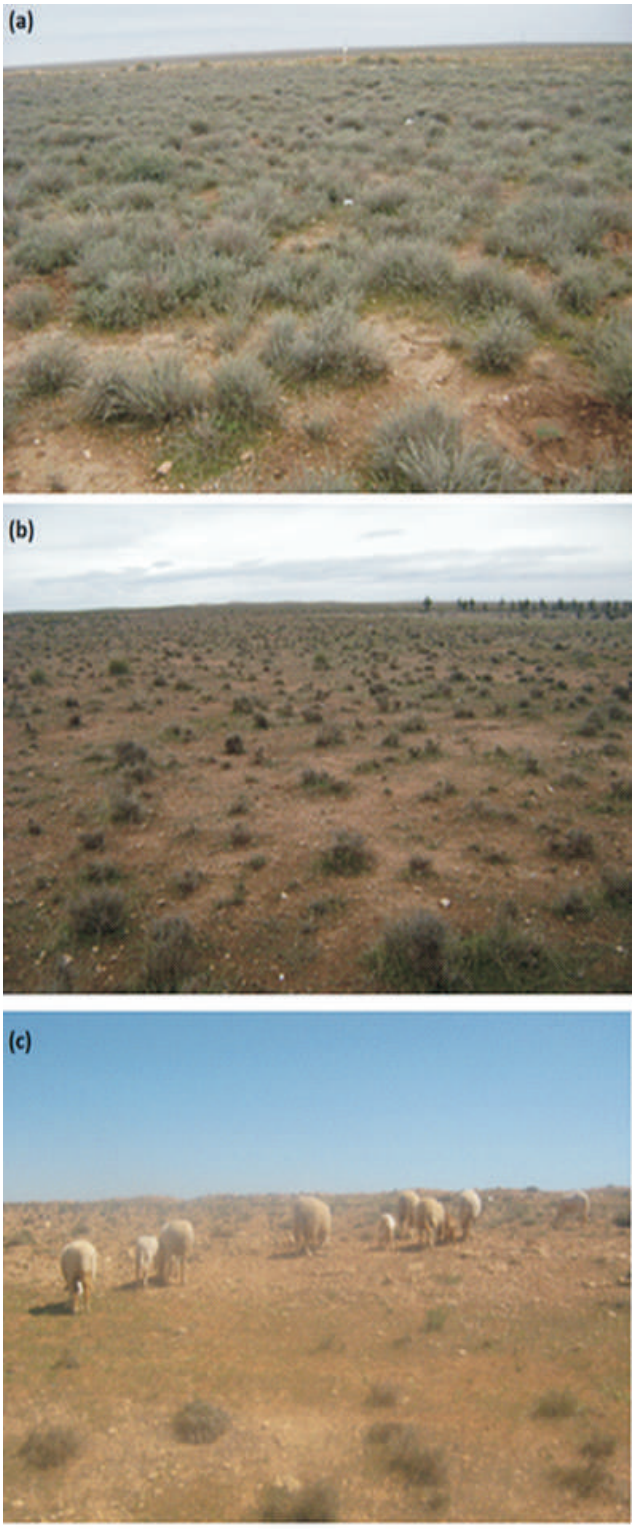

Fig. 3. Photographs showing different types of facies to *Artemisia herba alba* Asso: (a), facies to white Wormwood well growing; (b), facies to white Wormwood moderately degraded; (c), facies to white Wormwood degraded. (a,b), Station of Maamora. (c), Station of Aïn Skhouna, province of Saïda, Western Algeria

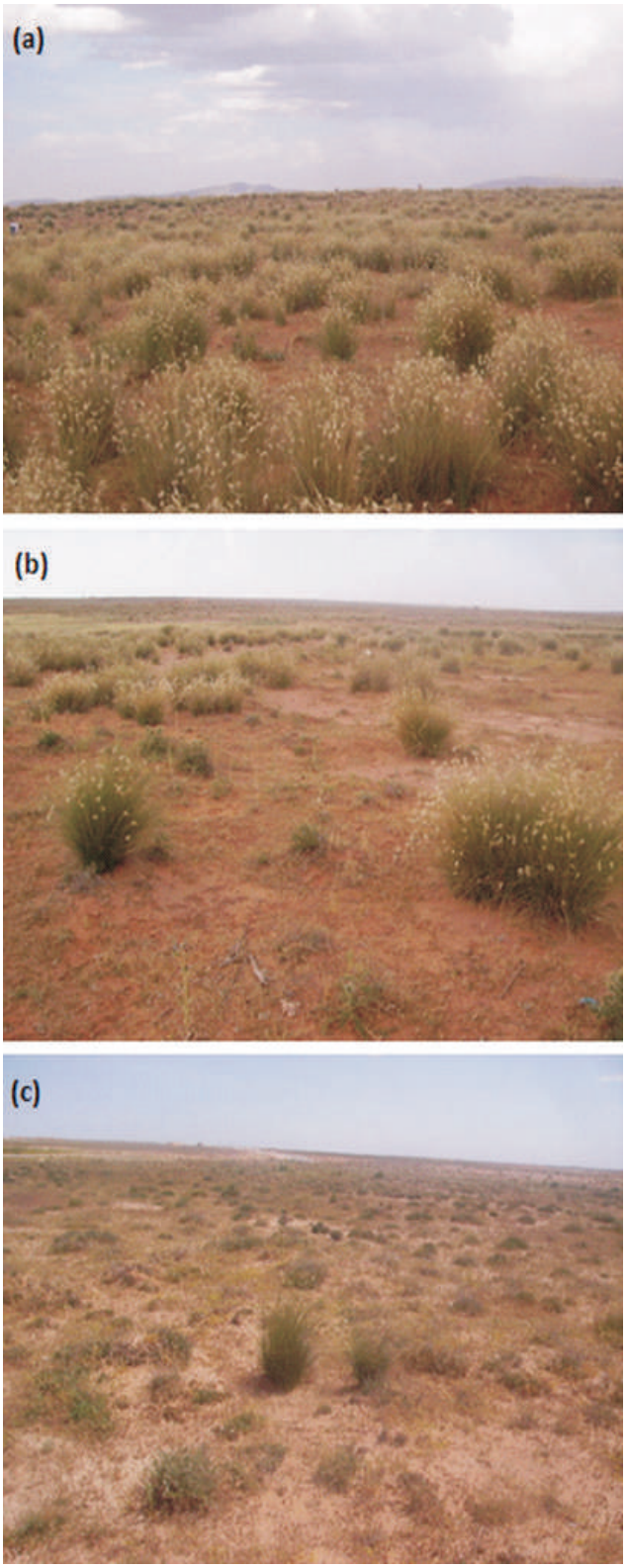

Fig. 4. Photographs showing different types of facies to *Lygeum Spartum* L.: (a), facies to Sparte Well growing; (b), facies to Sparte moderately degraded; (c), facies to Sparte degraded. Station of Aïnskhouna; province of Saïda; Western Algeria

results obtained in the different facies studied shows an alarming regressive dynamic. It should be noted that facies to Alfa considered in good state are, in fact, under a striking regression. Indeed, the aboveground biomass estimated by 2100 kg DM / ha in 1976 (Aidoud and Nedjraoui 1992) fell to 1750 kg DM / ha in 1996 (Aidoud and Touffet 1996), to 1500 kg DM / ha in 2001 (Nedjraoui 2002).

Facies to *Artemisia herba alba* Asso.: The facies in good state gives an aerial biomass of 3234 kg DM/ha for white Wormwood. These results are in agreement with those of Ayad et al (2015) who reported that the total dry matter biomass of white Wormwood is 3172 kg DM/ha. The comparison of the biomass calculated in the three facies highlights the degradation state of these courses, where the biomass has decreased by 76.46% going from that in good state to that in degraded (Figure 5). This decrease is due to overgrazing exerting on the rangelands. According to Li et al (2011), overgrazing diminishes soil nutrients, which in turn adversely affects rangeland biomass.

Facies to *Lygeum spartum* L.: The different measures of biomass obtained from the three different facies to *L. spartum* show a very important variation. The average of the biomass of Sparte in good state goes from 341.3 to only 103.1kg DM/ha in the degraded (Figure 5). Heavy grazing intensity significantly decreased the vegetation height, coverage, diversity and above-ground biomass (Wei Li et al 2011). According to Nedjraoui (2002), the steppes to Sparte are little productive with an annual average production ranging from 300 to 500 kg DM/ha.

The biomass of the plants association is relatively important in the degraded facies. It represents 45.56% of the total biomass of the facies. On the other hand, it is 39.60% in the moderately degraded and 39.84% in good state facies. The strong pressures on the courses modify the plant association in a progressive way giving rise to formations rich in species indicative of degradation with low pastoral values (cases of *Noaea mucronata* (frossk), *Peganum harmala* L.).

Analysis of Soil

Texture: The dominance of the texture sandy loam appears in 80 stations is 89%. The other texture is of fine loam appears in 10 stations, be 11% (Table 2). The textures proportions of samples have a high percentage of the sands which is in average between 50.5 and 57.1%, and a significant amount of silt that oscillates between 30.1 and 33.1%. The amount of clay is reduced for the degraded facies and ranged between 11% and 12.2 %.

Total $CaCO_3$: The analysis show low levels of total $CaCO_3$, with values that ranged between 5.58 and 7.7 % (Table 2). Benabadji (1996) reported that the $CaCO_3$ content in steppic soil is related to the nature of the parent rock.

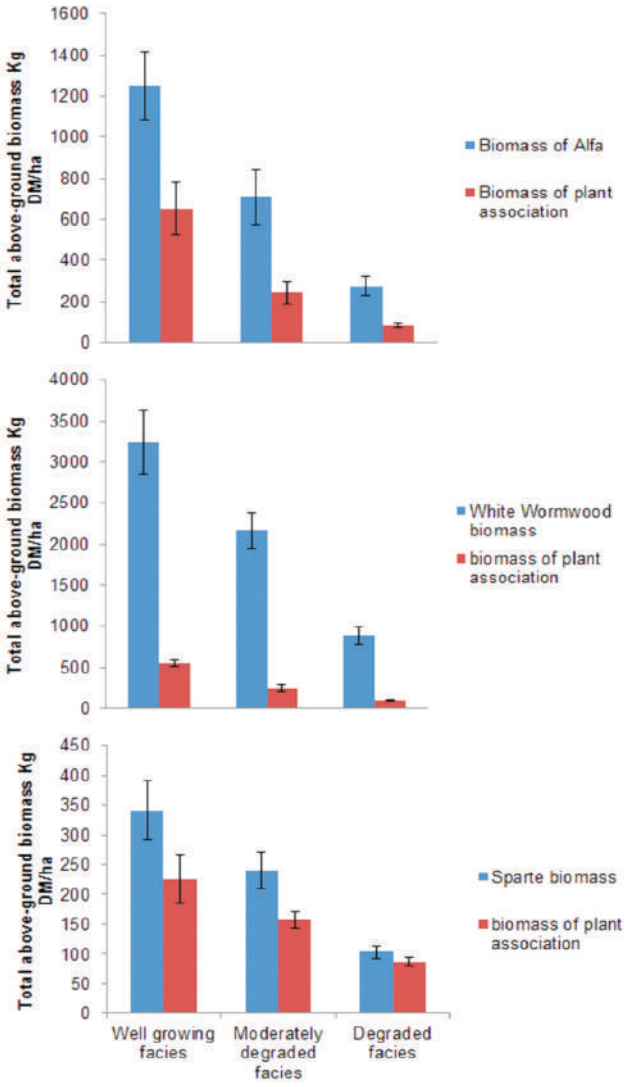

Fig. 5. Total aboveground biomass (mean values ± SD) for each structure and type of facies

Electrical conductivity: The overall salinity represented by the electrical conductivity, present low values, ranging between 0.31and 0.9 mS / cm. these results show that the soil of the study area is not salty.

pH: The pH varied from 8.29 to 8.54 indicating alkaline soil. These findings corroborate those of Benabadji et al (2009), Ghezlaoui et al (2011) and Hasnaoui and Bouazza (2015). In arid and semi-arid region, pH is alkaline due to cations that are not leached. Bases are accumulated on the soil surface because evapotranspiration is greater than precipitation. Rezaei and Gilkes (2005) suggest that pH values are mainly affected by the parental material, which varies from place to place, following rainfall and organic carbon levels.

Organic Matter (OM) and Soil Depth

In facies to Alfa: The decrease in the rate of organic matter is in correlation with the state of facies. The percentage in

average of 1.96 in good state to 0.62 in moderately degraded to low grades 0.33% in the degraded (Table 2). The reduction is due to the regression of the rate of vegetation cover (Benabadji and Bouazza 2002).

In general, soils of steppe are shallow. The different facies that occupy the steppe zones vary from one zone to another depending on the planimetry, climate and environmental conditions. In our case, the rates recorded in the various samples are variable. This variability depends on the dominance of Alfa. In sites to Alfa degraded, the depth of the soil is rather meager, on average of 7.1cm and 12.2cm in the moderately degraded formations and 17.6 cm in the good state. The depth parameter varies according to the degree of degradation due to the impact of wind, runoff. According to Dengfeng et al (2015) wind and water erosion are among the most important causes of soil loss. And also to the degradation or destruction of plant cover who leads to a disruption of the carbon cycle.

In facies to white wormwood: The organic matter content for samples of site in good state is on average of 1.24 %. As for the other two facies (moderately degraded and degraded), the average values of 0.61 and 0.37 percent respectively (Table 2). It remains too low. The effects of wind erosion result primarily in the loss of fine soil particles and soil organic matter (Zhao et al 2006). The soil depth of 9.8 to 13.6 cm and is lower compared to that of facies to Alfa. The flora of the facies to Alfa is less important than that of the white Wormwood facies. Thus the presence of Alfa favours the conservation of the soils (Hasnaoui and Bouazza 2015).

In facies to Sparte: The analysis show very remarkable low organic matter, content in moderately degraded and degraded facies with very low rates of 0.47 and 0.17 %, respectively. These results are very consistent with those of Benabadji et al (2009), which explain this by the nature of steppes with degraded facies, which are feebly productive. The depth of the soil varies between 7.2 and 17.6 cm. These values show a regression of one type to another, the soil truncation is very obvious.

Regressive evolution of facies (analyze of diachronic study): The diachronic study made it possible to detect the main changes between 1954 and 2014 which are:

The number of species inventoried goes from 132 in 1954 to 28 in 2014 and is 79% reduction where there are 113 species that no longer appear and 9 new species have appeared on our inventory. The number of families inventoried decreased from 29 to only 12 with the

Table 1. Statistical results of specific contribution inter facies

				P−Value					
Facies	A. GS	A. MD	A. D	W. GS	W.	W. D	S. GS	S. MD	S. D
Alfa GS	1	0,7829	0,0265[a]						
W.Wormwood GS				1	0,039	0,000			
Spart GS							1	0,025	< 0,0001

A= Alfa W= white Wormwood S= Spart GS= good state MD= moderately degraded D= degraded

Table 2. Values of soil physicochemical parameters (mean ± standard deviation) measured in different studied facies.

Facies	*Stipa tenassicima* L			*Artemisia herba alba* Asso			*Lygeum spartum* L		
sites	GS	MD	D	GS	MD	D	GS	MD	D
Granulometry %									
Sand	50.5±2.4	54.9±3.52	56.7±7.29	55.8±2.8	56.7±4.53	57.1±5.12	52.1±5.12	55.8±2,8	56.7±4.53
Silt	31±1.51	33.1±2.99	30.49±7.90	31±3.18	30.3±4.35	31.5±5.78	31.4±5.22	30.2±3.18	30.1±4.35
clay	18.5±1.4	12.8±3.71	11±2.97	13.2±0.35	13±0.23	11.4±0.12	16.5±3.12	14±1.07	12.2±3.28
Type of texture	Silt-loam	Sandy−Loam	Sandy−Loam	Sandy−Loam	Sandy−Loam	Sandy−Loam	Sandy−Loam	Sandy−Loam	Sandy−Loam
pH	8.29±0.2	8.49±0.34	8.54±0.22	8.32±0.26	8.4±0.27	8.3±0.22	8.34±0.11	8.49±0.15	8.52±0.14
EC mS/cm	0.7±0.06	0.6±0.13	0.33±0.11	0.9±0.29	0.5±0.13	0.55±0.13	0.31±0.2	0.64±0.11	0.76±0.09
$CaCO_3$ t %	6.17±1.7	7.7±1.24	5.63±2.2	5.58±1.04	7.15±1.06	5.92±1.7	5.58±1.04	7.15±1.06	5.92±1.7
OM	1.96±0.1	0.62±0.07	0.33±0.07	1.24±0.15	0.61±0.07	0.37±0.14	1.09±0.29	0.47±0.13	0.17±0.12
Depth (cm)	17.6±3.2	12.2±2.4	7.1±1.91	13.6±1.07	12.8±3.28	9.8±3.12	17±2.8	10.7±2.33	7.2±2.1

GS= good state MD= moderately degraded D= degraded EC= electrical conductivity OM= organic matter

disappearance of 20 families and the appearance of 3 new ones. According to Debuit and Simmoneau (1954), the facies to *Lygeum spartum* L are distinctly individualized on the South-east of Chott (from 34˚15′ to 34˚20′ North latitude and from 1˚1′ to 1˚6′ East longitude). Sixty years later, *L. spartum* facies are located on the North-west of Chott (from 34˚30′ to 34˚35′ North latitude and from 0˚41′ to 0˚47′ East longitude). The rhizomatous root system of *L. spartum* facilitates this extension and seems to be an opportunist species, the development of which is favored by drought and land degradation (Hirch et al 2011). Facies to *Stipa tenacissima* L. are replaced by facies to *Lygeum spartum* L. under association to *Artemisia herba alba* Asso and the facies to *Artemisia herba alba and Atriplex mauritanica* Boiss & Reut. are replaced by facies to *L. spartum* under association *to Noaea mucronata* Frosk. with the total disappearance of the *Atriplex mauritanica* specie. The replacement of dominants species by *L. spartum* and other species indicating land deterioration, a trend observed by other authors (Aidoud et al 2006). However Benabadji et al (2009) reported that the regression of some species for the benefit of others is due to climatic and especially anthropogenic factors. According to Debuis and Simmoneau (1954), the facies to Alfa are fairly tight to give the impression of a closed settlement appears like immense meadow called "Alfa Sea". Currently, the Alfa sites which are in good state (exclosure) do not even exceed the 60% of the recovery, while the other sites provide 5 to 35% of the recovery. The same phenomenon of decrease in Alfa cover has been observed in Tunisia (Hanafi and Jauffret 2007). Perennials vegetation is destroyed by anthropical anarchic action, clearing and grazing, this destruction is also aggravated by the increase in animal pressure on the increasingly reduced pastoral areas and by the collection of plants intended to satisfy culinary and medicinal needs. The strong decline of *Stipa tenacissima* L is disturbing, which presumably assumes its total disappearance in the coming years. The soil has changed from a silty-clay texture to a sandy loam texture for the white Wormwood facies. However the soil of the other facies has changed from a sandy-clay–loam to a sandy loam texture. Low vegetation cover helps to explain the importance and increase of wind speed and frequency (Nouaceur 2008).

CONCLUSION

The analysis of the current state of the study area reveals a regressive tendency of the pastoral areas and is accompanied by a worrying decrease in the quality of the vegetation cover. The increase of formations with indicator species of degradation, well adapted and of less forage value is made to the loss of Alfa and Wormwood sites; Formations more appreciated by the breeders. The edaphic data indicate the weakness of the elements essential to pedogenesis and confirm the low biological activity characteristic of the study area. The diachronic study reveals the degree of regression of soils and plant species. However, this study showed that some facies have completely disappeared and are replaced by others. In addition, the regressive evolution of the white Wormwood and Alfa steppes results in stages where these two species are replaced by Sparte and by indicator species of degradation such as *Noaea mucronata* and *peganum harmala* reflecting overgrazing. This investigation allowed us to visualize the alarming situation of these rangelands, indicating an erosion of the natural resources, following the combined impact of anthropogenic action and climatic damage; but overgrazing appears to be the major component of steppe degradation.

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Double Harmonization of Transcontinental Allometric Model of *Picea* spp.

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Abstract: For the first time the trans-Eurasian additive allometric mixed-effects model of tree biomass components (stems, branches, needles and roots) is designed using the database unique in terms of its volume in a number of 900 model trees of five species of *Picea* spp. taken on sample plots within species from natural habitats in Eurasia. The problem of double harmonization of the model was first solved, in the structure of that two approaches are combined, both in ensuring the principle of additivity of biomass components and in involving into the model the block of dummy variables localizing it along eco-regions of Eurasia. Trivial model involving the dummy and numeric (stem diameter at breast height and the tree height) variables in allometric equations without additivity components gives biomass estimates harmonized according to eco-regions but differing by the absolute value of the mass components only. The fundamental distinction and advantage of the developed model of double harmonization is that unlike of trivial mixed-effects model, it provides compatibility and difference by eco-regions not only of absolute values of biomass components, but also of their ratios, i.e. reflects regional traits of biomass component structure.

Keywords: Biosphere role of forests, Biomass component additivity, Mixed-effects model

Allometric models of single-tree biomass as a basis of taxation standards, intended to estimating biological productivity of forests, are characterized by some uncertainties, and therefore a problem of harmonization of regression models, including allometricones, is originated. The greatest development received at least two methods, or the two procedures of their harmonization, namely associated respectively with the introduction of "dummy" variables and the implementation of principle of additivity of biomass components. The first method is used to harmonize the characteristics of equations having a number of separate levels. For example, the dependency tree biomass upon stem diameter ($P \sim D$) in different edaphic conditions will have different values of the regression coefficients. When having the aim to harmonize them, in the equation along with numerical variable (in this case D) a block of artificial variables (dummy− or indicator variables), that encodes the equations related to one or another type of forests, is introduced. There are quite a few works dedicated to designing such models (Li and Zhang 2010, Fu et al 2012, Zeng 2015, Usoltsev et al 2017). Lately the equation with a combination of numerical and dummy variables are included in the category of mixed-effects models. With respect to the assessment of tree bitomass, the model that includes a combination of numerical and dummy variables has the form (Fu et al 2012). The second method harmonization was developed in response to the need to harmonize the equations calculated for different biomass components. This uncertainty was noted already in the first works devoted to the evaluation of tree biomass by means of equations involving the two main dendrometric indicators, namely stem diameter D and tree height H (Young et al 1964). It is in violation of the principle of additivity, according to which the total biomass (stem, branches, foliage, roots), obtained from component equations, should be equal (but usually not equal) to the value obtained using the equation for total biomass.

A special review devoted to the history of development of regression equations of additive biomass, starting from the very first works (Kurucz 1969, Kozak 1970), which was examined two methods of harmonization in terms of additivity, based on alternative algorithms: respectively "from particular-to general" and “from general-to particular” (Usoltsev 2017). The method “from general-to particular” harmonizating tree biomass components in terms of additivity was proposed in China (Tang et al 2000, Dong et al 2015). It is based on the principle of disaggregating (disaggregation model) or on a scheme of three-step proportional weighting-3SPW. The details of the disaggregation principle in the sequence "from general −to

particular", and its advantages in comparison with the algorithm" from particular − to general" are shown on the example of *Picea* spp. and *Abies* spp. single-trees when designing the additive generic transcontinental model of biomass component composition (Usoltsev et al 2017). In the previous paper (Usoltsev et al 2017) the transcontinental additive generic model of tree biomass for all species *Picea* spp. on overall Eurasia was proposed. In this article on the example of *Picea* spp. tree biomass the first attempt is taken to develop transcontinental allometric model of double harmonization, the structure of which combines both approaches that were above mentioned, namely, the principle of additivity of biomass component composition and the introduction of "dummy" variables, localizing the additive model into regions of Eurasia.

MATERIAL AND METHODS

As a basis of the developed models, the database of single-tree bitomass of woody species in Eurasia is used (Usoltsev 2016a,b), from which the data are taken in a number of 900 sample trees of five vicarious species of the genus *Picea* spp., namely *P. abies* (L.) H. Karst., *P. obovata* L., *P. schrenkiana* F. and C.A. Mey., *P. jezoensis* (S.&Z.) Carrièr, *P. purpurea* Masters. They are distributed in seven eco-regions and marked respectively by seven dummy variables, from X_0 to X_6 (Table 1). A more detailed description of initial data was represented in our previous publication (Usoltsev 2016a).

The simple allometry $P_i \sim D$ gives the worst approximation to actual data compared with two-factorial allometry $P_i \sim D, H$, where the diameter (D) and tree height (H) are included in the equation separately, assuming their orthogonality in correct planning of the passive experiment (Nalimov 1971). Accordingly, such two-factorialallometry is widespread in the studies of the tree biomass structure (Battulga et al 2013, Li and Zhao 2013, Cai et al 2013, Usoltsev 2016a). Because the measurations of tree height compared to stem diameter is considerably more labour-consuming, regional (Rutishauser et al 2013) or special mixed-effects models $H \sim D$ are developed, which included dummy variables coding different tree species or different site conditions (Valbuena et al 2016). Today, numerous quantities of $H \sim D$ ratios can be obtained using modern techniques that combines forest canopy remote sensing data with terrestrial measurements of trees (Sullivan et al 2017, Iizuka et al 2018).

Two major mass-forming independent variables as predictors −stem diameter and tree height −were included in the allometric tree biomass equation. Attempts to use the additional independent variables related to tree and/or forest stand indices show that they either give a negligible increase of adequacy (Wirth et al 2004), either do not provide it at all (Fu et al 2016). Nevertheless, biomass allometry in pure spruce forests of Europe proved misplaced under the influence of soil conditions (Dutcă et al 2014), and comparison of allometric biomass models, designed on actual data of pure spruce stands and mixed spruce-beech ones, showed significantly lower values in the second case, at the expense of lesser percentage of the spruce crown in aboveground biomass (Dutcă et al 2017).

Because the minimum stem diameter at breast height (DBH) in the compiled database is 0.5-0.6 cm and minimum height 1.4 m, the traditional allometric relationship of tree biomass with DBH and tree height is broken as a result of the shift of taxation diameter up to stem. As a consequence, a correlation of residual dispersion appears, i.e. there is an underestimating of all component biomass at the smallest and most large trees and accordingly is overestimating at mean trees. This is eliminated by the introduction of variable (ln D) (ln H), that is statistically significant in all cases (Usoltsev et al 2017). As in previous studies (Usoltsev 2016a), we do not use as a predictor the so-called "form

Table 1. The scheme of encoding regional pools of *Picea* tree biomass data with dummy variables

Ecoregion*	Species *Picea* spp.	Block of dummy variables						Tree DBH range, cm	Tree height range, м	Number of trees
		X_1	X_2	X_3	X_4	X_5	X_6			
WME	*P. abies*	0	0	0	0	0	0	5.0÷68.0	4.2÷43.0	359
EPR	*P. abies*	1	0	0	0	0	0	0.6÷51.5	1.5÷32.4	183
Ur(nat.)	*P. obovata*	0	1	0	0	0	0	3.5÷38.0	3.2÷24.0	40
Ur(plant.)	*P. obovata*	0	0	1	0	0	0	0.6÷17.4	1.4÷13.5	276
WS	*P. obovata*	0	0	0	1	0	0	0.5÷6.4	1.5÷6.7	7
PT	*P. schrenkiana*	0	0	0	0	1	0	6.7÷43.5	6.8÷33.4	15
FE	*P. jezoensis,P. purpurea*	0	0	0	0	0	**1**	6.7÷30.7	5.8÷20.1	10

* WME – Western and Middle Europe; EPR – European part of Russia; Ur(nat.) – Ural, natural forests; Ur(plant.) – Ural, plantations; WS – Western Siberia, forest-steppe; PT – Pamir-Tien Shan province (Northwest China); FE – Far Eastern province (Primorye and North-East China).

cylinder" D^2H, because in its structure at the given diameter the dependence of biomass upon tree height is "enforced" positive, whereas when increasing height of trees of equal diameter the crown biomass is reduced by age and cenotical features of stands. Hence the worst explanatory ability of "form cylinder" compared with only DBH that is proven by numerous studies (Ruiz-Peinado et al 2012, Dong et al 2015,Magalhães and Seifert 2015, Bronisz et al 2016, Usoltsev 2016a). But the result of evaluating the crown biomass improves significantly, when along with the "form cylinder" the crown length index is included into model as the second predictor, which takes into account the mentioned features (Parresol 1999, Carvalho and Parresol 2003).

RESULTS AND DISCUSSION

In the first phase of the mentioned double harmonizing the independent (i.e. not additive) allometric equations are calculated in our study according to the following order (Table 2 in: Usoltsev et al 2017): first –for total biomass, then –for the aboveground (intermediate component) and underground biomass (Step 1), then –for intermediate components –tree crown and stem above bark (Step 2) and, finally, for the original (initial) components –needle and branches (Step 3*a*) and wood and bark of the stem (Step 3*b*) according to their adopted structure

$$\ln P_i = a_i + b_i(\ln D) + c_i(\ln H) + d_i(\ln D)(\ln H) + \Sigma e_{ij}X_j, \quad (2)$$

где*i* – designation of biomass components: total (*t*), aboveground (*a*), roots (*r*), tree crown (*c*), stem above bark (*s*), foliage (*f*), branches (*b*), stem wood (*w*) and stem bark (*bk*); *j* – code of dummy variable, from 0 to 6 (Table 1). $\Sigma e_{ij}X_j$ – the block of dummy variables for *i*–th biomass component of *j*–th eco-region. The model (2) after the anti-log circuits has the form

$$P_i = e^{ai} D^{bi} H^{ci} D^{di(\ln H)} e^{\Sigma eijXj} \quad (3)$$

Calculation of coefficients of initial equations (2) is made using the program of common regression analysis, and their characteristics are obtained that after correcting on logarithmic transformation by Baskerville (1972) and transforming their to the form (3) are shown in the Table 2. All the regression coefficients for numerical variables in equations (3) are significant at the level of probability $P_{0.95}$ or higher, and the equations are adequate to harvest data. Structure of additive model proposed by Chinese researchers (Tang et al 2000, Dong et al 2015), is modified in accordance with the character traits of research and is shown in Table 2.

In the second phase of our research, by involving the regression coefficients of independent equations from Table 2 into the structure of the additive model, presented in Figure 1, we obtain the transcontinental three-step additive model of

Table 2. The structure of three-step additive model designed under proportional weighting. Symbols here and further see in equation (2)

Step 1	$P_r = \frac{1}{1 + \frac{a_a D^{ba} H^{ca} D^{da} (InH) e^{\Sigma eajxj}}{a_r D^{br} H^{cr} D^{dr} (InH) e^{\Sigma erjxj}}} \times P_t$ $P_r = \frac{1}{1 + \frac{a_r D^{br} H^{cr} D^{dr} (InH) e^{\Sigma erjxj}}{a_a D^{ba} H^{ca} D^{da} (InH) e^{\Sigma eajxj}}} \times P_t$
Step 2	$P_r = \frac{1}{1 + \frac{a_s D^{bs} H^{cs} D^{ds} (InH) e^{\Sigma esjxj}}{a_c D^{bc} H^{cc} D^{dc} (InH) e^{\Sigma ecjxj}}} \times P_t$ $P_r = \frac{1}{1 + \frac{a_c D^{bc} H^{cc} D^{dc} (InH) e^{\Sigma ecjxj}}{a_s D^{bs} H^{cs} D^{ds} (InH) e^{\Sigma esjxj}}} \times P_t$
Step 3a	$P_r = \frac{1}{1 + \frac{a_b D^{bb} H^{cb} D^{db} (InH) e^{\Sigma ebjxj}}{a_f D^{bf} H^{cf} D^{df} (InH) e^{\Sigma efjxj}}} \times P_t$ $P_r = \frac{1}{1 + \frac{a_f D^{bf} H^{cf} D^{df} (InH) e^{\Sigma efjxj}}{a_b D^{bb} H^{cb} D^{db} (InH) e^{\Sigma ebjxj}}} \times P_t$
Step 3b	$P_r = \frac{1}{1 + \frac{a_{bk} D^{bbk} H^{cbbk} D^{dbbk} (InH) e^{\Sigma ebbkjxj}}{a_w D^{bfw} H^{cfw} D^{dfw} (InH) e^{\Sigma ewjxj}}} \times P_t$ $P_r = \frac{1}{1 + \frac{a_w D^{bfw} H^{cfw} D^{dfw} (InH) e^{\Sigma ewjxj}}{a_{bk} D^{bbk} H^{cbbk} D^{dbbk} (InH) e^{\Sigma ebbkjxj}}} \times P_t$

biomass component composition designed under proportional weighting scheme (Table 4). The final appearance of this model of double harmonization is shown on the Table 5.

The model is valid in the range of harvest data of stem height and DBH of sample trees shown in Table 1. Tabulating the obtained final model (Table 5) on the given values of *D* and *H*, as well as on the dummy variables localizing the total model according to eco-regions, gives as a result, regional regulations, additive on biomass components and designed to spruce biomass estimating on Eurasia. Taking into account the labour intensity, and sometimes the impossibility of measuring the heights of trees in the wild, we additionally design the auxiliary equation for calculating the biomass on the unit area of a forest stand with the application of the proposed additive biomass model:

$$H = 1.2\, D^{0.9128} e^{0.4364(1/D)} e^{-0.0445X1} e^{-0.1947X2} e^{-0.1405X3} e^{-0.0290X4} e^{-0.0118X5} e^{-0.2939X6}; \quad (4)$$

$adjR^2 = 0.958$; $SE = 0.16$.

Table 3. The characteristic of independent (initial)allometric equations (3).

Biomass component	Independent variables and regression coefficients of the model										adjR²*	SE*
P_t	0.5236	$D^{0.9170}$	$H^{0.1114}$	$D^{0.3210(lnH)}$	$e^{-0.0837X1}$	$e^{0.0436X2}$	$e^{0.2655X3}$	$e^{0.1163X4}$	$e^{0.0598X5}$	$e^{0.1590X6}$	0.990	1.19
Step 1												
P_a	0.6650	$D^{0.9268}$	$H^{-0.1407}$	$D^{0.3461(lnH)}$	$e^{-0.1197X1}$	$e^{0.0390X2}$	$e^{-0.0396X3}$	$e^{-0.2369X4}$	$e^{0.1701X5}$	$e^{0.1364X6}$	0.986	1.26
P_r	0.0725	$D^{0.9393}$	$H^{-0.1659}$	$D^{0.4236(lnH)}$	$e^{0.3392X1}$	$e^{0.2134X2}$	$e^{0.6642X3}$	$e^{0.8177X4}$	$e^{0.3315X5}$	$e^{0.4874X6}$	0.975	1.44
Step 2												
P_c	0.4809	$D^{1.6489}$	$H^{-1.1713}$	$D^{0.2887(lnH)}$	$e^{0.0268X1}$	$e^{0.4637X2}$	$e^{0.3302X3}$	$e^{-0.1674X4}$	$e^{0.2536X5}$	$e^{-0.0107X6}$	0.930	1.53
P_s	0.2343	$D^{0.6682}$	$H^{0.4936}$	$D^{0.3223(lnH)}$	$e^{-0.1357X1}$	$e^{-0.0855X2}$	$e^{-0.2480X3}$	$e^{-0.1305X4}$	$e^{0.1852X5}$	$e^{0.2759X6}$	0.992	1.22
Step 3а												
P_f	0.2817	$D^{1.6561}$	$H^{-1.2510}$	$D^{0.2831(lnH)}$	$e^{0.0115X1}$	$e^{0.3919X2}$	$e^{0.3107X3}$	$e^{-0.3497X4}$	$e^{0.3013X5}$	$e^{-0.3989X6}$	0.904	1.62
P_b	0.2054	$D^{1.6372}$	$H^{-1.1094}$	$D^{0.2987(lnH)}$	$e^{0.1494X1}$	$e^{0.6184X2}$	$e^{0.3768X3}$	$e^{0.1097X4}$	$e^{0.2840X5}$	$e^{0.3309X6}$	0.887	1.78
Step 3б												
P_w	0.2484	$D^{0.73414}$	$H^{0.3360}$	$D^{0.3286(lnH)}$	$e^{0.0061X1}$	$e^{-0.1181X2}$	$e^{-0.4134X3}$	$e^{-0.5122X4}$	$e^{0.1427X5}$	$e^{0.1640X6}$	0.991	1.23
P_{bk}	0.0441	$D^{0.7639}$	$H^{0.1592}$	$D^{0.2944(lnH)}$	$e^{0.0172X1}$	$e^{0.1567X2}$	$e^{-0.0368X3}$	$e^{0.5045X4}$	$e^{0.5520X5}$	$e^{0.7337X6}$	0.976	1.34

*$adj\ R^2$ – coefficient of determination adjusted for the number of observations; *SE* – standard error of equations in the initial dimension P_i(kg).

Table 4. The additive combination of the original analytical dependencies of component biomass upon tree height and DBH, calculated according to the principle of proportional weighing

$$Pt = 0.5236\ D^{0.9170} H^{0.1114} D^{0.3210(\ln H)}\ e^{-0.0837X1}\ e^{0.0436X2}\ e^{0.2655X3}\ e^{0.1163X4}\ e^{0.0598X5}\ e^{0.1590X6}$$

Step 1	$Pa=$		$\dfrac{1}{1+\dfrac{0.0725\ D^{0.9393} H^{-0.1659} D^{0.4236(\ln H)}\ e^{0.3392X1}\ e^{0.2134X2}\ e^{0.6642X3}\ e^{0.8177X4}\ e^{0.3315X5}\ e^{0.4874X6}}{0.6650\ D^{0.9268} H^{-0.1407} D^{0.3461(\ln H)}\ e^{-0.1197X1}\ e^{0.0390X2}\ e^{-0.0396X3} e^{-0.2369X4}\ e^{0.1701X5} e^{0.1364X6}}}$	$\times Pt$
	$Pr=$		$\dfrac{1}{1+\dfrac{0.6650\ D^{0.9268} H^{-0.1407} D^{0.3461(\ln H)}\ e^{-0.1197X1}\ e^{0.0390X2}\ e^{-0.0396X3} e^{-0.2369X4}\ e^{0.1701X5} e^{0.1364X6}}{0.0725\ D^{0.9393} H^{-0.1659} D^{0.4236(\ln H)}\ e^{0.3392X1}\ e^{0.2134X2}\ e^{0.6642X3}\ e^{0.8177X4}\ e^{0.3315X5}\ e^{0.4874X6}}}$	$\times Pt$
Step 2	$Pc=$		$\dfrac{1}{1+\dfrac{0.2343\ D^{0.6682} H^{0.4936} D^{0.3223(\ln H)}\ e^{-0.1357X1}\ e^{-0.0855X2} e^{-0.2480X3} e^{-0.1305X4}\ e^{0.1852X5} e^{0.2759X6}}{0.4809\ D^{1.6489} H^{-1.1713} D^{0.2887(\ln H)}\ e^{0.0268X1} e^{0.4637X2}\ e^{0.3302X3} e^{-0.1674X4}\ e^{0.2536X5} e^{-0.0107X6}}}$	$\times Pa$
	$Ps=$		$\dfrac{1}{1+\dfrac{0.4809\ D^{1.6489} H^{-1.1713} D^{0.2887(\ln H)}\ e^{0.0268X1} e^{0.4637X2}\ e^{0.3302X3} e^{-0.1674X4}\ e^{0.2536X5} e^{-0.0107X6}}{0.2343\ D^{0.6682} H^{0.4936} D^{0.3223(\ln H)}\ e^{-0.1357X1} e^{-0.0855X2} e^{-0.2480X3} e^{-0.1305X4}\ e^{0.1852X5} e^{0.2759X6}}}$	$\times Pa$
Step 3*a*	$Pf=$		$\dfrac{1}{1+\dfrac{0.2054\ D^{1.6372} H^{-1.1094} D^{0.2987(\ln H)}\ e^{0.1494X1}\ e^{0.6184X2}\ e^{0.3768X3}\ e^{0.1097X4}\ e^{0.2840X5}\ e^{0.3309X6}}{0.2817\ D^{1.6561} H^{-1.2510}\ D^{0.2831(\ln H)}\ e^{0.0115X1} e^{0.3919X2}\ e^{0.3107X3}\ e^{-0.3497X4} e^{0.3013X5}\ e^{-0.3989X6}}}$	$\times Pc$
	$Pb=$		$\dfrac{1}{1+\dfrac{0.2817\ D^{1.6561} H^{-1.2510}\ D^{0.2831(\ln H)}\ e^{0.0115X1} e^{0.3919X2}\ e^{0.3107X3}\ e^{-0.3497X4} e^{0.3013X5}\ e^{-0.3989X6}}{0.2054\ D^{1.6372} H^{-1.1094} D^{0.2987(\ln H)}\ e^{0.1494X1}\ e^{0.6184X2}\ e^{0.3768X3}\ e^{0.1097X4}\ e^{0.2840X5}\ e^{0.3309X6}}}$	$\times Pc$
Step 3*b*	$Pw=$		$\dfrac{1}{1+\dfrac{0.0441\ D^{0.7639} H^{0.1592} D^{0.2944(\ln H)}\ e^{0.0172X1}\ e^{0.1567X2}\ e^{-0.0368X3}\ e^{0.5045X4}\ e^{0.5520X5}\ e^{0.7337X6}}{0.2484\ D^{0.73410} H^{0.3360} D^{0.3286(\ln H)}\ e^{0.0061X1}\ e^{-0.1181X2} e^{-0.4134X3} e^{-0.5122X4}\ e^{0.1427X5} e^{0.1640X6}}}$	$\times Ps$
	$Pbk=$		$\dfrac{1}{1+\dfrac{0.2484\ D^{0.73410} H^{0.3360} D^{0.3286(\ln H)}\ e^{0.0061X1}\ e^{-0.1181X2} e^{-0.4134X3} e^{-0.5122X4}\ e^{0.1427X5} e^{0.1640X6}}{0.0441\ D^{0.7639} H^{0.1592} D^{0.2944(\ln H)}\ e^{0.0172X1}\ e^{0.1567X2} e^{-0.0368X3}\ e^{0.5045X4}\ e^{0.5520X5}\ e^{0.7337X6}}}$	$\times Ps$

Variable (1/D) is introduced in the model structure (4) for the allometry correction, broken in small trees due to the shift of measurement of diameter *D* in the upper part of the crown. Because the volume of taxation tables exceeds the format of journal article, we will focus on analyzing some of regional characteristics of the spruce biomass structure of equal size trees on the relevant table fragments (Table 6). Primarily, the Ural region is of our interest where within the south taiga subzone we have two pools of sample trees *Picea obovata*, data of which were obtained, respectively, in natural stands and plantations. A comparative analysis of the biomass structure of equal size trees (within the range of applicability of the model, as shown in Table 1) showed significant excess of tree biomass in plantations, namely, total, aboveground and underground biomass on 24, 14 and 88 percent respectively. The proportion of needles in the aboveground biomass varies slightly (13 and 15%, respectively), but the difference in root: shoot ratio is significant. The latter is in natural stands and plantations 0.22 and 0.37, respectively.

Spruce trees of two regions adjacent to the Pacific (*P. jezoensis*) and Atlantic (*P. abies*) Oceans differ significantly in the structure of their biomass: exceeding the first over the second is for total, aboveground and underground biomass on 17, 10 and 56percent respectively. The proportion of needles in the aboveground biomass is 5 and 10 per cent, respectively, and the root: shoot ratio is 0.26 0.18, respectively. Structure of tree biomass on two more distant regions (Pamir–TienShan province and European part of Russia) and of species growing on their territories (*P. schrenkiana* and *P. abies* respectively) also varies considerably: the difference between the first and the second is accounted for to total, aboveground and underground biomass 15, –9 and 22 per cent, respectively. The root: shoot ratio equal to 0.21 and 0.29, respectively, and there are no differences in the proportion of needles in the aboveground biomass (11%).

It was shown by some researchers (Cunia and Briggs 1984, Reed and Green 1985), that the removal of internal inconsistency of equations for tree biomass by ensuring their additivity does not necessarily mean any improvements in the accuracy of its estimates. Therefore it is necessary to clear whether adequate an additive model obtained and how its adequacy characteristics are comparable with those of the independent equations¯ To this purpose, the biomass estimates obtained using independent and additive equations are compared with observed biomass values in the database by calculating the coefficient of determination R^2 and the root mean squared error *RMSE* in accordance of the formulas

$$R^2 = 1 - \frac{\sum_{i=1}^{N}(Y_i - \bar{Y}_i)^2}{\sum_{i=1}^{N}(Y_i - \bar{Y}_i)^2} \quad RMSE = \frac{\sum_{i=1}^{N}(Y_i - \bar{Y}_i)^2}{\mathrm{N} - \mathrm{P}} \qquad (5)$$

Where $\hat{Y}_i$ is observed value; $\hat{Y}_i$ is predicted value; $\bar{Y}$ is the mean of *N* observed values for the same component; *p* is the number of model parameters; *N* is sample size of trees involving into calculating R^2 and *RMSE.*

Table 5. Three-step trans-Eurasian additive model of component biomass composition of spruce trees rdesigned under proportional weighing scheme

$$Pt = 0.5236\, D^{0.9170} H^{0.1114} D^{0.3210(\ln H)}\, e^{-0.0837X1}\, e^{0.0436X2}\, e^{0.2655X3}\, e^{0.1163X4}\, e^{0.0598X5}\, e^{0.1590X6}$$

Step 1	$Pa=$	$\frac{1}{1+0.1090\, D^{0.0125} H^{0.0252} D^{0.0775(\ln H)}\, e^{0.4589X1}\, e^{0.1744X2}\, e^{0.7038X3}\, e^{1.0546X4}\, e^{0.1614X5}\, e^{0.3510X6}}$	$\times Pt$
	$Pr=$	$\frac{1}{1+9.1724\, D^{-0.0125} H^{0.0252} D^{-0.0775(\ln H)} e^{-0.4589X1} e^{-0.1744X2} e^{-0.7038X3} e^{-1.0546X4} e^{-0.1614X5} e^{-0.3510X6}}$	$\times Pt$
Step 2	$Pc=$	$\frac{1}{1+0.4872\, D^{-0.9807} H^{1.6649} D^{0.0336(\ln H)} e^{-0.1625X1} e^{-0.5492X2} e^{-0.5782X3} e^{0.0369X4} e^{-0.0684X5} e^{0.2866X6}}$	$\times Pa$
	$Ps=$	$\frac{1}{1+2.0525\, D^{0.9807} H^{-1.6649} D^{-0.0336(\ln H)} e^{0.1625X1} e^{0.5592X2} e^{0.5782X3} e^{-0.0369X4} e^{-0.0684X5} e^{-0.2866X6}}$	$\times Pa$
Step 3*a*	$Pf=$	$\frac{1}{1+0.7291\, D^{-0.0189} H^{0.1416} D^{0.0156(\ln H)} e^{0.1379X1} e^{0.2265X2} e^{0.0661X3} e^{0.4594X4} e^{-0.0173X5} e^{0.7298X6}}$	$\times Pc$
	$Pb=$	$\frac{1}{1+1.3715\, D^{0.0189} H^{-0.1416} D^{-0.0156(\ln H)} e^{-0.1379X1} e^{-0.2265X2} e^{-0.0661X3} e^{-0.4594X4} e^{0.0173X5} e^{-0.7298X6}}$	$\times Pc$
Step 3*b*	$Pw=$	$\frac{1}{1+0.1775\, D^{0.0298} H^{-0.1768} D^{-0.0342(\ln H)} e^{0.0111X1} e^{0.2748X2} e^{0.3766X3} e^{1.0167X4} e^{0.4093X5} e^{0.5697X6}}$	$\times Ps$
	$Pbk=$	$\frac{1}{1+5.6326\, D^{-0.0298} H^{0.1768} D^{0.0342(\ln H)} e^{-0.0111X1} e^{-0.2748X2} e^{-0.3766X3} e^{-1.0167X4} e^{-0.4093X5} e^{-0.5697X6}}$	$\times Ps$

To properly comparing the adequacy of independent and additive equations, the observed data are given in comparable condition, i.e. independent equations for all biomass components are calculated according to the same data that the additive equation for the total phytomass (where were exclude the observations without root data). Characteristics of such "methodized" equations is given in the Table 7**.** The results of the comparison (Table 8) suggest that the additive equations not only internally consistent, but also for the most part of components possess the best

Table 6. Fragments of the additive biomass (kg) table of trees having DBH of 14 cm and tree height of 14 m in different eco−regions and the corresponding species of genus *Picea* spp

Biomass components, kg	Ecoregion and the corresponding species of genus *Picea*spp.					
	Ur(plant.) *P. obovata*	Ur(nat.) *P. obovata*	FE *P. jezoensis, P. purpurea*	WME *P. abies*	PT *P. schrenkiana*	EPR *P. abies*
Total biomass	96.36	77.19	86.63	73.89	78.45	67.96
Roots	25.80	13.68	17.71	11.32	13.75	15.12
Above-ground	70.56	63.51	68.92	62.58	64.70	52.84
Crown	22.76	20.08	11.51	13.19	14.38	12.63
Needles	10.34	8.33	3.45	6.21	6.83	5.52
Branches	12.42	11.75	8.05	6.98	7.55	7.11
Stem above bark	47.80	43.43	57.41	49.39	50.31	40.21
Stem wood	42.00	38.61	49.16	45.11	44.02	36.69
Stem bark	5.80	4.82	8.25	4.28	6.29	3.52

Table 7. The characteristic of "methodized" independent allometric equations (3)

Biomass components	Independent variables and regression coefficients of the model									
P_t	0.5236	$D^{0.9170}$	$H^{0.1114}$	$D^{0.3210(\ln H)}$	$e^{-0.0837X1}$	$e^{0.0436X2}$	$e^{0.2655X3}$	$e^{0.1163X4}$	$e^{0.0598X5}$	$e^{0.1590X6}$
Step 1										
P_a	0.4574	$D^{0.9133}$	$H^{0.1438}$	$D^{0.3054(\ln H)}$	$e^{-0.11604X1}$	$e^{0.0248X2}$	$e^{0.1955X3}$	$e^{-0.0223X4}$	$e^{0.0225X5}$	$e^{0.1004X6}$
P_r	0.0731	$D^{0.9405}$	$H^{-0.1699}$	$D^{0.4236(\ln H)}$	$e^{0.3325X1}$	$e^{0.2130X2}$	$e^{0.6597X3}$	$e^{0.8137X4}$	$e^{0.3313X5}$	$e^{0.4858X6}$
Step 2										
P_c	0.3116	$D^{1.5201}$	$H^{-0.6013}$	$D^{0.2170(\ln H)}$	$e^{-0.1713X1}$	$e^{0.4610X2}$	$e^{0.4770X3}$	$e^{-0.0157X4}$	$e^{-0.3839X5}$	$e^{-0.1722X6}$
P_s	0.1985	$D^{0.6511}$	$H^{0.5446}$	$D^{0.3254(\ln H)}$	$e^{-0.1526X1}$	$e^{-0.1169X2}$	$e^{-0.1364X3}$	$e^{0.0118X4}$	$e^{0.1396X5}$	$e^{0.2547X6}$
Step 3a										
P_f	0.1520	$D^{1.6252}$	$H^{-0.8756}$	$D^{0.2518(\ln H)}$	$e^{-0.0288X1}$	$e^{0.4179X2}$	$e^{0.8202X3}$	$e^{-0.0278X4}$	$e^{-0.2530X5}$	$e^{-0.5150X6}$
P_b	0.1429	$D^{1.4219}$	$H^{-0.3226}$	$D^{0.1818(\ln H)}$	$e^{-0.1750X1}$	$e^{0.6198X2}$	$e^{0.2591X3}$	$e^{0.1316X4}$	$e^{-0.3912X5}$	$e^{0.1427X6}$
Step 3b										
P_w	0.2484	$D^{0.73414}$	$H^{0.3360}$	$D^{0.3286(\ln H)}$	$e^{0.0061X1}$	$e^{-0.1181X2}$	$e^{-0.4134X3}$	$e^{-0.5122X4}$	$e^{0.1427X5}$	$e^{0.1640X6}$
P_{bk}	0.0441	$D^{0.7639}$	$H^{0.1592}$	$D^{0.2944(\ln H)}$	$e^{0.0172X1}$	$e^{0.1567X2}$	$e^{-0.0368X3}$	$e^{0.5045X4}$	$e^{0.5520X5}$	$e^{0.7337X6}$

Table 8. The comparison of adequacy indices of independent and additive equations for spruce tree biomass.

Indices	Biomass components*								
	P_t	P_a	P_r	P_s	P_w	P_{bk}	P_c	P_b	P_f
Independent equations									
R^2	0.950	0.902	0.777	0.898	0.943	0.875	0.728	0.800	0.660
RMSE	69.50	88.34	28.72	77.07	33.38	3.82	22.91	13.96	9.19
Additive equations									
R^2	0.950	0.916	0.786	0.914	0.905	0.844	0.825	0.836	0.631
RMSE	69.70	82.12	28.12	70.99	43.08	4.27	18.38	12.64	9.57

* Designations see equation (2). Bold fonts are components, for which the values of R^2 on the additive models higher than on independent ones, and *RMSE* values respectively below

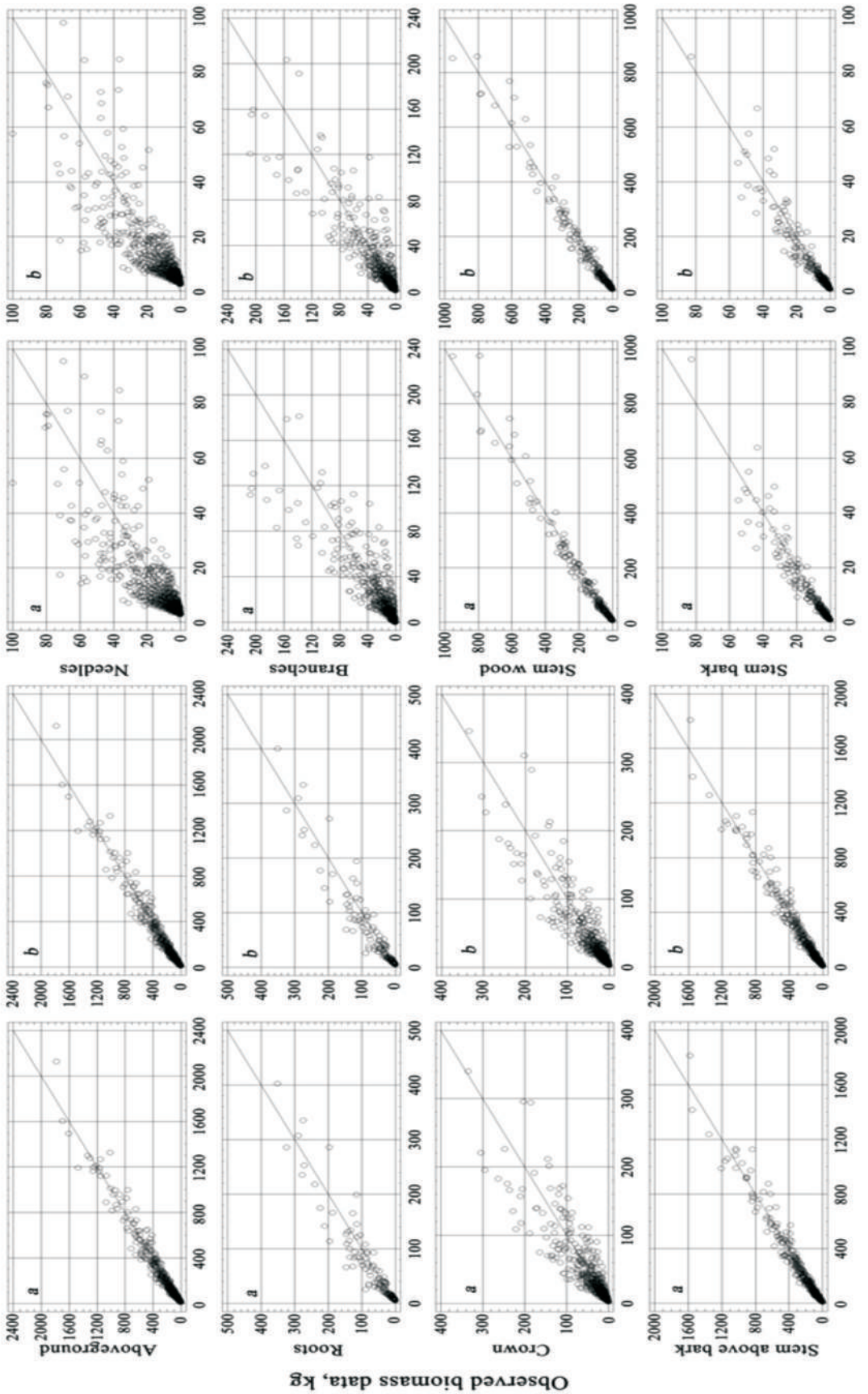

Fig. 1. The ratio of observed values and the values derived by calculation on independent (*a*) and additive (*b*) models of tree biomass.

indices of adequacy compared with independent equations. The ratio of observed values and the values derived by calculation on independent and additive models of tree biomass (Fig. 4) shows the degree of correlativeness of the above-mentioned indices and the lack of visible differences in the structure of residual variance, obtained in two types of models.

CONCLUSIONS

Thus, for the first time in Russian literature the Trans-Eurasian additive model of tree biomass of five species of genus *Picea* spp. is designed using the unique single-tree database. The model is harmonized in two ways: It eliminates the internal contradictions of the component equations and the total one, and in addition, it takes into account the regional (and, respectively species) differences between trees of equal size both in magnitude of common over ground and underground phytomass and its component structure. Trivial mixed-effects model involving the dummy and numeric variables in allometric equations without component additivity, gives biomass estimates harmonized according to eco-regions only but differing by the absolute value of the biomass components (Fu et al 2012). The fundamental distinction and advantage of the developed model of double harmonization is that unlike of trivial mixed-effects model, it provides compatibility and difference by eco-regions not only of absolute values of biomass fractions, but also of their ratios, i.e. reflects regional characteristics of biomass component structure. Thus belied the assertion by Bi et al (2004) that features of component structure of the additive model on several separate levels may not be taken into account, resulting in the harmonized characteristics are possible only for total biomass. The proposed model and corresponding tables for estimating tree biomass makes their possible to calculate spruce stand biomass (t/ha) on Eurasian forests when using measuring taxation.

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Habitat Selection for Lemongrass (*Cymbopogon citrates* Stapf.) Cultivation in Non-Reserve Forests of Southern Western Ghats, Tamil Nadu, India

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Abstract: In Anaimalais of Western Ghats, the two tribal communities, Pulayar and Muduvar are an integral part of ecosystem. These tribes did cultivation of lemongrass and distilled oil. After the declaration of Anaimalais as a protective area for biodiversity conservation, they are not permitted to continue the practice of lemongrass cultivation. However, they are allowed to extract oil from the existing populations, without adaptingany cultivation practices. Therefore, when rehabilitating thesetribes to other non-reserve forests of adjoining regions, habitats suitable for lemongrass cultivation with good oil quality similar to that of in Anaimalais must be identified. The present study aims to evaluate favourable habitat for lemongrass in Udumalpet Range of Anaimalais, among the areas where the lemongrass oil distillation is under practice by the tribal communities. The results of the study show that among the six sites, Kurumalai and Kulipatti are more favourable for lemongrass growth and oil yield. Correlation and regression analyses showed that the rainfall, relative humidity, pH, Ca and Mg contents of soil and altitude are largely determining the biomass production, oil concentration in biomass and citral percent in oil. Therefore, it is suggested to identify habitats in nearby non-reserved forests with more or less similar climatic conditions, soil pH and nutrients and altitude as in Kurumalai and Kulipatti for practicing agroforestry by lemongrass cultivation and oil distillation for tribal communities.

Keywords: Lemongrass biomass, Oil and citral contents, The Anaimalais

Anaimalais of Western Ghats, Tamil Nadu (10˚13′ and 10˚31′N and 76˚52′ and 77˚23′E),the unique ecological tract covering 958km^{2}has an undulating topography and climatic variation which support a wide variety of flora and fauna. The two tribal communities *viz.,* Muduvar and Pulayar who inhabit the reserve forests of this landscape are an integral part of this ecosystem. These tribes cultivated lemongrass (*Cymbopogon citratus*) in fragile areas and rocky slopes until 1970s with good economic returns (Paulsamy et al 2000). But after the declaration of this region as wildlife sanctuary in 1976, cultivation of any sort has been banned in this region even for tribals. However, the tribals are permitted to harvest the existing lemongrass populations for oil extraction in some localities of Udumulpet Range of Anaimalais without posing any environmental problem (Paulsamy 2004). For the better conservation of flora and fauna in recent years no human activities including lemongrass oil distillation are permitted and strict legal measures are imposed against violators. Therefore, to achieve the high degree of species conservation, the tribal communities may be rehabilitated to the adjoining non-reserve forests of nearby areas in coarse of time. For this purpose of rehabilitation, potential areas for lemongrass cultivation with similar environmental conditions of certain areas in Udumalpet Range where the lemongrass production is higher along with better yield and quality of oil must be identified. As the tribals have vast experience with lemongrass production and oil extraction, other non-reserved localities of Anaimalais that have favourable habitat for better lemongrass cultivation needs to be identified. By considering these facts, the present study was aimed to evaluate the best suited habitat among the sites where lemongrass oil distillation is being made by the tribals in Udumalpet Range of Anaimalais.

MATERIAL AND METHODS

Study areas: The study was carried out during, June2013-May, 2014 in six tribal settlement sites in Udumelpet range of Anaimalais *viz*., Kodanthur (ca. 4 ha) (10˚ 300463′ N, 77˚167928′ E), Mavadappu (ca .3 ha) (10˚ 4234′ N, 77˚0561′ E), Kulipatti (ca. 4 ha) (10˚ 437458′ N, 77˚ 051016′ E), Kurumalai (ca.4 ha) (10˚ 341382′ N, 77˚ 003955′ E), Aattumalai (ca. 5 ha) (10˚ 40036′ N, 77˚01464′ E) and Poochikotambarai (ca.5 ha) (10˚3746′ N, 77˚m2144′ E), where the lemongrass oil distillation is practiced by the tribals. The six study sites of this territorial range are situated at the altitude, Kodanthur-520m, Mavadappu-690m, Kulipatti-700m, Kurumalai-740m, Aattumalai-620m and Poochikotambarai-490m above MSL. The soil of all study

sites was sandy loam with the pH varied between 7.3 (Kodanthur) and 8.8 (Kurumalai) (Table 1). The contents of nutrients in the soil also showed considerable variation between the sites studied (Table 5).The climatic data such as maximum and minimum temperatures, rainfall and relative humidity were obtained from Kadambarai hydropower station for Poochikotambarai and Mavadappu, 0.9 km away from the station, Navamalai hydropower station for Kulipatti, Kurumalai and Aattumalai which are 0.7, 1.1 and 1.3 km away from the power station respectively and Amaravathy Reservoir for Kodanthur, 1.8 km away from the station. Both south-west monsoon (June-August) and north-east monsoon (October-November) were effective almost in all sites studied. The climatic factors were much different between the study sites during the study period (Fig. 1). The higher mean annual rainfall of 917 mm was recorded in Kulipatti site followed by 746mm in Kurumalai, 708 mm in Mavadappu, 659 mm in Aattumalai, 627 mm in Kodanthur, and 604 mm in Poochikotambarai. The maximum temperature varied between 20˚C (Kurumalai during December 2013) and 40˚C (Aattumalai during April, 2014) and that of the minimum ranged between16˚C (Poochikotambarai during December 2013) and 32˚C (Kulipatti during May, 2014). The relative humidity was varied between 53 per cent (Poochikottambarai during March, 2014) and 86 percent (Kurumalai during October, 2013).

Tribal communities: Among the six study sites, the tribal community, Muduvar has settlements in Attumalai and Poochikotambarai with 32 (7 families) and 36 (8 families) members respectively. In the other four sites *viz.,* Kodanthur, Mavadappu, Kurumalaiand Kulipatti, the tribal community, Pulayar numbering 40 (8 families), 92 (12 families), 61 (8 families) and 30 (6 families) respectively are residing. In addition to the maintenance of lemongrass community by eradicating dicot weeds and other unwanted monocots, these two tribal communities are engaged in a host of other activities like cattle rearing, honey collection, casual labour for forest department etc.

Soil attributes: Soil samples from A_1 layer (0-10cms) (1kg in each site) in triplicate were collected at all times of harvesting the lemongrass and mixed thoroughly to obtain composite sample. Working samples were obtained to analyze the soil for pH (Ghosh et al 1983), total nitrogen (Jackson 1962), available phosphorous (Bray and Kurtz 1945) and available potassium, calcium and magnesium (flame photometric method, Stanford and English 1949).

Biomass production: The tribals harvested lemongrass from the study sites6 times during June, August, October and December of 2013 and February and April of 2014 during the study period. The harvested grasses were sun dried adequately for 3-5 days and weighed before oil distillation. Thus the data on dry weight of total aboveground lemongrass for the total area of all the sites during different harvesting times were collected from the tribals. These biomass data of six harvesting times collected for respective site were pooled together over a study period to arrive the annual production of lemongrass (Singh and Yadhava 1974). As the grass was completely scraped at two months interval, the biomass harvested at every time is its production in the total area of the respective site.

Oil yield: The data on oil yield was collected site-wise from the respective tribal community directly after distillation every time. Percentage of oil content in biomass was arrived by using the data on total grass biomass harvested and oil content (%) available in grass. Oil yield in all harvesting times in each site were summed to get annual production of lemon grass oil.

Citral estimation: Oil samples collected from the tribal communities for each site were analyzed for citral content by following sodium bisulphate method (Guenther 1972). A 10 ml of oil was taken in a beaker to which 30g sodium bisulphate and 100 ml distilled water were added. This mixture was boiled and shaken well for 10 min. After the formation of a white precipitation, the beaker was dipped in water bath for 45 min to dissolve the precipitation completely. Then the beaker was cooled under tap water. The non-citral portion of the oil separates as an oily layer which has been measured conveniently in the neck of a cassia flask and there by determined the citral content of the oil.

Statistical analysis: Statistical significance between the sites for oil and citral contents were determined using one-way analysis of variance (SPSS 10.0) and the means were separated by Duncan's Multiple Range Test (DMRT) (P<0.05). Correlation coefficients were calculated (SPSS, 1998) to determine the relationships between production attributes of lemongrass (biomass production, oil content in biomass and citral percentage in oil) and certain climatic and soil attributes and attitude. Multiple regression analysis was used to test the interactive effect of climatic, soil and altitudinal factors on the production attributes of lemongrass.

RESULTS AND DISCUSSION

The range of minimum and maximum temperatures (16 and 32˚C and 20 and 40˚C respectively) and annual rain fall (527-847mm) recorded across the study sites during the study period of one year indicate the prevalence of suitable climate for lemongrass cultivation (Nambiar and Matela 2012) in Udumelpet range, the Anaimalais (Fig. 1). The relative humidity generally ranged between 53 and 86 percent. The soil of all study sites was sandy loam with the pH

varied between 7.3 and 8.8 during the study period (Table 1). The alkaline pH noted in the lemongrass community at all times of sampling during the study year showed the preference of alkalinity in soil for this grass growth (Quadry 2008-2009). The nutrient contents of soils of the study sites were generally they varied significantly between the sites studied (Table 5). The percentage variations of nutrients among the soils of study sites are as follows: N – 0.85 (Poochikotambarai) and 0.96 (Kurumalai), P-0.04 (Kodanthur, Aattumalai and Poochikotambarai) and 0.06 (Kulipatti and Kurumalai), K-0.15 (Poochikotambarai) and 0.26 (Kurumalai), Ca-0.10 (Poochikotambarai) and 0.14 (Kurumalai) and Mg-0.02 (Kodanthur, Aattumalai and Poochikotambarai) and 0.03 (Mavadappu, Kulipatti and Kurumalai). It indicates that Kurumalai and Kulipatti sites registered higher nutrients in their soils than that of the other sites.

Biomass production: The above ground biomass production estimated during the harvesting times in the study year (Jun, 2013-May, 2014) was higher at the end of the south-west monsoon period, August, 2013 in all the study sites and ranging between 1950 and 2750 kg/ha in Poochikotambarai and Kurumalai respectively (Fig. 2). It may be attributed to the fact that with the onset of monsoon in June, there was an active biomass build up and it attained maximum during August after two months of vegetative growth. Paulsamy et al (2000) showed an enhanced biomass production of lemongrass at the end of south-west monsoon season in some other parts of Anaimalais, the Western Ghats. The lemongrass production decreased progressively towards summer from August at all sites. Low or no rainfall except in the month of October, 2013 perhaps be the reason for this fact. However, lower biomass production during the rainy month of October, 2013 in all sites may be due to less quantity of nutrients available in soil caused by leaching owing to continued rain since June, 2013. The annual aboveground biomass production of lemongrass was greater in Kurumalai (11450 kg/ha) followed by Kulipatti (10100 kg/ha), Mavadappu (9100 kg/ha), Aattumalai (8550 kg/ha), Kodanthur (8000 kg/ha) and Poochikottambarai (7250 kg/ha) (Fig. 2 and Table 2). The annual biomass recorded at Kulipatti, Mavadappu, Aattumalai, Kodanthur and Poochikotambarai sites was 11.79-36.92 per cent lesser than those recorded at Kurumalai site. However, the production estimates for all these sites are not comparable to that of other cultivated fields of lemongrass elsewhere (Evans 2002, Aradhna and Yashpal 2014) as no cultivation practices like weed control, either organic or inorganic fertilizer application, annual burning, reseeding, are followed in the study sites. As in tropical regions, rainfall is the most influential factor for the vegetative growth of plants (Swamy et al 2010), the higher rainfall occurred in Kurumalai ranked first with respect to biomass production. Further, the levels of annual production in different study sites varied considerably according to the rainfall in the respective sites. This clearly indicates that rainfall is the major factor that determines the lemongrass production in the study areas. In addition, high alkalinity in the soils of the two study sites, Kurumalai and Kulipatti (annual mean pH 8.3-8.5) was also found to be a favourable factor for the higher biomass production of lemongrass (Srivastava et al 2013).

Table 1. Changes in soil pH of the lemongrass communities in the study sites during the study period

Year and Month	Site					
	I	II	III	IV	V	VI
2013						
Jun	7.9	7.8	8.5	8.8	7.9	7.9
Aug	7.6	7.6	8.3	8.3	7.7	7.5
Oct	7.3	7.5	8.3	8.3	7.7	7.3
Dec	7.5	7.7	8.5	8.5	7.7	7.7
2014						
Feb	7.6	7.9	8.3	8.6	7.8	7.7
Apr	7.7	8.1	8.1	8.6	7.9	7.7
Mean	7.6[b]	7.8[b]	8.3[a]	8.5[a]	7.8[b]	7.6[b]

Sites – I-Kodanthur, II-Mavadappu, III-Kulipatti, IV-Kurumalai, V-Aattumalai and VI-Poochikotambarai

Oil yield: The oil content in the aboveground biomass of lemongrass for the studied sites varied significantly between harvests (Table 6). The study sites, Kurumalai and Kulipatti recorded a higher oil content of 0.68 and 0.63 per cent, respectively, while the sites at Kodanthur and Poochikotambarai contained less oil content of 0.47and 0.48 per cent respectively. This may be attributed to the synergetic effect of all climatic and soil variables (Pirzad et al 2006). Brant et al (2008) also explained that various environmental factors collectively alter the quantitative and qualitative aspects of essential oils in plants by making changes in metabolism so as to produce defense chemicals against the adverse conditions.

Citral estimation: Citral is (3,7-dimethyl-2,6-octadien-1-al), the main constituent of lemongrass oil (Wilson et al 2002, Dudai et al 2005, Nhu-Trang et al 2006) varied markedly between the sites and harvests (Table 6). Significantly higher percentage of citral (88%) was in Kurumalai site (site IV) during summer month of April, 2013 and that of the lower occurred in Aattumalai site (site V) during the rainy month of August, 2013. Generally at all sites, the citral content in the oil was more during dry months (February and April) and less

during wet months (June-October). The mean annual percentage of citral content was higher in the lemongrass of Kurumalai site (81.3%), while the lower was determined in Aatumalai site (76.7%). Alsafar and Al-Hassan (2009) reiterate that different communities of same macroclimatic zone exhibit variation in their metabolites according to the combined action of microclimatic factors. Therefore, the coupled actions of environmental factors exist in the studied sites perhaps be the reason for this fact. As the concentration of oil in the lemongrass biomass at different periods of harvest varied, the oil production is also varied markedly between the sites (Table 2). The lemongrass of Kurumalai (site IV) recorded the highest oil production of 77.8kg/ha/yr and lowest of 34.8kg/ha/yr was recorded in Poochikotambarai (site VI). This was also reflected in the annual revenue generated from lemongrass oil distillation in the studied sites (Table 2). The tribal communities at Kurumalai (site IV) and Kulipatti (site III) sites earned greater returns of Rs. 1,32,260 and Rs. 1,08,120, respectively through lemongrass oil extraction. On the other hand, the tribals at Kodanthur (site I), Poochikotambarai (site VI) and Attumalai (site V) obtained less economic return due to poor oil concentration and hence the oil production in their sites.

Statistical analysis: An analysis of data elucidated several functional relations among the variables of lemongrass production (biomass, oil yield and citral content) and certain climatic, soil and altitudinal factors (Table 3). The rainfall and relative humidity and altitude were positively correlated to biomass production (r = 0.854 and 0.587, P<0.01 and 0.335, P<0.05). It is well known that in tropical communities, rainfall being a limiting factor influences largely on growth and biomass production (Gunarathne and Perera 2014). Taiz and Zeiger (2004) explained that high relative humidity favours stomatal opening which causes free flow of gases for photosynthesis, results in increasing of biomass production provided adequate rainfall occurs. The nutrients of soil *viz.,* Ca and Mg were also have positive correlations with the biomass production of lemongrass (r=0.505 and 0.468, P<0.01). Similar kind of observation on the requirement of nutrients like Ca and Mg for better growth of *Cymbopogon* spp. was made already (Jayalakshmi and Mohanarao 2013, Singh et al 2014). As the variations in altitude and annual rainfall in the study sites were directly related to each other, it is presumed to have the positive correlation between biomass production and altitude. Other studies have also demonstrated the positive relation of soil pH to lemongrass biomass (Jayasinha et al 1999, Paulsamy et al 2000). Relative humidity was positively correlated to per cent oil content in lemongrass (r = 0.424, P<0.01). The minimum temperature was negatively correlated to oil per cent (r = −

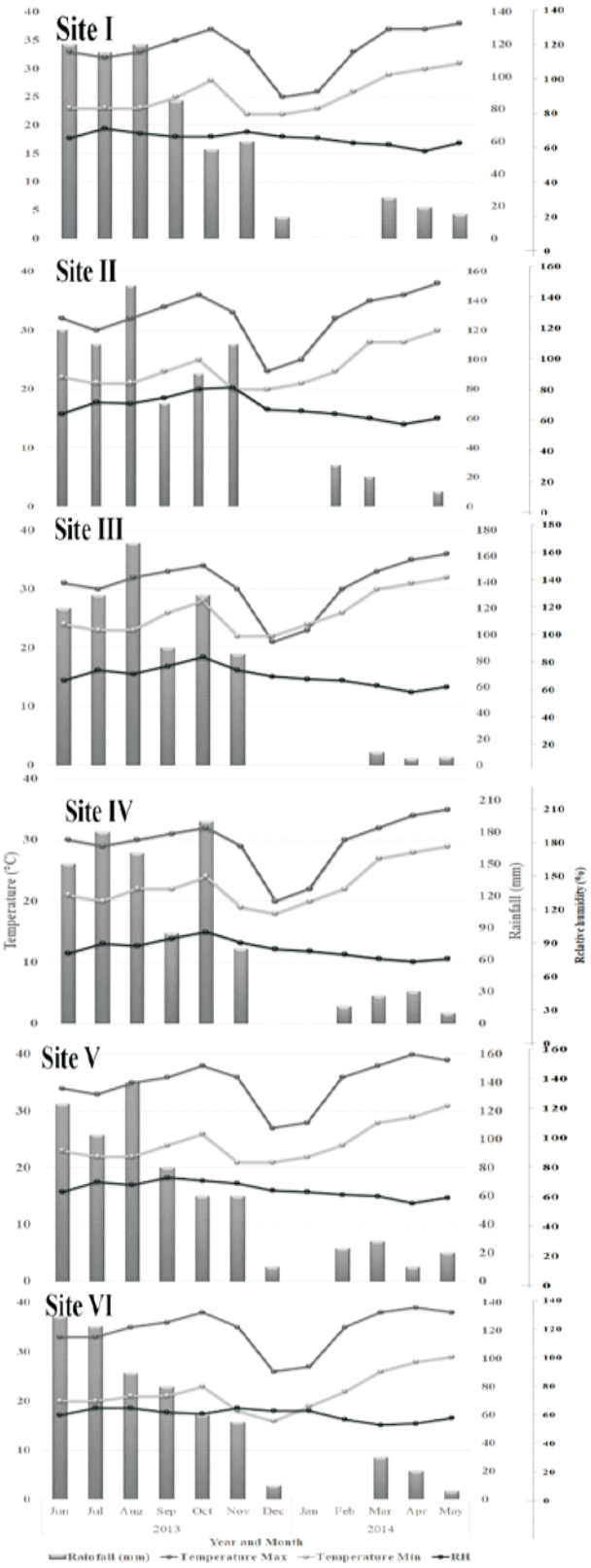

Fig. 1. Monthly maximum and minimum temperatures, total rainfall and relative humidity of the study sites in Anaimalais, the Western Ghats for the study period of one year from June, 2013 to May 2014

0.650, *P*<0.01). Low temperature generally results in closure of stomata in plants there by reducing oil volatilization, a defense mechanism to resist such adverse condition (Castelo et al 2012). This fact may be the possible reason for the inverse relationship of low temperature with oil per cent in lemongrass. The soil pH was positively correlated to the important chemical constituent of the oil, citral (r = 0.437, P<0.01). Results of many studies report that alkaline pH generally enhanced not only the biomass production but also the chemical constituents of lemongrass oil (Siribel et al 2001). It is evidenced that the citral content determined was higher in Kurumalai (site IV) (81.3%) and Kulipatti (site III) (78.7%) where the soil contained significantly higher alkalinity at all times of sampling during the study period when compared to other sites (Table 3). Plants growing in well drained soils like hilly slopes are highly adapted to alkalinity and may be more sensitive to changes in soil pH by producing certain secondary metabolites like essential oils (Evans 1996). This is practically true for lemongrass, which is known to grow better in alkaline soils (Quadry 2008-2009) and is producing high citral content in its vegetal parts. The soil nutrients *viz.,* N, P and K were also positively correlated to citral per cent (*r*=0.791, 0.713 and 0.714, *P*<0.01). These findings were in conformity with those of Singh et al (2005). In Pearson′s correlation, no significant correlation was found between biomass production and soil pH, oil per cent in biomass and rainfall, and citral percentage and minimum temperature and altitude. On the other hand the nitrogen content exhibited negative correlation to biomass production. Similarly, oil content and citral percentage were negatively correlated to minimum temperature and soil K content, and rainfall and relative humidity, respectively. A number of synergistic effects of climatic, soil and altitudinal factors on biomass production, oil content and citral percentage in the oil of lemongrass were detected, but for the sake of brevity, only the best equations for production variables are presented (Table 4). Therefore, despite the dominant role played by the rainfall, relative humidity, soil Ca and Mg contents and altitude for dry matter production, relative humidity for oil content and pH, N, P and Kof soil for citral percentage in oil, the multiple regression analysis showed relationships involving almost all climatic and soil variables studied. Previous literature also documents many complex interactions between climatic and soil factors on growth and oil yield variables of lemongrass (Paulsamy et al 2000, Paulsamy 2004).

The present investigation clearly suggests that lemongrass biomass production oil contents in biomass and citral percentage in oil are the functions of climatic factors particularly rainfall and relative humidity, soil nutrients and pH and altitude but their intensity of influence vary according to other climatic variables like maximum and minimum temperatures. Further, the environmental factors that exist in Kurumalai (site IV) and Kulipatti (site III) are more favorable

Table 2. Annual biomass production and area of lemongrass community, content and production of oil and revenue generated in the study sites

Sites	Annual production of lemongrass (kg/ha)	Area of lemon grass community (ha)	*Oil content (%)	Oil production (kg/ha/yr)	**Annual revenue (Rs/total area of grass community)
I	8000	4	0.47	37.6	63920
II	9100	3	0.55	50.0	63750
III	10100	4	0.63	63.6	108120
IV	11450	4	0.68	77.8	132260
V	8550	5	0.53	45.3	96262
VI	7250	5	0.48	34.8	73950

*Average content in six harvested biomass in an year.
**Calculated on basis of average price of oil (Rs. 425/kg) sold by the respective tribal community during the study year, 2013-2014.
See Table 1 for details of site

Table 3. Correlation coefficient (*r*) between the variables of lemongrass production and certain environmental factors in Udumalpet range, the Anaimalais

Lemongrass production attributes	Climatic variables				Soil variables						
	Ma.t	Mi.t	Rf	RH	pH	N	P	K	Ca	Mg	Alt
Biomass	-0.158	-0.276	0.854**	0.587**	0.241	-0.372*	-0.234	-0.042	0.505**	0.468**	0.335*
Oilyield	-0.2	-0.650**	0.087	0.424**	-0.193	-0.323	-0.232	-.383*	-0.132	-0.255	-0.152
Citral	-0.157	0.287	-0.514**	-0.365*	0.437**	0.791**	0.713**	0.714**	0.174	0.078	0.300

Ma.t – Maximum temperature; Mi.t – Minimum tempertature, Rf – Rain fall; RH – Relative humidity; Atl. – Altitude.
**Correlation is significant at 0.01 level, *Correlation is significant at 0.05 level

Table 4. Multiple regression between lemongrass production attributes (biomass production, oil per cent in biomass and citral per cent in oil) and certain environmental variables, maximum and minimum temperatures (Ma.t and Mi.t respectively) rainfall (Rf), relative humidity (RH), soil pH and altitude (alt)

Lemon grass production attributes	Equation	*r*	*p*
Biomass	Y= 4947.99 – 42.69 Ma.t + 3.75 Mi.t + 5.13 Rf – 18.96 RH −0.39 pH –3822.23 N + 896.80 P + 1119.75 K + 14962.50 Ca + 12278.04 Mg −0.63 alt	R=0.947	0.001
	Y= 4828.09 – 39.78 Ma.t + 5.13 Rf – 19.15 RH + 4.58 pH – 3741.02 N + 1088.56 P + 1040.65 K + 14959.22 Ca + 12521.35 Mg −0.61 alt	R=0.947	0.001
	Y= 4945.07 – 42.68 Ma.t + 3.74 Mi.t + 5.13 Rf – 18.96 RH – 3821.46 N + 894.23 P + 1118.11 K + 14958.92 Ca + 12274.85 Mg −0.63 0.893 alt	R=0.947	0.001
	Y= 4882.38 – 43.27 Ma.t + 4.15 Mi.t + 5.12 Rf – 18.71 RH + 2.48 pH – 3753.08 N + 1208.96 K + 14816.21 Ca + 11880.39 Mg – 0.59 alt	R=0.947	0.001
	Y= 4742.76 – 43.93 Ma.t + 2.27 Mi.t + 5.19 Rf – 20.93 RH + 15.96 pH – 3436.53 N + 1692.52 P + 15070.18 Ca + 13189.5 Mg – 0.51 alt	R=0.947	0.001
	Y= 4785.35 – 44.11 Ma.t + 1.19 Mi.t + 5.24 Rf −22.31 RH + 1.42 pH – 3307.37 N – 1151.63 P + 476.00 K + 13675.37 Ca + 13357.4 Mg	R=0.948	0.001
Oil yield	Y= −1.87 + 0.02 Ma.t – 0.04 Mi.t – 0.00042 Rf + 0.0095 RH + 0.14 pH + 1.72 N – 2.62 P – 1.86 K + 0.85 Ca – 4.03 Mg – 6.30 alt	R=0.917	0.001
	Y= – 1.96 + 0.020 Ma.t – 0.037 Mi.t – 0.00041 Rf + 0.0098 RH + 0.15 pH + 1.78 N – 2.98 P – 1.83 K – 3.78 Mg + 2.77 alt	R=0.915	0.001
	Y= – 1.89 + 0.02 Ma.t – 0.04 Mi.t – 0.00041 Rf + 0.0092 RH + 0.14 pH + 1.77 N – 2.83 P – 1.93 K + 0.72 Ca – 4.12 Mg	R=0.916	0.001
Citral	Y= – 43.68 + 0.37 Ma.t – 0.40 Mi.t – 0.00059 Rf – 0.11 RH + 1.20 pH + 27.59 N + 57.29 P + 20.94 K – 70.74 Ca – 32.40 Mg + 0.012 alt	R=0.872	0.001
	Y= 47.84 + 0.25 Ma.t – 0.32 Mi.t – 0.13 RH + 1.15 pH + 28.64 N + 57.14 P + 17.15 K – 78.16 Ca – 22.16 Mg + 0.011 alt	R=0.870	0.001
	Y= 43.89 + 0.39 Ma.t – 0.41 Mi.t – 0.0015 Rf – 0.11 RH + 1.10 pH + 27.54 N + 68.28 P + 18.11 K – 73.55 Ca + 0.011 alt	R=0.871	0.001

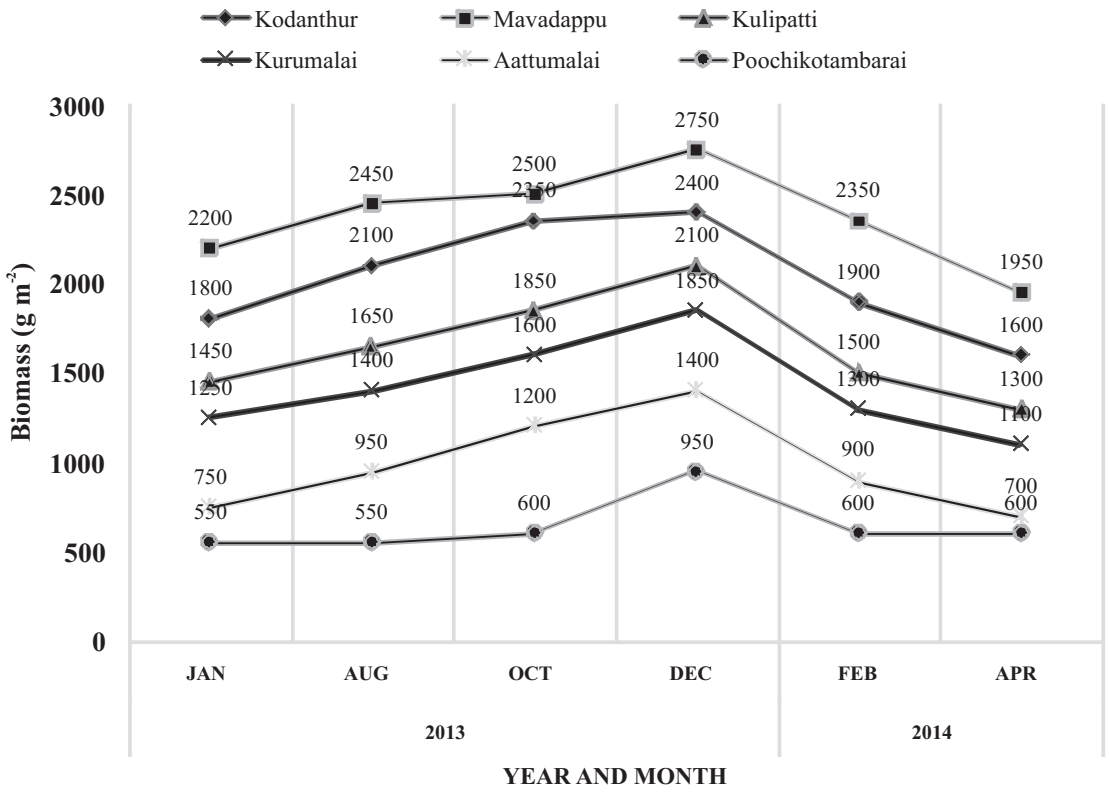

Fig. 2. Aboveground biomass of lemongrass in the study areas in Anaimalais, the Western Ghats during the sampling months

Table 5. Variation in the soil nutrient (%), in soils of A_1 horizon (0–10cms) in the study sites

	*Site					
	I	II	III	IV	V	VI
Soil nutrient						
Nitrogen	0.12	0.12	0.14	0.11	0.14	0.12
Phosphorous	0.12	0.12	0.14	0.11	0.14	0.12
Potassium	0.26	0.27	0.30	0.28	0.28	0.28
Calcium	0.08	0.08	0.12	0.09	0.09	0.10
Magnesium	0.05	0.05	0.06	0.05	0.04	0.05

*See Table 1 for details of site

for lemongrass growth and quality production of oil. Therefore, areas with similar climatic conditions as in these two sites may be identified in the adjoining non-reserve forest areas for the successful rehabilitation of triabal communities of Annamalais by better agroforestry practices through lemongrass cultivation.

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Pattern of Floristics and Biodiversity of Angiosperms of Purna Wildlife Sanctuary, Mahal, Gujarat

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Abstract: The present study illustrates the floristic and plant biodiversity resources of Purna Wildlife Sanctuary, Mahal, Dang district, Gujarat during the period of 2010-2013. A total 70 plant species were recorded which were represented by 46 families and 64 genera. Out of 70 species, 46 tree species, 22 herbs and 2 orchids. The maximum IVI was recorded for *Tectona grandis* (44.532) and followed by *Terminalia tomentosa*, *Sterculia urens*. Among the herbs species, the highest Shannon-Wiener index was for *Nervilia aragoana* (0.197). The present quantitative checklist indicates the potential plant resources of the range which can be used for future biodiversity inventories and species conservation.

Keywords: Phytosociological, Species richness, IVI, Shannon's diversity index, Purna Wildlife Sanctuary, Mahal, Gujarat

Forest (either pure or artificial) is an important for biodiversity, environmental and ecological benefits, food security, soil conservation potential, mitigation of the impact of climate change and job opportunity in tropics. Large scale of deforestation, human settlements, agricultural expansion, pollution, introduces invasive species, and other infrastructure related to development over the last century led to a rapid decline of tropical forests throughout the world, which in turn affected the biodiversity, climate change, ecological services, soil fauna, soil productivity and the livelihoods of forest dwelling as well as rural people (Kumar and Tiwari 2017, Kumar and Tripathi 2017). On the other hand, lack of technical and scientific infrastructure makes efforts of sustainable management of these natural resources extremely difficult (Stock 2010). Jhariya and Oraon (2012) reported that global biodiversity crisis has given rise to a growing concern at the prospect of a rapidly accelerating loss of species, population, domesticated varieties, medicinal herbs and natural habitats. The need of the hour is conservation and sustainable use of biodiversity as an integral component of economic development. All the species are not equally important but there are only a few overtopping species which by their bulk and growth modify the habitat and control the growth of other species of the community as these species are called dominants. The immense variety of the climatic, edaphic and altitudinal variations in this region pay the way for a great range of ecological habitats for the Gujarat. Gujarat has poor forest cover (less than 10% forest land of its geographical area) but it has fairly rich biodiversity (Kumar et al 2013). A major constraint faced in assessing threat status and ecological significance of rare, endangered and threatened species is lack of continuous monitoring over and over again in the previously explored areas or new areas often referred as unexplored areas. Thus, species once common remains common even though population becomes scarce or a rare species turns common as the forms of rarity are less understood (Kumar 2015). Understanding species diversity and distribution patterns is important for helping managers to evaluate the complexity and resources of these forests. In this view, objectives of this study was to analyze the patterns of species richness, species composition for conservation though best management, so that expansion of the protected area network can be suggested.

MATERIAL AND METHODS

The investigation was carried out the phytosociological study of Purna Wildlife Sanctuary, Mahal, Dang district at Gujarat which is near to Northern zone of Western Ghats (20˚ 45′-20˚ 75′ N and 73˚ 04′-73˚ 07′E) during 2010-2013 (Fig. 1). The average mean temperature varied from 28° −36° C and S−W monsoon brings a humid climate from mid-June to mid−September while the average rainfall was 130 cm. The land is drained by rivers and thus is a vast alluvial deposit of black soil and red loam. Quadrats were laid out to have maximum representation of different types of vegetation. Selection of

sites for sampling of vegetation was done by random sampling procedure. Accordingly quadrats of 20 x 20 m for the tree species and 2 x 2 m plots were laid out randomly for sampling shrub layer (Fig. 2).

To collect information on ground layer and other herbaceous species, quadrats of 1 x 1 m size were laid out within the tree quadrats of all corners and one in center. The girth at breast height (gbh) of all individuals in each quadrate was measured for all species of trees and woody climbers (if it available). All individuals with gbh > 30 cm were considered as trees (Parthasarathy and Karthikeyan 1997) were botanically identified by Revision of the Flora of Bombay Presidency (Blatter and McCann 1926–1935); Flora of Saurashtra (Santapau 1962); Vegetation of Dangs district (Jain 1963); Flora of Gujarat state (Shah 1978); Floristic, phytosociology and ethnobotanical study of Umarpada forest in South Gujarat (Vashi 1985); this also includes a sketch of the Flora of Gujarat (Shah et al 1981); and Flora of Saurashtra Vo. I and II (Bole and Pathak 1988). Basal area of plants was measured following Philips (1959). The primary data recorded on number of individuals in a species and girth was analyzed for secondary attributes like density and frequency, following standard phyto-sociological methods of Misra (1968). Relative values were calculated by following Philips (1959).

Importance Value Index (IVI): Data collected were subjected to analysis by assessing relative density, relative frequency and relative dominance. Based on these parameters, the Importance Value Index (IVI) at species level was calculated following the method of Cottam and Curtis (1956). The IVI was calculated following the method of Cottam and Curtis (1956), Kent and Coker (2001), as:

Density (ni): Number of individuals of the species 'A'

Dominance (D): Sum of the basal areas (at 1.37 m) of individuals of the same species

$$\text{Relative density (RD)} = \frac{\text{Total no. of individuals of species}}{\text{Total no. of individuals of all species}} \times 100$$

$$\text{Relative Frequency (RF)} = \frac{\text{Frequency value of individual species}}{\text{Sum of frequency value of all species}} \times 100$$

$$\text{Relative Dominance (RD)} = \frac{\text{Total basal area of individual species}}{\text{Sum of total basal area of all species}} \times 100$$

Shannon's diversity index: The species richness and Shannon-Wiener index is used to describe the species diversity (Whittaker 1972). Species richness (N) was measured as the absolute number of unique species in each sample plot; Shanon-Wienner index (H') was calculated

$$\text{Shanon} - \text{Wienner index (H)} = -\sum_{i=1}^{s} Pi\ In\ Pi$$

Where, H=Shannon-Wiener index; S= the number of species; ln = log base$_n$ and *Pi* is the relative importance value of species.

Simpson's floristic diversity index: The dominance of the species was computed by using Simpson's index (Simpson, 1949) as under:

$$\text{Simpson's index(CD)} = \sum_{i=0}^{s} (pi)^2$$

Here, pi=the proportion of individuals or the abundance of the ith species *i.e.*, (ni/N) whereas, S= Number of species in the plot i=1; ni = Number of individuals of the species i and N= Total number of individuals in the plot.

RESULTS AND DISCUSSION

The present investigated based three years of study of

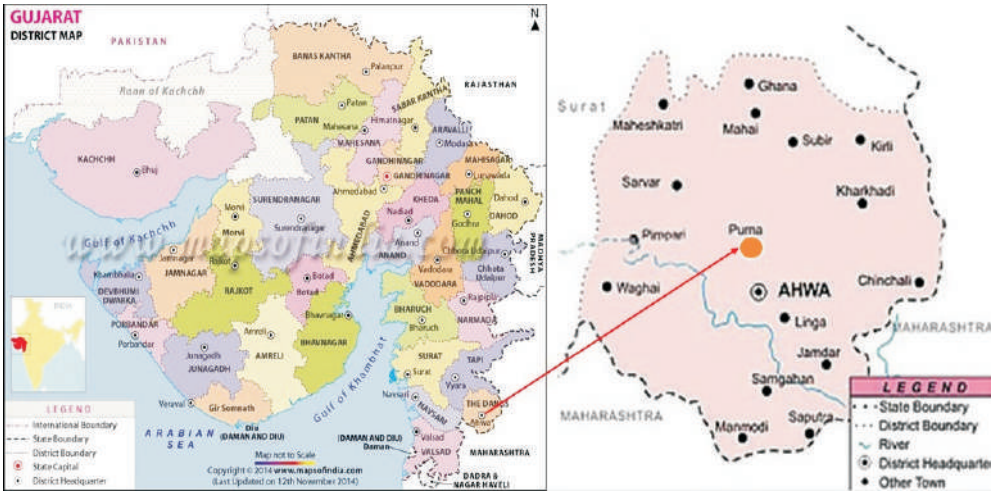

Fig. 1. Geographic map of the study area and dark dot indicate the place of the research area

Table 1. Density, basal area, Importance value index and Shannon-Wiener index of the tree species in Purna Wildlife Sanctuary, Mahal, Gujarat

Species name	F	D	BA	RF	RD	RDOM	IVI	H′	Conc. of D	Simpson
Acacia catechu	0.4	0.7	0.70	3.51	3.40	3.56	10.46	0.1149	0.0012	
Alangium salvifolum	0.1	0.1	0.02	0.88	0.49	0.09	1.45	0.0259	0.0000	
Albizia lebbeck	0.1	0.1	0.13	0.88	0.49	0.70	2.06	0.0259	0.0000	
Albizia procera	0.2	0.4	0.45	1.75	1.94	2.27	5.97	0.0765	0.0004	
Anogeissus latifolia	0.3	0.3	0.41	2.63	1.46	2.09	6.17	0.0616	0.0002	
Bombax ceiba	0.1	0.1	0.18	0.88	0.49	0.95	2.31	0.0259	0.0000	
Boswellia serrata	0.2	0.2	0.08	1.75	0.97	0.44	3.16	0.0450	0.0001	
Bridelia retusa	0.2	0.2	0.03	1.75	0.97	0.15	2.88	0.0450	0.0001	
Butea monosperma	0.5	0.9	0.47	4.39	4.37	2.38	11.13	0.1368	0.0019	
Callophylum inophyllum	0.1	0.1	0.11	0.88	0.49	0.59	1.95	0.0259	0.0000	
Careya arborea	0.2	0.3	0.05	1.75	1.46	0.27	3.49	0.0616	0.0002	
Cassia fistula	0.1	0.2	0.06	0.88	0.97	0.32	2.17	0.0450	0.0001	
Cassia siamea	0.1	0.2	1.01	0.88	0.97	5.13	6.98	0.0450	0.0001	
Cassine glauca	0.2	0.3	0.08	1.75	1.46	0.40	3.61	0.0616	0.0002	
Cordia dichotoma	0.1	0.1	0.01	0.88	0.49	0.05	1.41	0.0259	0.0000	
Dichrostachys cineria	0.1	0.1	0.02	0.88	0.49	0.11	1.47	0.0259	0.0000	
Dillenia pentagyna	0.2	0.3	0.09	1.75	1.46	0.49	3.70	0.0616	0.0002	
Diospyros melanoxylon	0.7	0.9	0.39	6.14	4.37	1.98	12.49	0.1368	0.0019	
Erythrina indica	0.1	0.1	0.01	0.88	0.49	0.09	1.45	0.0259	0.0000	
Ficus racemosa	0.5	0.5	2.49	4.39	2.43	12.58	19.40	0.0903	0.0006	
Gmelina arborea	0.1	0.1	0.13	0.88	0.49	0.69	2.05	0.0259	0.0000	
Grewia tiliaefolia	0.1	0.1	0.01	0.88	0.49	0.09	1.45	0.0259	0.0000	
Haldina cordifolia	0.3	0.4	0.09	2.63	1.94	0.49	5.07	0.0765	0.0004	
Hardwickia binata	0.1	0.1	0.03	0.88	0.49	0.19	1.55	0.0259	0.0000	
Heterophragma quadriloculare	0.2	0.2	0.23	1.75	0.97	1.20	3.93	0.0450	0.0001	
Holoptelea integrifolia	0.3	0.3	0.06	2.63	1.46	0.32	4.41	0.0616	0.0002	
Madhuca indica	0.2	0.4	1.49	1.75	1.94	7.53	11.22	0.0765	0.0004	
Miliusa tomentosa	0.1	0.1	0.15	0.88	0.49	0.77	2.14	0.0259	0.0000	
Mitragyna parvifolia	0.2	0.3	0.43	1.75	1.46	2.18	5.39	0.0616	0.0002	
Morinda tomentosa	0.1	0.1	0.02	0.88	0.49	0.11	1.47	0.0259	0.0000	
Oroxylum indicum	0.5	0.8	0.22	4.39	3.88	1.15	9.42	0.1262	0.0015	
Ougeinia oojeinensis	0.3	0.3	0.26	2.63	1.46	1.32	5.41	0.0616	0.0002	
Phyllanthus emblica	0.1	0.1	0.50	0.88	0.49	2.55	3.91	0.0259	0.0000	
Pterocarpus marsupium	0.1	0.1	0.11	0.88	0.49	0.57	1.93	0.0259	0.0000	
Sapindus emarginatus	0.1	0.1	0.06	0.88	0.49	0.35	1.71	0.0259	0.0000	
Schleichera oleosa	0.2	0.2	0.09	1.75	0.97	0.48	3.21	0.0450	0.0001	
Sterculia urens	1	2	0.85	8.77	9.71	4.31	22.79	0.2264	0.0094	
Syzygium cumini	0.2	0.2	0.65	1.75	0.97	3.33	6.05	0.0450	0.0001	
Tectona grandis	1	4.1	3.14	8.77	19.90	15.86	44.53	0.3213	0.0396	
Terminalia arjuna	0.1	0.2	0.02	0.88	0.97	0.11	1.96	0.0450	0.0001	
Terminalia bellirica	0.2	0.3	0.49	1.75	1.46	2.51	5.72	0.0616	0.0002	
Terminalia tomentosa	1	3.6	3.48	8.77	17.48	17.58	43.83	0.3048	0.0305	
Thespesia populnea	0.1	0.1	0.02	0.88	0.49	0.13	1.49	0.0259	0.0000	
Wrightia tinctoria	0.1	0.1	0.02	0.88	0.49	0.10	1.47	0.0259	0.0000	
Wrightia tomentosa	0.1	0.1	0.17	0.88	0.49	0.88	2.24	0.0259	0.0000	
Zizyphus mauritiana	0.1	0.1	0.11	0.88	0.49	0.57	1.93	0.0259	0.0000	
Grand Total	11.4	20.6	19.84	100	100	100	300	3.0312	0.0907	0.909

the flora of Purna Wildlife Sanctuary indicate, total of 70 species which were represented by 46 families and 64 genera (Table 1). Out of these, 46 tree species 22 herb and 2 orchids (Table 2). In tree species *Tectona grandis* was the dominant species and followed by *Terminalia tomentosa* and *Sterculia urens*. Other dominance species were recorded *Ficus racemosa, Diospyros melanoxylon, Butea monosperma, Acacia catechu* and *Oroxylum indicum.* In herb, *Gloriosa superba* was the dominant species. In orchid, *Nervilia aragoana* was dominant and followed by *Nervilia discolor.* Taxonomically, woody vegetation of Purna Wildlife Sanctuary, Fabaceae was most diverse family with three number of species followed by Amaranthaceae, Asteraceae and Malvaceae (Fig. 3). Among the tree species, the maximum IVI recorded for *Tectona grandis* (44.53) and followed by *Terminalia tomentosa* (43.83), *Sterculia urens* and *Ficus racemosa* respectively (Table 1). In herbs species, the highest Shannon-Wiener index recorded for *Gloriosa superba* (0.197) (Table 2).

In a diverse community the species are adapted to narrowly drawn niches and are extraordinarily successful within those niches. On the basis of basal area and density, *Shorea robusta* prefers the mid-hills at 900–1100 m and *Syzygium cumini* prefer to grown in upper hills (1100–1350 m). The Shannon-Wiener index (H′) value was 0.2.72, which is lower compared to 5.68 Shannon value of the Tropical forest in the Eastern Ghats (Reddy et al 2011) and Tropical forest of Similipal Biosphere reserve (Reddy et al 2007). Similar results are reported by Khatri et al (2004) at Satpura National Park, Hoshangabad, Madhya Pradesh and Ahir et al (2012) in Western Ghats of Karnataka. In another study, Jeevan (2007) reported that *Vateria indica* was the most dominant tree based on the species importance value index and based on the family importance value index, Dipterocarpaceae was the most dominant family in Western Ghats of Karnataka.

Several workers have studied floristic composition and biological spectrum of different regions in India such as

Table 2. Density and Shannon-Wiener index of the herbs and orchids species in Purna Wildlife Sanctuary, Mahal, Dang district, Gujarat, India

Species name	F	D	RF	pi	Log Pi	H′	Conc. of Do
Achyranthes aspera	0.3	0.3	3.85	0.038	-3.258	0.125	0.001
Alternenthera triandra	0.3	0.3	3.85	0.038	-3.258	0.125	0.001
Bergia ammannioides	0.3	0.3	3.85	0.038	-3.258	0.125	0.001
Cassia occidentalis	0.3	0.3	3.85	0.038	-3.258	0.125	0.001
Commelina benghalensis	0.3	0.3	3.85	0.038	-3.258	0.125	0.001
Corchorus tridens	0.3	0.3	3.85	0.038	-3.258	0.125	0.001
Costus speciosus	0.3	0.3	3.85	0.038	-3.258	0.125	0.001
Crotolaria sp.	0.3	0.3	3.85	0.038	-3.258	0.125	0.001
Curculigo orchioides	0.3	0.3	3.85	0.038	-3.258	0.125	0.001
Curcuma odorata	0.3	0.3	3.85	0.038	-3.258	0.125	0.001
Cyathocline purpurea	0.3	0.3	3.85	0.038	-3.258	0.125	0.001
Desmodium gangeticum	0.3	0.3	3.85	0.038	-3.258	0.125	0.001
Gloriosa superba	0.3	0.7	7.69	0.077	-2.565	0.197	0.006
Helicteris isora	0.3	0.3	3.85	0.038	-3.258	0.125	0.001
Holarrehna antidysentrica	0.3	0.3	3.85	0.038	-3.258	0.125	0.001
Ipomoea fistulosa	0.3	0.3	3.85	0.038	-3.258	0.125	0.001
Lawsonia inermis	0.3	0.3	3.85	0.038	-3.258	0.125	0.001
Ludwigia octovalvis	0.3	0.3	3.85	0.038	-3.258	0.125	0.001
Mimosa pudica	0.3	0.3	3.85	0.038	-3.258	0.125	0.001
Nervilia aragoana	0.3	0.7	7.69	0.077	-2.565	0.197	0.006
Nervilia discolor	0.3	0.3	3.85	0.038	-3.258	0.125	0.001
Ruellia tuberosa	0.3	0.3	3.85	0.038	-3.258	0.125	0.001
Spilanthes calva	0.3	0.3	3.85	0.038	-3.258	0.125	0.001
Swertia minor	0.3	0.3	3.85	0.038	-3.258	0.125	0.001
Total	8.0	8.7	100	1.000	0.000	3.151	0.044

Simpson Index: 0.995

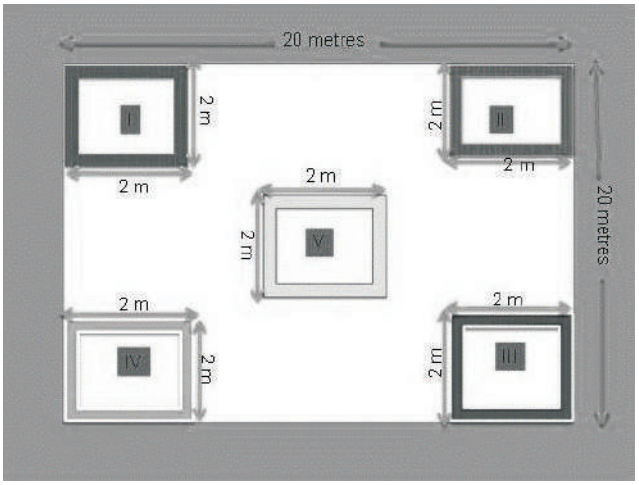

Fig. 2. Assessment of phytosociological study through quadrate method

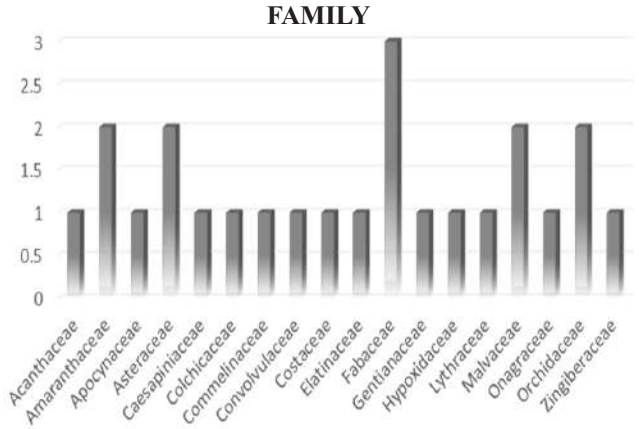

Fig. 3. Family basis of woody vegetation of Purna Wildlife Sanctuary, Mahal, Gujarat

Shukla and Mishra (2006) in Dewghat Forest, UP; Pharswan et al (2010) in Alpine Medows of Kedavnath; Thakur et al (2012) in Darlaghat Wild Life Sanctuary, HP.; Sindhuja et al (2012) in Maruthamalai Hills, Southern Western Ghats; Sarkar and Devi (2014) in Hollongapar Gibbon Wildlife Sanctuary, Assam; Chauhan et al (2014) in Madhav National Park, MP; Sundarapandian and Subbiah (2015) in Sivagangai district, TN; Kumar and Desai (2016a) in Chikhali Taluka, Navsari District, Gujarat and Kumar and Desai (2016b) in Dang district of South Gujarat.

CONCLUSION

Total 70 species (46 tree, 22 herbs and 2 orchids) were recorded in Purna Wildlife Sanctuary, Mahal, Gujarat during the period of 2010-2013. The maximum IVI was for *Tectona grandis*) and followed by *Terminalia tomentosa.* Among the herbs species, the highest Shannon-Wiener index was for *Nervilia aragoana.* Apart from physical and ecological conditions and the natural evolutionary process, the flora biodiversity has also been greatly influenced by diverse social-cultural preferences, economic condition, food habit and needs.

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Habitat Distribution Modelling of Seabuckthorn (*Hippophae salicifolia* D. Don.) in Sikkim, Eastern Himalaya, India

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***Abstract*:** Seabuckthorn (*Hippophae salicifolia*) is one of the underutilized plant species having enormous potential for socio-economic upliftment and sustainable livelihood of rural communities. In Sikkim it grows naturally in Lachen and Lachung valleys of North district and it has not been explored for economic benefits. Due to its restricted distribution in Sikkim, ecological niche modelling (ENM) was performed to identify suitable habitat for *in-situ* conservation through identification of suitable areas and for further reintroduction in its natural habitat. The model was developed using Maximum Entropy (MaxEnt) distribution modelling algorithm and predicted that the suitable habitats of Seabuckthornare restricted to an area of *ca*. 286 km^2 in Sikkim. The distribution of the potential habitat was strongly influenced by NDVI layer for October and January, which corresponds to the period of fruiting phenology of the species, thus indicating the importance of fruiting phenology in determining the distribution of the species. Population status was positively correlated with very high model thresholds at three locations, confirming the usefulness of the habitat model in population monitoring. Therefore the approach presented here emerge to be quite promising in predicting the suitable habitat for species with restricted distribution and moreover it can be an effective tool for conservation planning, monitoring and management of the species.

Keywords: Seabuckthorn, ENM, Conservation, Macro propagation, Protected area

Seabuckthorn (*Hippophae salicifolia* D. Don) is a thorny, deciduous shrub (Singh 1998, Nepal et al 2001) belonging to the family Elaeagnaceae. The species is restricted to the Himalayan region, between 1500-3500 m asl (Gaur 1999, Hooker 1894). In India *H. salicifolia* grows naturally in high altitude areas of Himachal Pradesh, Jammu and Kashmir, Uttar Pradesh (Singh et al 1995, Singh 1998) and Sikkim (Basistha 2001). In Sikkim, the species is found naturally growing in Lachen and Lachung Valleys of North district between the altitude of 2700 and 3700 m. Ecological niche modelling (ENM) also known as species distribution modelling is a recent tool which uses computer algorithms to generate predictive maps of species distribution in a geographic space by correlating the point distributional data with a set of environmental raster data. Predicting and mapping the suitable habitat for threatened and endangered species is critical for monitoring and restoration of their declining native populations (Kumar and Stohlgren 2009). Species reintroduction is one such ecological strategy for restoration of depleted species population reclamation of degraded habitats and ecosystems (Adhikari et al 2012). To reintroduce and rehabilitate a threatened species a detailed knowledge of its potential habitats is essential. Species distribution modelling or ENM therefore helps to identify the suitable habitats for reintroduction, and in developing effective species specific conservation measures. It has been successfully used in restoring critical habitats and predicting the impact of environmental and climate change on species and ecosystems (Brooks et al 2004, Franklin 2009, Giriraj et al 2008, Gogol-Prokurat 2011, Khanum et al 2013).

Identification of suitable habitat is prerequisite for species restoration programme (Adhikari et al 2012, Pradhan and Chettri 2017). To achieve such restoration of threatened species require GIS based techniques like ENM which reconstructs the niche of a species in an ecological space by correlating the occurrence points (geographic coordinate) with a set of environmental variables. The present work was therefore undertaken with the aim of identifying suitable habitat for conservation through large scale propagation of species. Such predicted habitat identified through ENM could be used for reintroduction of species in near future.

MATERIAL AND METHODS

Species occurrence records: Primary occurrence data

(geographic coordinate) were collected from Lachung and Lachen valley in North Sikkim District of Sikkim and recorded using a Garmin GPS 78s with an accuracy of 3–10 m. The coordinate were then converted to decimal degree which was used for modeling.

Ecological niche modeling: The model was developed using maximum entropy modeling (Phillips et al 2006). Twenty replicated model runs were executed for the species to validate the model robustness with a threshold rule of 10 percentile training presence. In the replicate runs cross validation technique were employed. All other parameters were set to default as the program was already calibrated on a wide range of species datasets (Phillips and Dudik 2008). From the replicated runs, average, maximum, minimum, median and standard deviation were generated. Model quality was evaluated based on Area under Curve (AUC) value (Thuiller et al 2005) and the model was graded as: poor (AUC < 0.8), fair (0.8 < AUC < 0.9), good (0.9 < AUC < 0.95) and very good (0.95 < AUC < 1.0). The model were developed using NDVI (Normalized Difference Vegetation Index) data downloaded from the website (http://glcf.umiacs.umd.edu/data/ndvi).

Protected area analysis: To identify protected area suitable for conservation of *H. salicifolia* in Sikkim, the habitat suitability map were overlaid onto protected areas of Sikkim. The network was downloaded from World Database of Protected Areas (UNEP-WCMC 2012); (http:// protectedplanet.net). The analysis was performed using Arc View GIS v. 3.3.

Population status vis-à-vis model thresholds: In order to explore the robustness of the model, the population status of *H. salicifolia* were determined through a direct count of all the individual in 250 x250m grid at different threshold. The population data were then correlated with model threshold to ascertain whether the region covered in the very high and high suitability thresholds of the model maintain higher populations or not and vice-versa.

Assessment of habitat status and identification of areas for reintroduction: The assessment of actual habitat type in the localities of occurrence as well as in the entire predicted potential area was carried out through repeated filed surveys. The predicted potential areas were also superimposed on Google Earth Ver. 6 (www.google.com/earth) imageries for habitat quality assessment. The predicted suitability maps were exported in KMZ format using Diva GIS ver. 7.5 (www.diva-gis.org). The exported KMZ files were overlaid on satellite imageries in Google Earth to ascertain the actual habitat condition prevailing in the areas of occurrence.

RESULTS AND DISCUSSION

Ecological niche modeling: The model calibration test for *H. Salicifolia* yielded satisfactory results (AUC_{train} = 0.9857 ± 0.003 and AUC_{test} = 0.9636 ± 0.05). The 10 percent training presence logistic thresholds value for binary conversion were 0.3751. Only 286 km^2 were predicted to be suitable at this threshold (4.62 % of the total areas of Sikkim). Amongst the input environmental variables, NDVI for October and January was the most influential and contributed 37.3 percent and 23.7 percent to the Max Ent model. Rest of the remaining layers collectively contributed 39 percent to the habitat model of the species (Fig. 1 & 2 and Table 1). Considering the permutation importance, NDVI for October also had the maximum influence on the habitat model and contributed to 43.4 per cent, while rest together contributed to 56.6 per cent (Table 1). In the present study NDVI for October and January played a key role in determining the distribution of potential habitat of *H. salicifolia* in its native range. Interestingly, the NDVI for the month of October and January which contributed most to the habitat model corresponds to the period of fruit ripening month of the species (Basistha et al 2001), indicating the significance of fruiting phenology in determining the distribution of the species.

Protected area analysis: A total of 116 km^2areas were

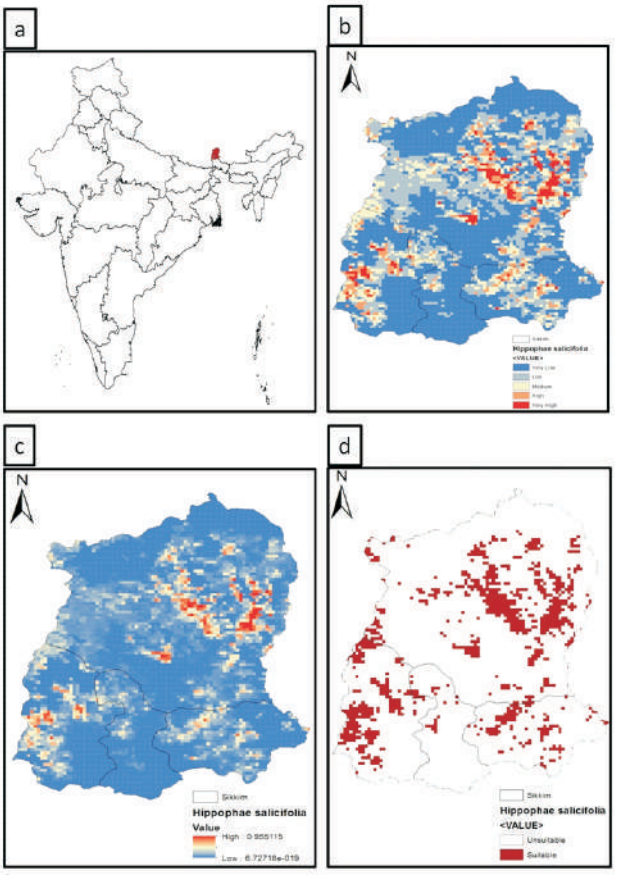

Fig. 1. (a) Study area (b) Habitat suitability map (c) Logistic format (d) Threshold format

predicted to be suitable in the eight protected area identified in Sikkim. Kanchenjunga National Park (KNP) had the highest area predicted to be suitable followed by Singba. Protected areas *viz*. Kyongnosla Alpine, Maenam Wildlife Sanctuary and Kyongnosla extension were unsuitable for insitu conservation of species (Table 2).

Population and habitat status assessment: Field surveys for assessing the habitat types of *H. salicifolia* in the predicted potential areas revealed that the species occurred abundantly in riverine area (Riverside) and human settlement (Table 3). Superimposing the predicted potential habitat map of the species on Google Earth satellite imageries revealed, areas with very high and high suitability for the species were mostly human habitat area along roadside and river banks. The areas with medium and low suitability were degraded landslide area with dense evergreen forest. The areas with low to very low suitability were open evergreen forest and degraded area (Table 3). Apart from Lachung and Lachen Valley areas such as Latong, Talam, Yathang and Lingzah–Tolung in North Sikkim were identified as suitable for species restoration.

Table 1. List of NDVI data used for modeling and contribution to the model

Variable	Description of the variable	Percent contribution	Permutation importance
eu1	Month of January	23.7	18.5
eu2	Month of February	4.1	2.5
eu3	Month of March	0.1	0
eu4	Month of April	12.6	2.4
eu5	Month of May	2	0.2
eu6	Month of June	10.5	21.2
eu7	Month of July	0.6	0.1
eu8	Month of August	4.8	8.3
eu9	Month of September	2.9	3.4
eu10	Month of October	37.3	43.4
eu11	Month of November	–	–
eu12	Month of December	1.5	0.1

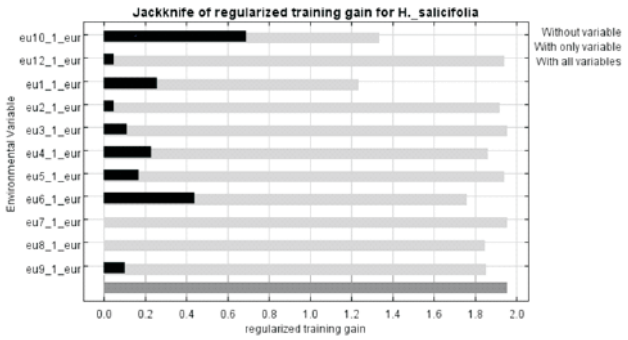

Fig. 2. Result of jackknife test for evaluating the relative contribution of the predictor environmental variables to the habitat model of *H. salicifolia* in Sikkim

Raising plantlets for propagation: The seeds of Seabuckthorn were collected from Lachen Valley in North Sikkim district of Sikkim and were planted in a nursery (600/150 cm length/breadth) at Lachen at an elevation of 2725m. Out of *ca*. 1000 seeds planted in the nursery more than 90 percent of seeds developed into healthy sapling. The sapling was further distributed amongst the local residents for restoration of depleting population, through reintroduction in the natural habitat.

CONCLUSION

The population of seabuckthorn in its natural habitat is considerably high, however, deforestation through destruction of forest trees including Seabuckthorn for fuel and extensive construction of road has led to the depletion of natural population. At Lachung valley, Seabuckthorn is mostly dominant in the riverine area. The very high population density dominated by Sea buckthorn in the riverside areas unlike in mixed forest areas where the population were low to moderate. The population data through direct count in the area predicted through ENM thus

Table 2. Protected area identified as suitable for insitu conservation (10 % training presence threshold)

Protected Area	IUCN management category	Type of protected area	Total area (km^2)	Predicted suitable area (Km^2)
Khangchendzonga National Park	II	National Park	1784	69
Fambong Lho Wildlife Sanctuary	IV	Wildlife Sanctuary	51	12
Kyongnosla Alpine Sanctuary	IV	Sanctuary	31	0
Maenam Wildlife Sanctuary	IV	Wildlife Sanctuary	35	0
Kyongnosla extension	Not Applicable	Sanctuary	21	0
Singba Rhododendron Sanctuary	Not Reported	Sanctuary	57	25
Barsey Rhododendron Sanctuary	IV	Sanctuary	104	10
			2083	116

Table 3. Population status and habitat type of *H. salicifolia* to model thresholds

Occurrence localities	Geographic coordinate	Elevation (m asl)	Habitat suitability thresholds	Habitat types identified using high resolution Google Earth satellite imageries	No. of Individuals
Lachung 1	88˚ 44′ 08.00″ E 27˚ 40′ 38.42″ N	3524	Very High	Riverside area, human settlement	125
Lachung 2	88˚ 45′0 7.94″ E 27˚ 42′ 52.47″ N	3363	Very High	Riverside area, human settlement	112
Lachung 3	88˚ 44′ 34.70″ E 27˚ 41′ 20.60″ N	3611	Very High	Riverside area, human settlement	50
Lachen 1	88˚ 32′ 27.79″ E 27˚ 43′ 00.07″ N	3363	Very High	Mixed forest, human settlement	25
Lachen 2	88˚ 32′ 44.92″ E 27˚ 43′ 08.69″ N	3126	High	Mixed forest, human settlement	73
Lachen 4	88˚ 33′ 44.30″ E 27˚ 41′ 33.65″ N	3121	Medium	Dense evergreen forest, Degraded landslide area	57
Lachen 5	88˚ 32′ 51.16″ E 27˚ 44′ 41.02″ N	3034	Low	Mixed forest, Degraded landslide area	12

Habitat suitability thresholds: very low, 0-0.1910; low, 0.1910-0.3820; medium, 0.3820-0.5731; high, 0.5731-0.7641; very high, 0.7641-1

validates the robustness of the model, as it maintains high population density in the very high and high suitability threshold and low to moderate population in lower suitability threshold (Medium and low) areas. Moreover, this study further provided a considerable lead for development of easy and effective propagation technique for large scale propagation of species for further domestication of species leading to socio-economic upliftment and sustainable livelihood enhancement in the region.

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Effect of Container and Growing Media on *Terminalia bellirica* Roxb. Seedling Performance under Nursery Conditions

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Abstract: Investigation on the effect of containers (root trainer 250 cc, root trainer 300 cc, polybags 16 x 24 cm–1500cc and polybag 23 x 28 cm–4200cc) and potting media (soil, soil: sand: FYM–1:1:1 and soil: sand:vermicompost–1:1:1 on the growth of *Terminalia bellirica* was carried out at Sher-e-Kashmir University of Agricultural Sciences and Technology-Jammu, Chatha, Jammu (India) during 2015-2016. Among the different container sizes and media, the polybag of 23 x 28 cm size and soil: sand: vermicompost (1:1:1) growing media resulted in significantly higher seedling height, collar diameter, number of leaves, length of primary root, fresh shoot and root weight, total seedling fresh weight, dry shoot and root weight, total seedling dry weight, root: shoot ratio and seedling quality. The effect of containers on number of secondary roots and sturdiness quotient was significant whereas it was non-significant in case of media. The sturdiness quotient decreased with increase in container size. The effect of interaction of containers x potting media was significant on growth parameters *viz.* seedling height, number of leaves, fresh shoot weight, total seedling fresh weight, root: shoot ratio and sturdiness quotient, however, it was non-significant in case of germination percentage, collar diameter, number of primary roots, fresh shoot weight, dry shoot weight, dry root weight, total seedling dry weight and seedling quality index. The interaction polybags (23 x 28 cm) x medium (soil: sand: VC–1:1:1) resulted insignificantly higher values for the most of the studied growth parameters than the remaining interactions. The large sized containers (polybag of 23 x 28 cm) in combination with soil: sand: VC (1:1:1) media resulted in better growth of *T. bellirica* seedlings. Thus the seedling of this species should be grown in polybag (23 x 28 cm) using soil: sand: VC (1:1:1) as growing media to obtain better quality planting stock.

Keywords: *Terminalia bellirica,* Container size, Potting media, Farm yard manure, Vermicompost, Root trainers, Polybags, Nursery

Terminalia bellirica Roxb. (family Combretaceae), is one of the important multipurpose trees of Indian subcontinent, Sri Lanka and South East Asia. It is called "Belric myrobalan" and also known as "Bahera" in India. Its distribution extends from 0–1330 m elevation above mean see level. In India it is generally found in Himalayan tract up to 1200 to 1300 m in Sal and miscellaneous forest of the subtropical zone. Due to multifarious uses of *T. bellirica* is being over-exploited resulting in shrinkage of its population. Further, collection of its fruits for medicinal uses also results in its poor regeneration. Thus, it is necessary to supplement its natural regeneration through afforestation programme. This would require production of quality planting stock for afforestation. During the containerised seedling production, container size, and growth medium are important determinants of seedling quality (Tsakaldimi et al 2005, Aghai et al 2014). Hence the present study was taken to obtain the quality planting stock of the species. The objective to the study was to standardise container size and potting media to obtain better quality seedlings of the species under open nursery conditions.

MATERIAL AND METHODS

Study area: The study was conducted in the Division of Agroforestry, Sher-e-Kashmir University of Agricultural Sciences and Technology-Jammu located at Chatha, Jammu. The experimental site was the subtropical Jammu region of Jammu and Kashmir state, located at 332 m above mean sea level with 32° 40` N latitude and 74° 58` E longitude. The annual rainfall in the study area ranges from 1000 mm to 1200 mm.

Climate and weather conditions: The weather data recorded at meteorological observatory of SKUAST-Jammu, Chatha, during study period (January–October, 2016) are given in Fig. 1.

Design of experiment: The treatments of the experiment consisted of different four container sizes root trainer 250 cc, root trainer 300 cc, polybags 16 cm x 24 cm–1500cc and polybag 23 x 28 cm-4200cc and three media types: soil, soil: sand: FYM (1:1:1) and soil: sand: vermicompost (1:1:1). Each root trainer was in block of 12 cells. The soil of the study site is sandy loam (Rana and Sood 2012), which was utilised for the current study. The pH of the study soil was 7.81 and EC 0.04 ds/m. The available N, P and K was 214 kg/ha, 13.8 kg/ha and 129.8 kg/ha, respectively (Rana 2008). Factorial CRD (Complete Randomization Design) was used to conduct the experiment. All the treatments were replicated

thrice. There were 12 plants in a single replication for each treatment and observations were recorded on nine plant randomly (three per replication) selected plants per treatment.

Seed collection: A reconnaissance survey was carried out at various places in and around the study area to identify trees bearing sufficient fruits. Three trees were marked and fruits were collected from these trees in November–December, 2015. The seeds were extracted by mechanically breaking the kernel. Seeds were sown in different containers (containing media in different proportions) in April, 2016. Before the sowing of seeds, soil was treated with metalaxyl 8% + mancozeb 64% WP (2%) and Imidacloprid (0.7%) to avoid fungal infection and pest damage to tender seedlings and light irrigation was provided in the containers after sowing of seeds. Timely weeding and hoeing was done until the harvesting of seedlings. Watering of containers was done as per requirement.

Observations: The observation on germination percentage was recorded after 40 days of sowing. The seedling height (cm), collar diameter (mm), number of leaves, length of primary root (cm), number of secondary roots, fresh shoot and root weight (g), dry shoot and root weight (g), total seedling fresh and dry weight (g), root: shoot ratio (dry weight basis), sturdiness quotient and seedlings quality index were recorded after six months of sowing of the seedlings. The fresh shoots and roots of each sampled plant were dried in hot air oven at 65^0 C in the paper bags for 48 hours to obtain respective dry weights. Sturdiness quotient was calculated by using the formula given by Roller (1977).

$$\text{Sturdiness Quotient (S.Q.)} = \frac{\text{Seedling height (cm)}}{\text{Collar diameter (mm)}}$$

Seedling Quality Index assessment was made by using the formula given by Dickson et al (1960).

$$\text{Quality Index (Q.I.)} = \frac{\text{Seedling dry weight(g)}}{\dfrac{\text{Height of seedling (cm)}}{\text{(Collar diameter of seedling (mm)}} + \dfrac{\text{Shoot dry weight (g)}}{\text{Root dry weight (g)}}}$$

RESULTS AND DISCUSSION

Effect on germination percentage: The container size showed a significant effect on seed germination (Table 1). The maximum germination (38.87%) was observed for seeds sown in polybag of 23 x 28 cm size, which was statistically at par with those sown in polybags of 16 x 24 cm size and root trainer (300 cc) but significantly higher than the remaining containers (Table 1). The minimum germination (28.69 %) was in 250 cc root trainer. Potting media also had significant influence on germination percentage. Maximum germination (37.46 %) was in soil: sand: vermicompost (1:1:1) whereas the minimum germination (28.47%) was in soil only. The effect of interaction of container x potting media on germination percentage was non-significant (Table 1).

Effect on aboveground growth parameters: Seedling height, collar diameter, number of leaves, fresh shoot and dry shoot weight were significantly influenced by containers and potting media (Table 2).

The maximum seedling height (32.24cm), collar diameter (8.44 cm), number of leaves (18.55), fresh shoot weight (16.51g) and dry shoot weights (6.11 g) were in polybags 23 x 28 cm which were statistically superior to the remaining containers for the respective parameter. Similarly the maximum values of all the pre-said parameters were recorded in soil: sand: VC (1:1:1) and were statistically superior to respective values in the remaining media (Table

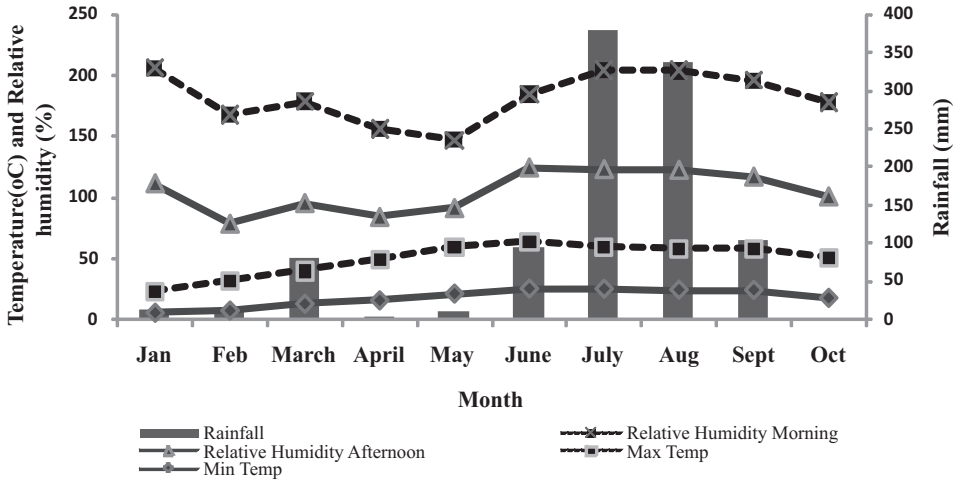

Fig. 1. Daily average temperatures, relative humidity and rainfall

2). However, the interaction container x media showed significant influence in case of shoot weight, number of leaves and fresh shoot weight only. The interaction polybag (23 x 28 cm) x soil: sand: VC (1:1:1) produced tallest seedling (36.50 cm) which was statistically at par with polybags (16 x 24 cm) x soil: sand: VC (1:1:1) interaction but statistically superior to remaining interactions.

The interaction polybag (23 x 28 cm) x soil: sand: VC (1:1:1) resulted maximum number of leaves (21.55), which was statistically superior to remaining interactions (Table 2). The interaction polybag (23 x 28 cm)x soil: sand: VC (1:1:1) also resulted in highest fresh shoot weight (19.96 g/seedling) which was statistically superior to all other remaining interactions .

Effect on belowground parameters: The containers significantly affected all the studies below ground parameters *viz*. length of primary root, number of secondary roots, fresh and dry root weights (Table 3). The polybag 23 x 28 cm

Table 1. Effect of container and potting media on germination percentage of *T. bellirica* seedlings

Media	Containers				Mean
	Root trainer 250 cc	Root trainer 300 cc	Polybag16cmx24cm	Polybag 23cmx28cm	
Soil only	25.00 (29.88)	27.77 (31.74)	27.77 (35.14)	33.33 (32.15)	28.47 (32.22)
Soil: Sand: FYM (1:1:1)	30.55 (33.49)	30.55 (33.49)	36.10 (36.89)	38.88 (38.83)	34.02 (35.67)
Soil: Sand: VC (1:1:1)	30.53 (33.49)	33.33 (35.24)	41.60 (40.28)	44.40 (41.78)	37.46 (37.69)
Mean	28.69 (32.28)	30.55 (33.49)	35.15 (37.43)	38.87 (37.58)	

Figures in parenthesis are transformed (angular) values, FYM : Farm Yard Manure, VC : Vermicompost

CD (p=0.05)

Container =2.75, media=2.38 , container x media = N S

Table 2. Effect of container and potting media on aboveground growth parameters of seedlings of *Terminalia bellirica*

Media	Parameter	Containers				Mean
		Root trainer 250 cc	Root trainer 300 cc	Polybag 16cm x 24cm	Polybag 23cm x 28cm	
Soil only	SH	17.97	20.45	24.93	30.13	23.37
	CLD	3.54	4.70	6.06	7.61	5.47
	NL	8.22	11.10	14.66	15.44	12.35
	FSW	11.42	11.40	13.90	13.70	12.60
	DSW	2.49	3.00	3.92	4.27	3.42
Soil: Sand: FYM (1:1:1)	SH	21.06	22.50	26.70	30.10	25.09
	CLD	4.14	5.30	6.47	8.96	6.22
	NL	11.37	13.21	12.99	18.66	14.06
	FSW	13.09	14.07	15.17	15.88	14.55
	DSW	3.60	4.08	4.78	6.35	4.70
Soil: Sand: VC (1:1:1)	SH	23.10	26.10	35.43	36.50	30.28
	CLD	5.40	5.96	7.50	8.76	6.90
	NL	14.77	15.55	18.44	21.55	17.58
	FSW	13.82	14.53	17.97	19.96	16.57
	DSW	4.23	4.33	5.83	7.71	5.52
Mean	SH	20.17	23.01	29.02	32.24	
	CLD	4.36	5.32	6.67	8.44	
	NL	11.45	13.28	15.36	18.55	
	FSW	12.77	13.32	15.68	16.51	
	DSW	3.44	3.80	4.84	6.11	

FYM : Farm Yard Manure, VC : Vermicompost, SH-Seedling height, CLD-Collar Diameter, NL-Number of leaves, FSW-Fresh shoot weight, DSW-Dry shoot weight, N S–Non-significant

CD (p=0.05)

SH: Container= 1.45, Media= 1.26, Container x Media=2.52

CLD: Container= 0.53, Media= 0.45, Container x Media=N S

NL: Container= 1.06, Media= 0.92, Container x Media=1.84

FSW: Container= 0.83 , Media= 0.72, Container x Media=1.44

DSW: Container= 0.60, Media= 0.52, Container x Media= N S

exhibited maximum values of the pre-said parameters which had statistically higher values than those in the remaining containers.

The potting media also significantly influenced length of primary root, fresh and dry weights of roots but the effect was non-significant in case of number of secondary roots. The longest primary roots (26.13 cm), highest fresh root weight (6.20 g) and dry root weight (2.37 g) was in polybags 23 x 28 cm which were statistically superior to respective values in the remaining containers. The interaction container x media had no significant effect on all the studied below ground parameter.

Total seedling fresh and dry weight: Each container size significantly differed from other with respect to total fresh weight of the seedlings (Table 4). The effect of containers and media was significant on total fresh as well as dry weights of the seedlings (Table 4). Total fresh weight (23.22 g) and total dry weight (9.22 g) per seedling was maximum in polybags 23 x 28 cm which wee statistically higher than those in the remaining containers in the respective category. The potting media were significantly different from each other with respect to total fresh as well as total dry weight of the seedlings. The highest seedling fresh weight (22.97 g) and dry weight (7.87 g) was found in media sand: soil: VC (1:1:1).The interaction effect of container x media was significant in case total fresh weight but was non-significant in case of total dry weight. The interaction polybag (23 x 28 cm) x soil: sand: VC (1:1:1) had the highest (28.49 g) seedling fresh weight which was statistically superior to all the remaining interactions of container sizes and potting media.

Root:shoot ratio: The container size exhibited significant influence on root:shoot ratio (Table 5). The maximum root:shoot ratio (0.55) was recorded in polybag 23 x 28 cm which was statistically higher than remaining sizes. The root:shoot ratio in each medium was significantly different from the other. The root: shoot ratio was highest (0.50) in pure soil which was statistically at par with soil: sand: VC (1:1:1) but superior to soil: sand: FYM (1:1:1). The interaction effect with respect to root:shoot ratio was non-significant.

Sturdiness quotient: The container size exhibited a significant influence on sturdiness quotient (Table 5). The smallest containers *i.e.* root trainer (250 cc) had the highest sturdiness quotient (4.94) which was statistically higher than that of in the remaining sizes. The media type showed a non-significant effect on sturdiness quotient. The interaction container x media also exhibited a significant effect on sturdiness quotient of seedlings .The sturdiness quotient of 5.27 was highest in root trainer (250 cc) x soil only interaction which was statistically at par with 5.03 in root trainer (250cc) x soil: sand: FYM (1:1:1) and polybag (16 x 24cm) x (soil: sand: FYM, 1:1:1) but superior to remaining interactions (Table 5).

Seedling quality index: The seedling quality index varied significantly with size of the containers (Table 6). The seedling quality index of each container size differed significantly from the other. The seedling quality index increased from 0.52 in smallest containers (root trainer 250

Table 3. Effect container and potting media on belowground growth parameters of seedlings of *Terminalia bellirica*

Media	Parameter	Containers				Mean
		Root trainer 250 cc	Root trainer 300 cc	Polybag 16cm x 24cm	Polybag 23cm x 28cm	
Soil only	LPR	18.55	19.47	22.48	24.16	21.16
	NSR	21.22	21.23	26.88	32.22	25.41
	FRW	3.12	3.52	4.75	5.34	4.18
	DRW	0.73	1.27	2.20	3.02	1.80
Soil: Sand: FYM (1:1:1)	LPR	20.74	22.61	25.74	27.69	24.19
	NSR	21.77	19.55	27.77	34.55	25.91
	FRW	3.95	4.33	6.44	7.18	5.47
	DRW	0.73	1.63	2.24	3.10	1.92
Soil: Sand: VC (1:1:1)	LPR	21.06	23.14	28.36	26.98	26.13
	NSR	25.11	20.66	27.99	35.44	27.30
	FRW	4.41	5.89	6.74	7.79	6.20
	DRW	1.27	2.21	2.62	3.37	2.37
Mean	LPR	21.06	21.74	25.53	26.98	
	NSR	22.70	20.51	27.31	34.07	
	FRW	3.82	4.58	5.97	6.77	
	DRW	0.91	1.70	2.35	3.16	

FYM : Farm Yard Manure, VC : Vermicompost, LPR-Length of primary root, NSR-Number of secondary roots, FRW-Fresh root weight, N S – Non-significant
CD (p=0.05)
LPR: Container= 0.99, Media= 0.86, Container x Media= N S
NSR: Container= 1.98, Media= N S, Container x Media= N S
FRW: Container= 0.56, Media= 0.48, Container x Media= N S
DRW: Container= 0.41, Media= 0.35 , Container x Media= N S

cc) to 1.60 in largest containers (polybag 23 x 28 cm).The quality index increased from 0.83 in soil only to 1.05 in soil: sand: FYM (1:1:1) and finally to 1.17 in soil: sand: VC (1:1:1). The interaction between container x media resulted in a non−significant effect on seedling quality index.

In current study, the seedlings raised in largest container size (polybag 23 x 28 cm) performed the best with respect to seedling height, collar diameter, number of leaves. length of primary root, number of secondary roots, fresh shoot and root weight (g), fresh root weight, total seedling fresh and dry weight, dry shoot and root weight, root:shoot ratio and seedling quality index However, the sturdiness quotient was highest in 250 cc root trainer. The increase in these parameters could be attributed to more volume of growing media and space for root establishment and growth, more water retention and availability of more quantity of nutrients. These findings are in conformity with those reported by Bali et al (2013), Mugloo et al (2015) and Zalzaleh (2009) where germination percentage, seedling height, collar diameter and number of leaves increased with increase in container size in *Terminalia bellirica*, *Picea smithiana* and *Acacia saligna,* respectively. Jabbar et al (2010) also found that higher values on root: shoot ratio existed in seedling of *Albizia procera* raised in large sized containers. In the current study, sturdiness quotient was the highest in smallest containers (root trainer 250 cc) and the lowest sturdiness quotient was in largest sized containers (polybag 23 x 28 cm). The reason for lower sturdiness quotient in largest sized containers 23 x 28 cm could be due to better photosynthetically active radiation reaching in lower portion of the plants owing to lower stocking density (less number of plant per unit area) than that of other container sizes. This finding is corrobated by Jabber et al (2010) in Albizia procera seedling grown in polybags who reported similar results. The maximum germination percent in the current study was slightly lower than reported by Bali et al (2013) for *Terminalia bellirica* in light textured soils.

The potting media significantly influenced all the studied parameters except number of secondary roots and sturdiness quotient. The best performance of various seedling parameters in soil: sand: VC (1:1:1) could be attributed to better porosity and higher nutrient content owing

Table 4. Effect of container and potting media on seedling fresh and dry weights (g) of *Terminalia bellirica* seedlings

Media	Parameter	Containers				Mean
		Root trainer 250 cc	Root trainer 300 cc	Polybag 16cm x 24cm	Polybag 23cm x 28cm	
Soil only	TFW TDW	14.54	14.92	18.65	19.05	16.79
Soil: Sand: FYM (1:1:1)	TFW TDW	17.04	18.40	21.61	22.13	19.79
Soil: Sand: VC (1:1:1)	TFW TDW	18.23	20.44	24.71	28.49	22.97
Mean	TFW TDW	16.60	17.92	21.65	23.22	

TFW−Total fresh weight, TDP−Total dry weight, FYM : Farm Yard Manure, VC :Vermicompost, N S: Non-significant
CD (p=0.05)
TFW: Container= 1.03, Media= 0.89, Container x Media= 1.79
TDW: Container= 0.79, Media= 0.68, Container x Media= N S

Table 5. Effect of container and potting media on root:shoot ratio and sturdiness quotient of *Terminalia bellirica* seedlings

Media	Parameter	Containers				Mean
		Root trainer 250 cc	Root trainer 300 cc	Polybag 16cm x 24cm	Polybag 23cm x 28cm	
Soil only	R:S SQ	0.31	0.42	0.57	0.72	0.50
Soil:Sand:FYM (1:1:1)	R:S SQ	0.20	0.39	0.47	0.49	0.39
Soil:Sand:VC (1:1:1)	R:S SQ	0.30	0.52	0.45	0.44	0.42
Mean	R:S SQ	0.27	0.44	0.49	0.55	

R:S: Root-shoot ration, SQ−Sturdiness quotient, FYM : Farm Yard Manure, VC :Vermicompost, N S: Non-significant
CD (p=0.05)
R:S: Container= 0.10, Media= 0.09, Container x Media= N S
SQ: Container= 0.42, Media= N S, Container x Media= 0.72

Table 6. Effect container size and type and potting media on seedling quality index of *Terminalia bellirica* seedlings

Media	Containers				Mean
	Root trainer	Root trainer	Polybag	Polybag	
Soil only	0.36	0.62	1.01	1.35	0.83
Soil: Sand: FYM (1:1:1)	0.50	0.84	1.12	1.75	1.05
Soil: Sand: VC (1:1:1)	0.71	1.03	1.21	1.72	1.17
Mean	0.52	0.83	1.11	1.60	

FYM : Farm Yard Manure, VC :Vermicompost, N S: Non-significant
CD (p=0.05)
Container= 0.10, Media= 0.09, Container x Media= N S

to vermicompost in this medium than that of the remaining media. Similar findings were also reported in case of *Acacia nilotica* seedlings by Devaranavadgi et al (2010) in their experiment at Bijapur (Karnataka).

The interaction effect of container x potting media showed significant effect on seedling height, number of leaves, fresh shoot weight, total seedling fresh weight, root shoot ratio and sturdiness quotient only. The reason could be attributed to more volume of growing media, higher water holding capacity coupled with more quantity of nutrients and space. The results were in accordance with that Chand et al (2007) in *Terminalia tomentosa who reported* that addition of manures in soil media enhance the growth and development of the seedlings.

CONCLUSIONS

The current study implies that largest sized containers (polybag 23 x 28 cm) and potting media soil: sand: VC (1:1:1) should be used to obtain better growth of *Terminalia bellirica* to obtain better growth of seedlings under nursery conditions. Further, studies need to be carried out to find out the out planting success of the seedling raised using different container sizes and media.

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Biomass and Carbon Stocks in Agroforestry Land use System in Sub-tropics of J&K

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Abstract: Biomass, carbon stocks and carbon dioxide equivalent (CO_2e) in agroforestry land use system was assessed for *kandi* areas in sub–tropics of Jammu & Kashmir. Agri-hoticultural system was the prominent agroforestry land use system in the study area. *Mangifera indica* gave the highest above and below ground biomass (46.19 Mg ha^{-1}). The average total biomass in tree component was 14.28 Mg ha^{-1}, out of which, the contribution of above ground biomass in tree component was 75.28 percent and 24.78 percent in below ground biomass.. Similarly, carbon stocks in tree component were 6.62 Mg ha^{-1} and the highest were recorded in Mangifera indica (21.28 Mg ha^{-1}). The contribution towards carbon stocks of trees and understorey component in agroforestry land use was found to be 6.62 Mg ha^{-1}(81.23 percent) and 1.47 Mg ha^{-1} (18.17 percent), respectively. The total output from agroforestry land use system towards biomass was 17.62 Mg ha^{-1} and corresponding carbon stock was 8.09 Mg ha^{-1}.

Keywords: Agroforestry, Carbon stocks, Carbon dioxide equivalent, Carbon sequestration

The role of various land use systems in alleviating the atmospheric CO_2 concentration and reducing the CO_2 emissions or on increasing the carbon sink of forestry and agroforestry systems has gained momentum in recent years (Murthy et al 2013). There is substantial interest to increase the carbon storage potential of terrestrial vegetation through land use practices such as reforestation, afforestation & natural regeneration of forests, silvicultural practices and agroforestry (Canadell et al 2008). Agroforestry land use system has proved to give positive impact to conventional agricultural and woody tree production through increase in productivity, biodiversity, social, economic and ecological benefit (ICRAF 1995). Agroforestry systems are significantly important especially when large population depend on land for their livelihood and food security; and the need for integrating food production with environmental services under climate change scenario (Garrity 2004). The biomass productivity, soil fertility, soil conservation, nutrient cycling, microclimate improvement and carbon sequestration potential of an agroforestry system is better than that of a conventional annual system. The Third Assessment Report on Climate Change (IPCC 2000) encompasses an endorsement of the potential for agroforestry to contribute to increase in carbon stocks in agricultural lands.

The sub-tropics of J&K state is characterized by presence of *kandi* region, covering three districts, namely Jammu, Samba and Kathua. The landscape of *kandi* area comprise of undulating topography, steep and irregular slopes, erodible and low water retentive soils and badly dissected terrain by numerous gullies with prominent land use systems of agriculture, horticulture, agroforestry and forests. The upper portion of *kandi* (above 500 m) consists of low hills covered by shrubs and forest, while the lower terrain has cultivated lands and gully beds. People usually practice rainfed agriculture, horticulture, agroforestry for their sustenance and are intrinsically dependent on nearby forests to meet their energy and fodder requirements. Human activities such as degradation of forests, perennial felling/lopping of trees and shrubs for domestic purposes (especially fuel wood and fodder) and unmanaged agricultural practices have substantially aggravated the denudation rate. Also, the literature on carbon sequestration potential of agroforestry land use systems in *kandi* belt of Jammu region is scarce. Thus, the present study was carried out to assess the biomass, carbon stocks of agroforestry land use system in *kandi* region of Jammu sub tropics which primarily comprised of agri-horticultural system.

MATERIAL AND METHODS

The present study was carried in out in sub-montane region of the outer Himalayas fringing *shivalik* hills is popularly known as *bhabar* or *kandi* which stretch between 74^0 21´ to 75^0 45´ E longitude and 32^0 22´ to 32^0 55´ N latitude. The total area covered by *kandi* belt in J&K State is estimated to be 811 km^2, which is primarily located in three districts namely, Jammu, Samba and Kathua. It is characterized by

10-30 km wide sloping belt extending over approximately 1700 km in length intermittently from Jammu & Kashmir in west to Teesta River in East (Goyal and Rai 2000). The inventory of farmers was prepared in all three districts under study and five farmers for agroforestry land use system were randomly selected from the inventory in each district. GPS was used during the field survey exercise to locate the geo-coordinates and altitude of sampling points. In all, 15 quadrates of 10 m x 10 m (0.01 ha) were used in the study area. The study was carried out from *kharif*, 2015 to *kharif*, 2016. Non-destructive method was for assessment of biomass and carbon which is more rapid and much larger area & number of trees can be sampled, thus reducing the sampling error encountered with the destructive method (Hairiah et al 2011). The standing biomass and carbon stock of trees along with the intercrop (understorey component) was assessed in *kandi* region of Jammu sub-tropics. Trees were enumerated and their diameter at breast height (DBH) and height were measured. The stem volume of trees was calculated by using basal area (BA), height and form factor. For standing trees, general form factor of 0.5 was taken regardless of taper or form (Butterfield and Espinoza 1995). The stem volume was converted into biomass by using wood density (Mg m^{-3}) from the available literature (Brown 1997). Irrespective of size and length, the total number of branches were counted on each of the sample tree and were categorized into three parts *viz*., lower, middle and upper. Fresh weight of one sampled branch from each group was recorded separately. The dry weight of branches was determined (Chidumaya 1990). The fresh leaves segregated from the harvested branch were weighed and a representative sample thereof (0.1 kg) was retained to estimate the dry weight of leaves. Leaves were oven dried to obtain the constant weight. The below ground biomass of trees was calculated by using the ratio of below-ground to above-ground biomass (Mokany et al 2006). The biomass for intercrop was estimated using 1m x 1m quadrates. The total herb biomass occurring within the quadrate was cut at the ground level. The collected samples were weighed, sub-sampled and taken to the laboratory for oven drying at $65^0 \pm 5^0$ C to obtain the constant dry weight. Carbon concentration in plants was calculated using combustion method (Negi et al 2003). Oven dried plant components (leaves, bark and wood) were burnt in electric furnace at 400°C temperature, ash content (inorganic elements in the form of oxides) left after burning was weighed and carbon was calculated using the following equation:

Carbon percent = 100 – (Ash weight+ molecular weight of O_2 (53.3) in $C_6H_{12}O_6$)

This carbon concentration was converted in to carbon stock (Mg ha^{-1}) by multiplying it with the biomass. The proportion of stem wood used as long-lived wood products as suggested by Wang and Feng (1995).

Long-lived carbon storage = carbon mass in stem wood x 42% stem wood put for long term locking

Heat from biomass combustion and carbon storage from coal substitution (Mg ha^{-1}) was simulated on the basis of thermal efficiency of biomass (Wang and Feng 1995).Heat from biomass combustion = [Biomass – (stem wood weight x 0.42)] x 8 x 10^9 J ton^{-1}

$$\text{Carbon storage from coal substitution} = \frac{(\text{Heat of biomass combustion} \times 0.60 \times 0.70)}{(18 \times 10^9)}$$

The estimated carbon stock was converted into CO_2 equivalent by multiplying the carbon stock of 3.67 (AACM 1997 and Van Kooten 1999) for calculating CO_2 assimilation by biomass.

RESULTS AND DISCUSSION

Agroforestry land use system in *kandi* areas primarily comprised of fruit tree based systems. The dominant fruit trees in the study area were *Mangifera indica, Litchi chinensis Phyllanthus emblica, Grewia asiatica* (Table 1). The average total biomass (14.28 Mg ha^{-1}) with 10.75 Mg ha^{-1} as above ground biomass (AGB) and 3.53 Mg ha^{-1} as below ground biomass (BGB) was assimilated in tree component irrespective of age and sampling site (Table 2).

The data evinced that *Mangifera indica* possessed the highest (37.25 Mg ha^{-1}) above ground biomass (AGB) and below ground biomass BGB (8.94 Mg ha^{-1}). Similarly, above ground carbon stock (AGCS; 17.21 Mg ha^{-1}), below ground carbon stock (BGCS; 4.07 Mg ha^{-1}) was highest in *Mangifera indica.* The carbon sequestered in *Mangifera indica* was 21.28 Mg ha^{-1} which was highest among all the species. The lowest value for the same variables was recorded for *Litchi chinensis.* Carbon stocks are dependent on biomass. Thus, higher the biomass accumulation higher will be the carbon stock. Carbon stock in different carbon pools under study indicated that vegetation stock i.e., above-ground biomass contributed the maximum towards aggregate carbon pool under agroforestry system. Similar results were also reported by Chauhan et al (2012). The perusal of data showed that tree component in agroforestry land use system gave maximum biomass to the tune of 14.28 Mg ha^{-1} (Table 2) and intercrop (understorey) contributed 1.47 Mg ha^{-1}(Table 4); sequestering 6.62 Mg ha^{-1} carbon from tree component, and assimilating 24.30 Mg $ha^{-1}CO_2e$ across the agroforestry land use system. The tree component of agroforestry land use system across the sites had maximum biomass compared to

agriculture component and therefore, the higher carbon stocks and CO_2 equivalent were removed from the atmosphere as compared to intercrop. Similar results were also reported by Thakur et al (2011) for shrubs under different agroforestry systems. The overall average carbon storage from coal substitution (Mg ha^{-1}) in agroforestry land use system (Table 3) was 2.77 Mg ha^{-1}. However, the highest carbon storage from coal substitution among different species in agroforestry land use was in Mangifera indica (10.32 Mg ha^{-1}) followed by *Psidium guajava* and lowest in *Citrus reticulata* Blanco. *S*everal workers have reported that tree incorporation in cropland would result in better net carbon storage in above and belowground components (Palm et al 2004, Haile et al 2008, Kumar and Nair 2011).

Table 1. Different agroforestry system(s) prevalent in the study area

Agroforestry system	Tree component/species	Understorey crop
Agri-Horticulture	*Citrus reticulata* Blanco	*Triticum aestivum* + *Zea mays*
	Litchi chinensis	*Triticum aestivum* + *Vigna mungo*
	Mangifera indica	*Abelmoschus esculentus* + *Triticumaestivum*
	Mangifera indica	*Zea mays* + *Triticum aestivum*
	Emblica officinalis	*Triticum aestivum* + *Zea mays*
	Prunus persica	*Triticum aestivum* + *Zea mays*
	Psidium guajava	*Curcuma longa*
Agri-Horti-pastoral	*Litchi chinensis*	*Zea mays* + perennial grasses
	Emblica officinalis	*Grasses*+ *Zea mays*
Horti-Pastoral	*Grewia asiatica*	*Grasses*

Table 2. Biomass, carbon stocks and carbon sequestered by different tree species in agroforestry land use system

Species	Biomass (Mg ha^{-1})		Total biomass (Mg ha^{-1})	Carbon stock (Mg ha^{-1})		Total carbon sequestered (Mg ha^{-1})
	Above ground	Below ground		Above ground	Below ground	
Citrus reticulata Blanco	6.25	2.15	8.40	2.75	1.08	3.83
Grewia asiatica	4.10	2.30	6.40	1.83	1.15	2.98
Litchi chinensis	2.37	1.33	3.70	1.09	0.66	1.75
Mangifera indica	37.25	8.94	46.19	17.21	4.07	21.28
Emblica officinalis	6.07	1.70	7.77	2.77	0.85	3.62
Psidium guajava	8.46	4.74	13.20	3.89	2.37	6.26
Average of all species irrespective of age and sampling site	10.75	3.53	14.28	4.92	1.70	6.62

Table 3. Long-lived carbon storage, heat from biomass combustion, carbon storage from coal substitution and carbon dioxide equivalent (CO_2e) in tree component of agroforestry land use system

Species	CO_{2e} (Mg ha^{-1})	long-lived carbon storage (Mg ha^{-1})	heat from biomass combustion (Giga Joules ha^{-1})	carbon storage from coal substitution (Mg ha^{-1})
Grewia asiatica	14.06	0.11	16.98	0.29
Citrus reticulata Blanco	10.94	0.04	9.06	0.15
Litchi chinensis	6.42	0.11	124.91	2.10
Mangifera indica	78.10	2.34	614.49	10.32
Emblica officinalis	13.29	1.62	182.69	3.07
Prunus persica	22.97	0.04	83.84	1.41
Psidium guajava	24.30	0.31	123.61	2.08
Average of all tree species irrespective of diameter class and sampling site	24.30	0.65	165.08	2.77

Table 4. Biomass and carbon stocks in understorey component of agroforestry land use system

Intercrop/ Parameter	*Triticum aestivum*		*Zea mays*		*Zingiber officinale*		*Setaria sp.*		*Vigna mungo*		Average	
	Biomass (Mg ha^{-1})	Carbon content (Mg ha^{-1})	Biomass (Mg ha^{-1})	Carbon content (Mg ha^{-1})	Biomass (Mg ha^{-1})	Carbon content (Mg ha^{-1})	Biomass (Mg ha^{-1})	Carbon content (Mg ha^{-1})	Biomass (Mg ha^{-1})	Carbon content (Mg ha^{-1})	Biomass (Mg ha^{-1})	Carbon content (Mg ha^{-1})
Whole (leaf + stem) biomass	5.73	2.51	3.58	1.53	0.38	0.16	0.54	0.23	0.22	0.1	2.09	0.91
Seed Biomass	1.15	0.5	1.89	0.86	0	0	0	0	0.13	0.06	0.63	0.28
Root/ Rhizome Biomass	1.48	0.68	0.36	0.14	1.09	0.48	0.02	0.01	0.17	0.08	0.62	0.28
Total	8.36	3.69	5.83	2.53	1.47	0.64	0.56	0.24	0.52	0.24	3.35	1.47

Among the similar ecological conditions, agroforestry systems were considered to have higher carbon sequestration potential compared to pasture and crop lands (Roshetk et al 2002).

Analogous trend (as in case of carbon storage from coal substitution) was seen for heat from biomass combustion among the different horticultural species. However, the data computed for long-lived carbon storage showed the highest value for *Mangifera indica* (2.34 Mg ha^{-1}) followed by *Emblica officinalis*. Among all these species, only *Mangifera indica* has commercial timber value and can fix long lived carbon for longer duration (70-80 years). For all other species recorded under study, long lived carbon storage commensurate with the biological rotation which here may vary from 10 to 30 years except *Mangifera indica.* The result for carbon dioxide equivalent showed the maximum assimilation for *Mangifera indica* (78.10 Mg ha^{-1}) followed by *Psidium guajava*. The understorey component comprised of mainly cereal (wheat and maize) based intercrop. However, in certain sampling sites, pulses and grassed were also recorded (Table 4).

The highest biomass and carbon stocks in the understorey component was in the order *Triticum aestivum>Zea mays >Zingiber officinale> Setaria> Vigna mungo.* Among all the crops, *Triticum aestivum* had the highest biomass (8.36 Mg ha^{-1}) and maximum carbon stock (3.69 Mg ha^{-1}). However, for understorey component in agroforestry land use system as a whole, the average biomass the intercrop was found to be 3.35 Mg ha^{-1} and carbon stock of 1.47 Mg ha^{-1} The average total biomass in tree component was 14.28 Mg ha^{-1}, out of which, the contribution of above ground biomass in tree component was 75.28 percent and 24.78 percent in below ground biomass. The total contribution of understorey crops in the biomass pool was 3.34 Mg ha^{-1} which was 19.15 percent of the total agroforestry land use system. Similarly, the contribution towards carbon stocks of trees and understorey component in agroforestry land use was 6.62 Mg ha^{-1}(81.23 percent) and 1.47 Mg ha^{-1} (18.17 percent), respectively. The total output from agroforestry land use system as a whole, total biomass harnessed was 17.62 Mg ha^{-1} and corresponding carbon stock was 8.09 Mg ha^{-1}.

Thus, it is evident from this study that agroforestry plays important role in livelihood and food security in *kandi* areas where dependence on traditional sole cropping is not feasible due to rainfed farming. Therefore, both tangible and intangible benefits of agroforestry should be harnessed for income augmentation.

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Rainfall-Runoff Modelling Using Artificial Neural Network and Adaptive Neuro-Fuzzy Inference System

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***Abstract*:** Rainfall is one of the most complicated hydrological process in runoff prediction. Development of rainfall-runoff relations in hydrological modeling is a very important issue. Since it directly affects the design and operation of many water resources structures. The present study was undertaken to predict runoff for Usri river basin. The Usri river basin is located in Giridih district of Jharkhand with an area of about 731.02 km^2. In this study, two techniques were considered namely artificial neural networks (ANNs) and adaptive neuro-fuzzy inference system (ANFIS) to predict runoff. Data of monsoon period (15th June to 30th September) of years 1998-2005 were used for calibration of the models and data of years 2006-2008 were used for validation of models. The data of rainfall and runoff with three days lag as inputs and current day runoff as output were used for runoff prediction. The performance of the models were evaluated qualitatively by visual observations and quantitatively using performance indicators such as root mean square error (RMSE), correlation coefficient (r) and coefficient of efficiency (CE). It is concluded that the performance of the ANFIS model is better than ANN model for runoff prediction of the study area.

***Keywords*:** Adaptive neuro-fuzzy inference system, Artificial neural networks, Modelling, Rainfall, and Runoff

Soil and water are the two important natural resources and the basic needs for agricultural production. During the last century, it has been observed that the pressure of increasing population has led to degradation of these natural resources. The watershed has prolonged been considered as the most effective unit for conservation of natural resources. The need for reliable information on watershed runoff has got momentum since past decades along with watershed management programme. The hydrologic behaviour of watershed in rainfall-runoff conversion procedure is very typical event which is managed by number of climatic and topological aspects that differ with both the time and space.

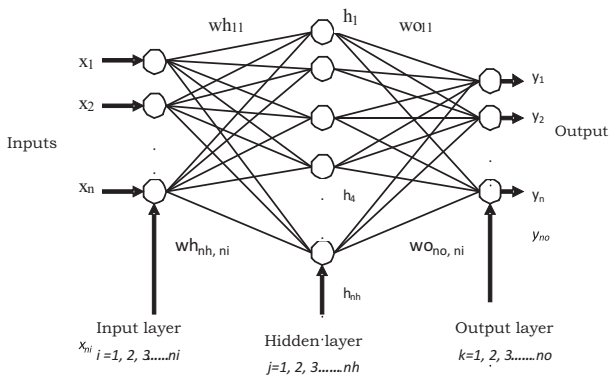
Hydrological models have been developed since 1930′s for describing the processes of rainfall-runoff in a watershed fluvial system. Rainfall–runoff models can be categorized as deterministic, conceptual and parametric models. Deterministic models describe the rainfall–runoff process using physical laws of mass and energy transfer. Conceptual models provide simplified representations of key hydrological process using a perceived system (such as a series of interconnected stores and flow pathways). Parametric models use mathematical transfer functions (such as multiple linear regression equations) to relate meteorological variables to runoff. Hydrological models are further classified as either lumped or distributed. In the recent years, Artificial Neural Network (ANN), which is basically a lumped model have been applied successfully to model complex non-linear input-output relationships (Zhang and Govindaraju 2000, Singh et al 2013). Adaptive neuro-fuzzy inference system (ANFIS) which is integration of neural networks and fuzzy logic has the potential to capture the benefits of both these fields in a single framework. A fuzzy rule-based system (FRBS) using the Takagi-Sugeno-Kang approach has been developed for rainfall-runoff Modeling (Casper et al 2007). The performance of the ANFIS have been compared with MLR and found better than MLR for rainfall-runoff modelling (Singh et al 2016). The present study has been undertaken to develop rainfall-runoff models using artificial neural network (ANN) and adaptive neuro-fuzzy inference system (ANFIS) approaches for Usri river basin, to validate the formulated models and performance of the developed models for their comparison.

MATERIAL AND METHODS

Study area: The Usri river basin was selected as study area, which is the tributary of Barakar river and the Baraka river is the main tributary of the Damodar River in eastern India. The Usri river basin is located 13 km east in Giridih district of Jharkhand that occupies11.74 per cent of the total area. The

total catchment area of Usri river basin is 731.02 km^2 and is situated within the geographical coordinates of 86°20°E longitude to 24°11°N latitude. The daily rainfall and runoff data of the period (June 15th to September 30th) for the years 1998–2008 were obtained from Soil and Water Conservation Division of Damodar Valley Corporation, Hazaribagh. The 70% data were used for model calibration and remaining 30% data were used for validation.

Artificial neural networks (ANN$_s$): In the present study, the feed forward error back propagation algorithm is used for ANN training (Rumelhart et al 1986). The ANN network used for the present study is shown in Fig. 2. There are three basic layers or levels of data processing units viz., the input layer, the hidden layer and the output layer. Each of these layers consists of processing units called nodes of the neural network. The interconnections between nodes of different layers are called weights of the neural network. Different artificial neural network (ANN) structures were trained with the help of back-propagation algorithm using the training data set. The single and double hidden layer and the different number of neurons in each hidden layer were used for structures of ANN and their performance in converging towards the desired output. After training is over, the ANN performance is validated. Depending on the outcome, either the ANN has to be re-trained or it can be implemented for its intended use.



Adaptive neuro-fuzzy inference system (ANFIS): Adaptive neuro-fuzzy inference system (ANFIS) model, an integration of neural networks and fuzzy logic, has been successfully applied in modelling of non-liner time series. ANFIS consists of inputs and output database, a fuzzy system generator, a fuzzy inference system (FIS) and an adaptive neural network. The combination of a FIS and an adaptive neural network is known as the Sugeno−type fuzzy inference system (Takagi and Sugeno 1985). An optimization method, hybrid learning algorithm, which utilizes system adaptability by using both back propagation and least mean square optimization algorithms is used. ANFIS architecture based on the first-order Sugeno model, a common rule set with two fuzzy if-then rules is as follows:

Rule 1: If x_1 is A_1 and x_2 is B_1, then $f_1 = a_1 x_1 + b_1 x_2 + c_1$. … (1)

Rule 2: If x_1 is A_2 and x_2 is B_2, then $f_2 = a_2 x_1 + b_2 x_2 + c_2$. … (2)

where, x_1 and x_2 are the crisp inputs to the node and A_1, B_1, A_2, B_2 are fuzzy sets, a_i, b_i and c_i (i = 1, 2) are the coefficients of the first-order polynomial linear functions.

The weights w_1 and w_2 are assigned to rules 1 and 2 respectively. Weighted average is calculated as

$$f = \text{weighted average} = \frac{w_1 f_1 + w_2 f_2}{w_1 + w_2} \quad (3)$$

The ANFIS consists of five layers (Jang, 1993, Dursun et al 2012) (Fig. 3).

Performance evaluation: The performance evaluation statistics used for ANN training in the present work are correlation coefficient (r), root mean square error (RMSE) and coefficient of efficiency (CE). These parameters have been determined using the following equations:

$$r = \frac{\sum_{j=1}^{n}\left\{\left(Y_j - \bar{Y}_j\right)\left(Y_{ej} - \bar{Y}_{ej}\right)\right\}}{\sum_{j=1}^{n}\left(Y_j - \bar{Y}_j\right)^2 \sum_{j=1}^{n}\left(Y_{ej} - \bar{Y}_{ej}\right)^2} \times 100 \quad (4)$$

$$RMSE = \sqrt{(1/n)\left(\sum_{i-1}^{n}\left(Y_{ej} - Y_j\right)^2\right.} \quad (5)$$

$$CE = \left[1 - \frac{\sum_{i=1}^{n}\left(Y_{ej} - Y_j\right)^2}{\sum_{i=1}^{n}\left(Y_{ej} - \bar{Y}_{ej}\right)^2}\right] \times 100\ \% \quad (6)$$

where, Y_j is the predicted values, Yj is the mean of predicted values, Y_{ej} is the observed values; n is the number of observations and Y_{ej} is the mean of observed values

RESULTS AND DISCUSSION

In present study for input data selection, gamma test (GT) was used. The 2^n-1 possible meaningful combinations of inputs were evaluated, from which the best model was determined using gamma statistic values. The most effective input vectors were selected based on the minimum values of gamma test (┌), standard error and V-ratio. For runoff prediction models, inputs were rainfall of current day, past one days, past two days, past three days and runoff of previous one day, two days and three days expressed as P_t, P_{t-1}, P_{t-2}, P_{t-3}, Q_{t-1}, Q_{t-2}, Q_{t-3}, respectively. In total 127 combinations

of these variables were examined for runoff prediction. Finally, rainfall of current day, previous one day, previous two days, previous three days, runoff of previous one day, two days were selected as the prime input variables for runoff prediction based on gamma test as shown in Table 1. The ANN models were trained utilizing different number of neurons in the single and double hidden layers, for training and testing periods. Log-sigmoid activation function was used in each hidden layer and pureline used in output layer and Levenberg-marquardt learning algorithm were used for maximum 1000 epochs. ANFIS models were developed using Takagi-Sugeno-Kang type fuzzy inference system with number of epochs equal to 50 and was used to identify the one which trains the network more efficiently. Four different types of membership functions (MFs) were used for ANFIS networks as: Gaussian, Generalized-bell, Trapezoidal, Triangular membership function.

The comparative performance of various ANN and ANFIS models based on r, RMSE and CE estimation are given in Table 2 and 3, respectively. During calibration, the values of r, RMSE and CE for all the developed models vary in the range of 0.608 to 0.854, 17.16 to 26.54 m^3/sec and 45.18 to 73.05 %, respectively and for ANFIS models, these indices vary in the range of 0.544 to 0.934, 11.80 to 27.74 m^3/sec and 29.64 to 87.25% (Table 3). It was concluded based on the greater values of r, CE and the lower value of RMSE that ANN model with architecture 6-28-1 and 6-45-45 and ANFIS model gauss 3 are as the best model with respective technique for the study area than the other models. The values of r for the best network using ANN(6-28-1 and 6-45-45-1) and ANFIS (Gauss 3) runoff prediction models are 0.844, 0.854 and 0.934 for training periods and 0.820, 0.848 and 0.866 for testing, respectively (Table 4). The RMSE values for the selected network6-28-1remain 17.80 and 41.04 m^3/sec and for network 6-45-45-1 are 17.16 and 44.64 m^3/sec for both the periods and RMSE for ANFIS-

Table 1. Comparison of various models to select the best model for runoff prediction

Input	Mask	Gamma (Γ)	Standard error	V-ratio
$P_{t-3}, P_{t-2}, P_{t-1}, P_t, Q_{t-3}, Q_{t-2}, Q_{t-1}$	1111111	0.119	0.0211	0.475
$P_{t-2}, P_{t-1}, P_t, Q_{t-3}, Q_{t-2}, Q_{t-1}$	0111111	0.143	0.0248	0.572
$P_{t-3}, P_{t-1}, P_t, Q_{t-3}, Q_{t-2}, Q_{t-1}$	1011111	0.123	0.0144	0.492
$P_{t-3}, P_{t-2}, P_t, Q_{t-3}, Q_{t-2}, Q_{t-1}$	1101111	0.135	0.0228	0.540
$P_{t-3}, P_{t-2}, P_{t-1}, Q_{t-3}, Q_{t-2}, Q_{t-1}$	1110111	0.171	0.0231	0.684
$P_{t-3}, P_{t-2}, P_{t-1}, P_t, Q_{t-2}, Q_{t-1}$	1111011	0.118	0.0172	0.471
$P_{t-3}, P_{t-2}, P_{t-1}, P_t, Q_{t-3}, Q_{t-1}$	1111101	0.124	0.0179	0.493
$P_{t-3}, P_{t-2}, P_{t-1}, P_t, Q_{t-3}, Q_{t-2}$	1111110	0.134	0.0151	0.535

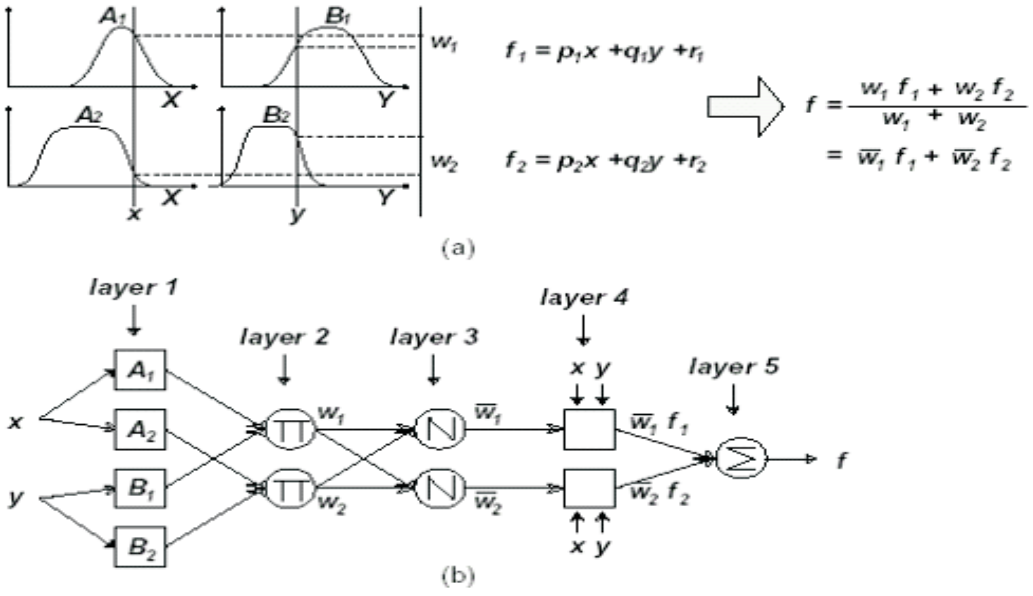
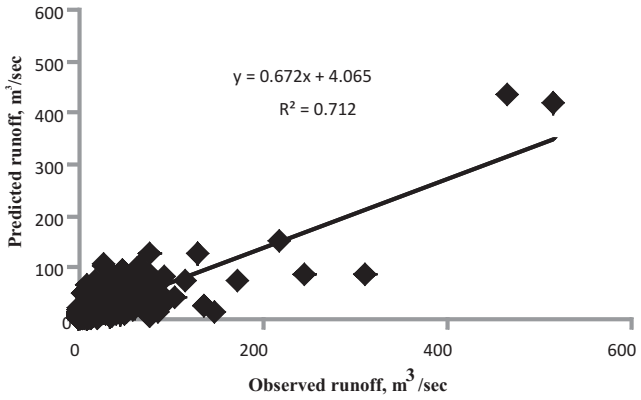


Fig. 2. ANFIS architecture

Table 2. Comparison of various ANN models for runoff prediction

Networks	r	RMSE (m^3/sec)	CE
6–1–1	0.608	26.54	45.18
6-3-1	0.780	20.79	66.33
6-6-1	0.733	22.55	53.49
6-8-1	0.812	19.30	65.94
6–12–1	0.799	19.86	63.93
6–15–1	0.821	18.90	67.84
6–19–1	0.835	18.26	69.51
6-25-1	0.795	20.11	63.01
6-28-1	0.844	17.80	71.41
6-31-1	0.821	19.16	66.41
6-8-8-1	0.777	20.93	59.93
6–14–14–1	0.766	21.66	57.09
6-35-35-1	0.822	18.91	67.33
6-38-38-1	0.779	20.75	60.63
6-40-40-1	0.842	18.07	70.14
6-45-45-1	0.854	17.16	73.05
6-52-52-1	0.824	18.84	67.52
6-55-55-1	0.710	23.28	50.42



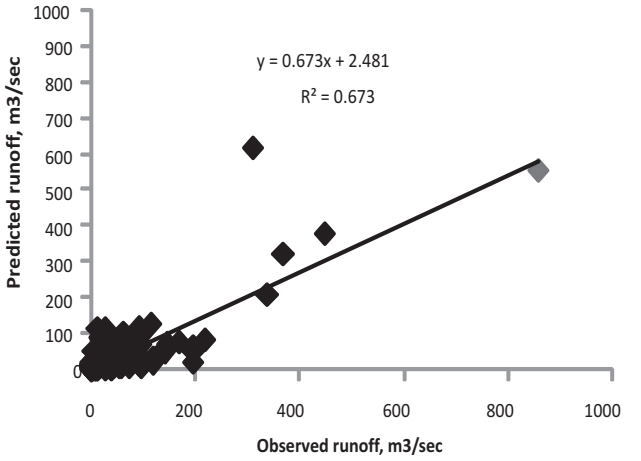
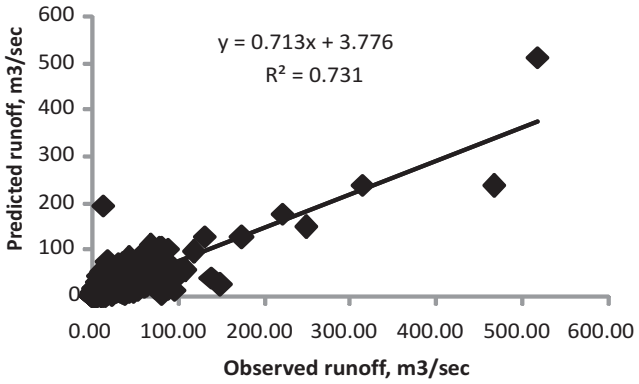


Fig. 3. Scatter diagram between observed and predicted runoff using ANN model (6-28-1) during training and testing periods

Gauss 3 during training and testing periods are 11.80 and 33.79 m^3/sec . The values of CE for network 6-28-1 are 71.02 and 74.43 % and for network 6-45-45-1 are 73.05 and 69.73 % at the time of both the periods. Similarly, the values of CE for ANFIS-Gauss 3 are 87.25 and 79.66 % for runoff prediction models (Table 4). The qualitative assessment of models were shown in graphical form by plotting the predicted daily runoff values with the corresponding

Table 3. Comparison of various ANFIS models for runoff prediction

Networks	r	RMSE (m^3/sec)	CE
Gauss (2)	0.870	16.26	75.82
Gauss (3)	0.934	11.80	87.25
Generalized Bell (2)	0.877	15.86	77.00
Generalized Bell (3)	0.930	12.12	86.56
Trapezoidal (2)	0.544	27.74	29.64
Trapezoidal (3)	0.858	16.95	73.71
Triangular (2)	0.872	16.16	76.11
Triangular (3)	0.911	13.61	83.06



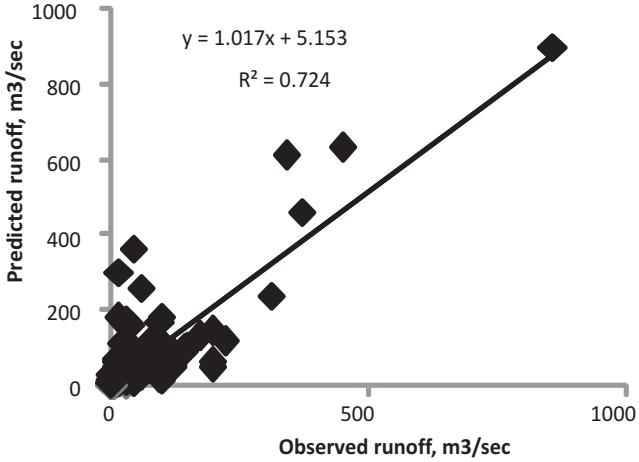


Fig. 4. Scatter diagram between observed and predicted runoff using ANN model (6-45-45−1) during training and testing periods

Table 4. Performance evaluation of developed ANN and ANFIS models for runoff prediction during training and testing periods

Model	Training			Testing		
	r	RMSE	CE	r	RMSE	CE
ANN(6-28-1)	0.844	17.80	71.02	0.820	41.04	74.43
ANN(6-45-45-1)	0.854	17.16	73.05	0.848	44.64	69.73
ANFIS (Gauss, 3)	0.934	11.80	87.25	0.866	33.79	79.66

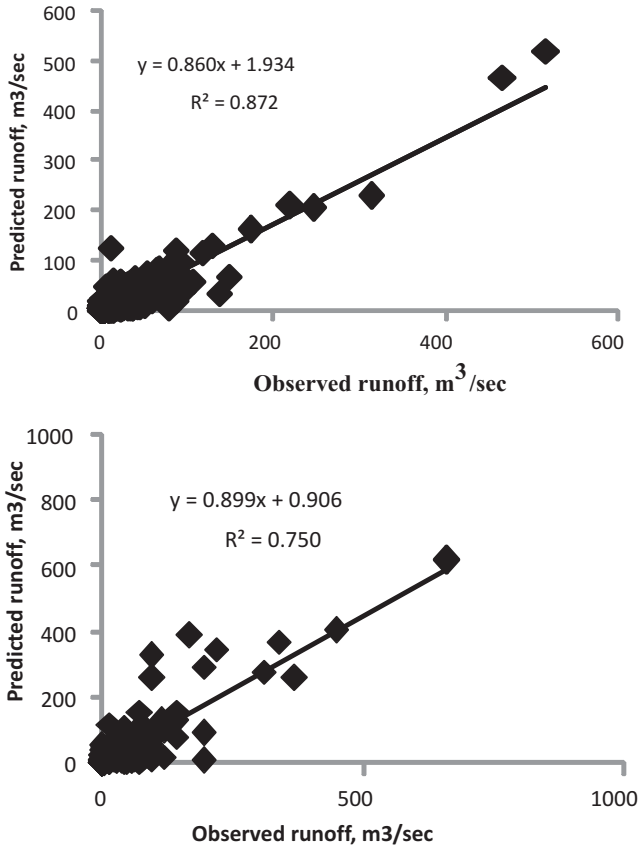


Fig. 5. Scatter diagram between observed and predicted runoff using ANFIS model (Gauss, 3) during training and testing periodsa

observed ones (Fig. 3 to 5). Theses graph indicates that there is a close agreement between the predicted and observed runoff. Based on qualitative and quantitative performance evaluations, the results showed that ANFIS based simulation provided better results in terms of selected performance criteria in comparison to ANN models.

CONCLUSIONS

Neural networks play an important role to overcome this complexity and nonlinearity because they are inherently suited to problems. On the basis of visual observation for observed and predicted values of runoff during calibration and validation periods using the developed models showed satisfactory results. The ANN double hidden layers model (6-45-45-1) outperformed the single hidden layer model (6-28-1) for runoff prediction based on performance evaluation criteria. The ANFIS model (Gauss, 3) provided better results for runoff prediction in comparison with other models. The results showed the (Gauss, 3) ANFIS model is better than ANN model (6-45-45-1) for runoff prediction.

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GIS based Multi-Criteria Decision Making System for Assessment of Landslide Hazard Zones: Case Study in the Nilgiris, India

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***Abstract*:** Landslides are considered as one of the most common natural hazards occurring in the Nilgiris since immemorial time that leads to the tremendous loss of human life, property and economy. In this study, landslide hazard zonation (LHZ) map for the Nilgiris district located in the state of Tamil Nadu, was prepared using various thematic layers such as Precipitation, Slope, Geology, Aspect, Land cover, Distance from road, Lineament Density, Distance from river, Elevation. The results obtained by adopting analytical hierarchy process (AHP) for updation of LHZ map found that nearly 52.5% of the total district area falls under risk zone in which 6% of the regions is fall under highly risk zone. Comparison the LHZ map with the inventory data, data it is found that nearly 90% of the landslides fall under hazardous zone.

***Keywords*:** Analytical hierarchy process, Landslides, Remote Sensing, GIS, Landslide hazard zonation map

Nilgiris is a part of western ghats situated at the junction of Tamil Nadu, Karnataka and Kerala at an elevation of 900m to 2636m above mean sea level. Nilgiris hills plays a major role in tourism between the months of March and August every year as it experiences a relative temperature of 21˚C during summer. Covering an area of 2551 km^2, the district receives heavy rainfall between June to August and October to December. Nilgiris has a long history of disastrous landslides events across decades and experience landslides since immemorial time, but the records are available since 19^{th}century. Due to heavy rain in 1824, a huge landslide in the Kundah hills was recorded. Since then, records are being maintained for the Nilgiris district for every landslides events.

It is noted that in the Nilgiris both the steep and gentle slopes have failed across years and the landslides are spread out in areas that are utilized for various purposes. The areas of crop cultivation and vegetation is found to experience large landslides than other areas. The regions of reserve forest are found to experience less landslides as the erosion of soil is less in Reserved Forests compared to that of cultivation areas. The major triggering factor for landslides in the Nilgiris is the rainfall and deforestation. In Nilgiris, generally landslides season is in between October and December .

The landslides in the Nilgiris doesn't have any standard guidelines which results in consideration of various parameters for identification of landslides hazard zones. Remote Sensing and GIS is the advanced technology that plays a major role in the identification of the hazardous zones. An attempt has been made in the present study for the identification of landslide hazard zonation map considering various parameters such as Precipitation, Slope, Geology, Aspect, Land cover, Distance from road, Lineament Density, Distance from river, Elevation. The LHZ map obtained can help the local authorities in case of disaster event for proper management and save human lives.

MATERIAL AND METHODS

Description of the study area: The Nilgiris is located between 76˚ 14´ E and 77˚ 02´ E longitude and 11˚ 10´ N and 11˚ 42´ N latitude of Tamil Nadu, India (Fig. 1).Charnockite and pyroxene granulite type of rocks cover the major part of the district . Lateritic soil and small patches of sandy loam soil type covers major part of the district. According to the report from Geological Survey of India, Nilgiris district falls under judicious landslide hazard zone. Debris type of landslides is said to occur in major portion of Nilgiris and the major triggering factor is heavy rainfall. The district receives an average annual rainfall of 1700mm.

Thematic layers preparation: The spatial dataset was created in GIS platform with various remote sensing and collateral data. District boundary was obtained with the help of SOI Toposheets (58A/6,7,8,10,11,12,14,15) at an available scale of 1: 50,000. Geology layer was prepared with the help of Geological Quandrangle Map obtained from Geological Survey of India at 1: 2,50,000 scale (Fig. 2 (a)).

INSAR 3D IMR rainfall was downloaded from MOSDAC and processed to obtain the rainfall data for the Nilgiris district. Based on the daily data downloaded it is found that the peak rainfall was experienced on 4th October, 2017, and the corresponding data is taken for analysis. The distribution of rainfall in the Nilgiris district as on 4th October, 2017 (Figure 2 (b)). SRTM DEM (30m) was downloaded from GMTSAR website for the study area and was processed to obtain slope, aspect and elevation layers. Figure 2 (c) shows the DEM of the study area. Generated slope map, aspect map and elevation map are shown in Figure 2 (d), 2 (e) and 2 (f), respectively. Using DEM as input, the streams for the study area was obtained under QGIS Platform (Integrated with GRASS). The stream segment was classified based on the distance into different classes (Figure 2 (g). Landuse/Landcover map was obtained for the study area using Landsat 8 with bhuvan datasets as reference (Figure 2 (h). The roads for the Nilgiris District was obtained from the SOI toposheet and are classified into five different classes Figure 2 (i). Using DEM and Landsat 8 Image as reference, the lineaments for the study area was obtained. Figure 2 (j) shows the lineament density of the study area. The detailed methodology adopted with various layers are shown in Figure 3.

Analytical hierarchy process: One of the most commonly used method for the assessment of complex problems is the analytic hierarchy process (AHP) which reflects the judgement of human thinking by comparison of different layers with respect to each other (Kayastha et al 2013, Tazik et al 2014). The parameters are compared and the weights are normalized based on the sum values and the normalized matrix is obtained. The eigen vector is also calculated for the normalized matrix to check the consistency ratio of the judgement matrix (Subramanian and Ramanathan 2012). Consistency ratio is calculated to validate the AHP pair-wise judgement matrix framed. If the values of consistency ratio are less than 0.1, weightage assigned are to be assumed correct, therefore the process can be performed easily. In case the value of consistency ratio is greater than 0.1, the procedure is to be repeated with new set of values (Alonso and Lamata 2006). Consistency ratio is calculated by using the following formula.

$$CR = \frac{CI}{RI} \qquad (1)$$

Where

CR = Consistency Ratio

CI = Consistency Index

RI = Random Consistency Index = 1.45 (for n = 9) obtained from Table 1 (Franek and Kresta 2014).

RESULTS AND DISCUSSION

The parameters for the study area namely Precipitation, Slope, Geology, Aspect, Land cover, Distance from road, Lineament Density, Distance from river, Elevation were arranged hierarchically and based on the pair-wise

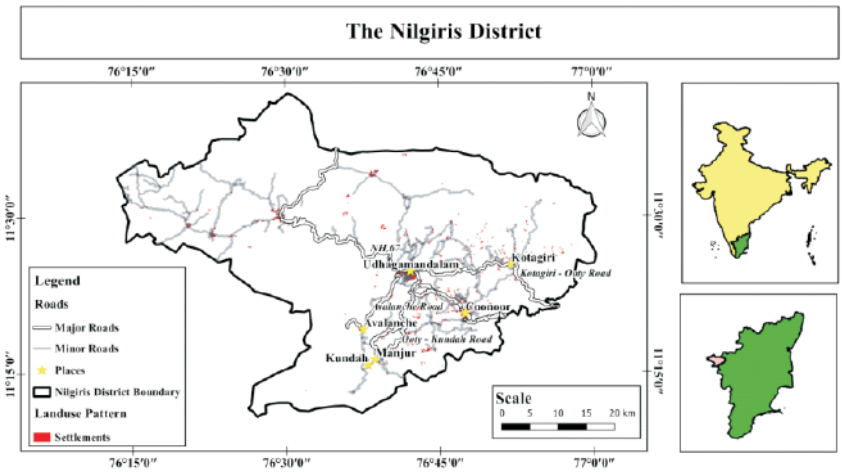

Fig. 1. Geographical location of the study area

Table 1. Random Index values obtained from Saaty's book

n	1	2	3	4	5	6	7	8	9	10
RI	0	0	0.58	0.9	1.12	1.24	1.32	1.41	1.45	1.49

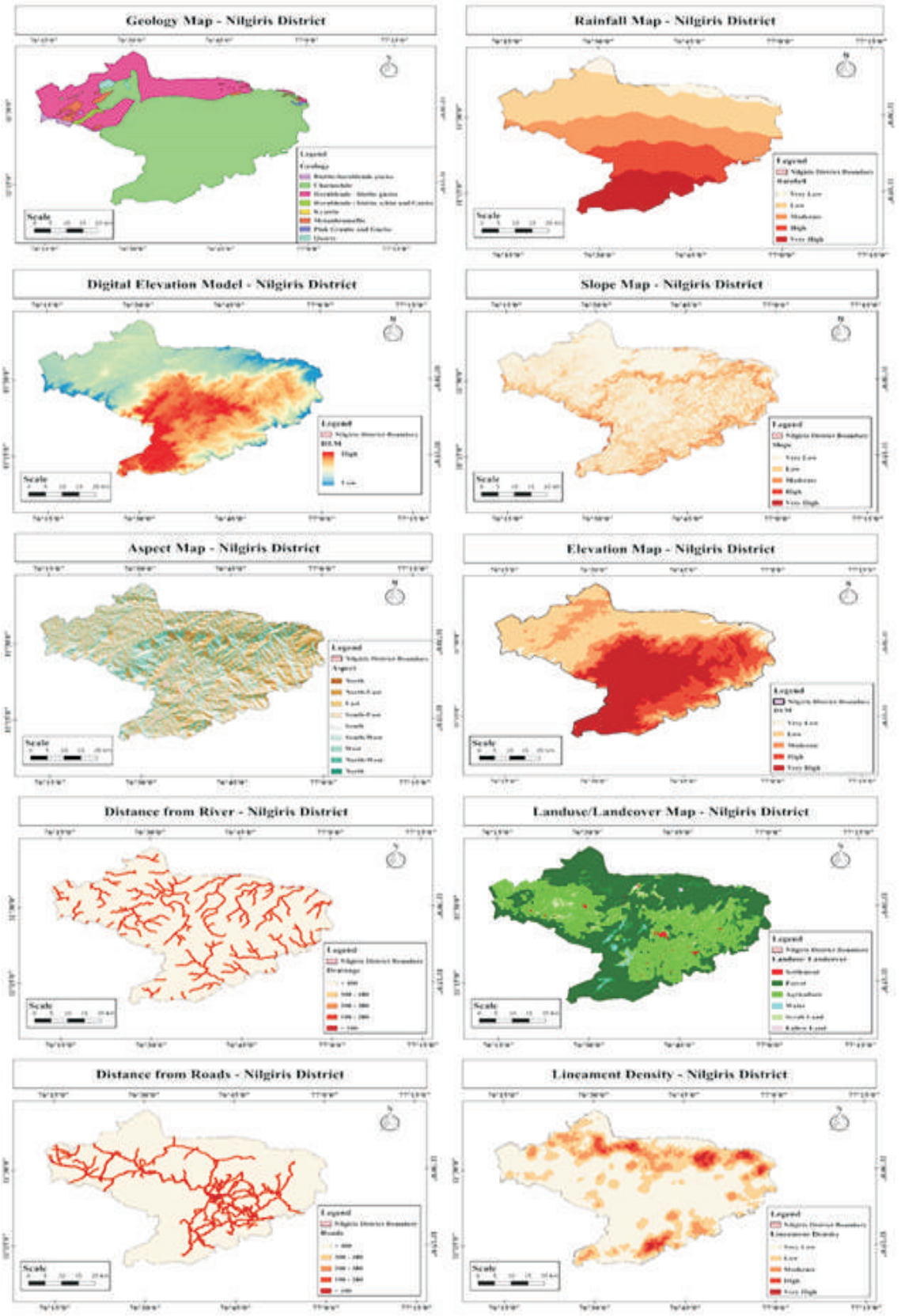

Fig. 2. Nilgiris District (a) Geology Map, (b) Rainfall Map, (c) Digital Elevation Model, (d) Slope Map, (e) Aspect Map,(f) Elevation Map, (g) Distance from Rivers, (h) Landuse/Landcover Map, (i) Distance from Roads, (j) Lineament Density

comparison values are assigned to a scale of 9 for each parameters. In the present study, rainfall, slope and geology were treated as strong parameters. The AHP comparison of all the parameters is shown in Table 2.

The above weights are normalized based on the sum values and the normalized matrix is obtained. The eigen vector is also calculated for the normalized matrix to check the consistency ratio of the judgement matrix. Consistency ratio is the ratio of consistency index and random consistency index. Consistency Index is calculated by using the formula,

$$CI = \frac{\lambda_{max} - N}{N - 1} \quad (2)$$

$$CI = \frac{9.49 - 9}{9-1} = 0.06125$$

$$CR = \frac{0.06125}{1.45} = 0.04$$

In the present study, the consistency ratio 0.04 which is less than 0.1. So the pair wise comparison is found to be acceptable. Based on the weights obtained, the overlay analysis is performed for various layers in QGIS platform. The weightage obtained using AHP matrix and the classification for each layer based on criteria and rank age is shown in Table 3.

CONCLUSIONS

Based on the study, it was found that blocks of Coonor and Udhagamandalam blocks are very highly sensible to landslides. Roads network connecting Udhagamandalam with places like Avvalanche, Manjur and Kundah are also highly sensitive to landslides. Proper remedies are to be taken along the roads to reduce the fatalities. Being a tourism spot, entry can be restricted to the places during the month of October to December. The main objective is to obtain a landslide hazard zonation map using AHP technique for the

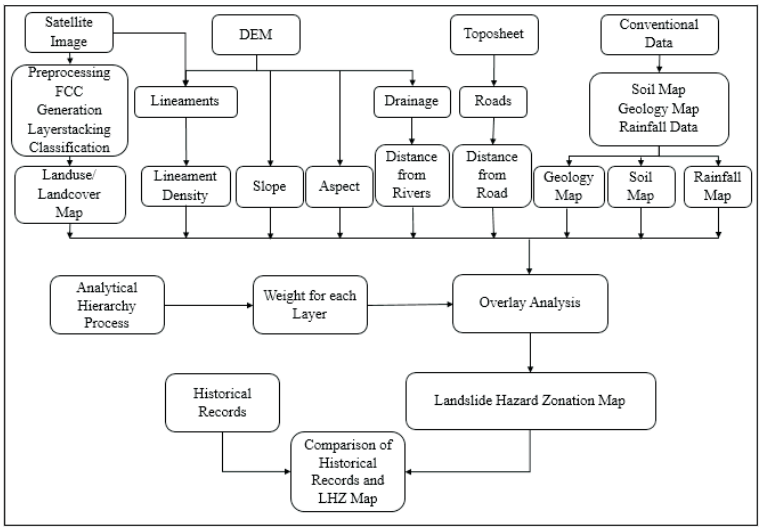

Fig. 3. Detailed methodology of landslide hazard zonation mapping

Table 2. Pair-wise comparison matrix for AHP method

Weight-decision matrix	Precipitation	Slope	Geology	Aspect	Land cover	Distance from road	Lineament Density	Distance from river	Elevation
Precipitation	1	2	2	3	4	3	3	4	7
Slope	1/2	1	3	3	3	4	3	4	7
Geology	1/2	1/3	1	3	2	3	4	4	7
Aspect	1/3	1/3	1/3	1	2	2	1	2	4
Land cover	1/4	1/3	1/2	1/2	1	2	2	2	3
Distance from road	1/3	1/4	1/3	1/2	1/2	1	2	1	4
Lineament density	1/3	1/3	1/4	1	1/2	1/2	1	2	3
Distance from river	1/4	1/4	1/4	1/2	1/2	1	1/2	1	3
Elevation	1/7	1/7	1/7	1/4	1/3	1/4	1/3	1/3	1
Sum	3.63	4.96	7.8	12.75	13.83	16.75	16.83	20.33	38

Table 3. Weightage obtained for various thematic layers with their classification

Layer	Classification	Values	Rank	Weightage
Slope	Very low	0 −15	1	21.87
	Low	15 −30	3	
	Moderate	30 −45	5	
	High	45 −60	7	
	Very high	60 −80	9	
Aspect	North	0.00 −22.50	9	8.92
	North-East	22.50 −67.50	5	
	East	67.50 −112.50	1	
	South-East	112.50 −157.50	5	
	South	157.50 −202.50	7	
	South-West	202.50 −247.50	7	
	West	247.50 −292.50	5	
	North-West	292.50 −337.50	9	
	North	337.50– 360.00	9	
	Flat	-1.00	1	
Lineament density	Very low	0 −25	1	6.32
	Low	25 −50	3	
	Moderate	50 −75	5	
	High	75 −100	7	
	Very high	100 −125	9	
Rainfall	Very low	< 5	1	24.36
	Low	5 −9	3	
	Moderate	9 −13	5	
	High	13 −17	7	
	Very high	17 −21	9	
Distance from roads		0 -100	9	6.55
		100 −200	7	
		200 −300	5	
		300 −400	3	
		400 −600	1	
Elevation	Very low	1 −530	1	2.3
	Low	530 −990	3	
	Moderate	990 −1450	5	
	High	1450 −1910	7	
	Very high	1910 −2620	9	
Distance from rivers		0 -100	9	8.03
		100 −200	7	
		200 −300	5	
		300 −400	3	
		400 −600	1	
Landuse/Landcover	Settlement		9	4.91
	Forest		3	
	Agricultural		5	
	Water		1	
	Scrub land		7	
	Fallow land		7	
Geology	Pink Granite and Gneiss		7	16.72
	Hornblende – biotite schist and Gneiss		5	
	Kyanite		5	
	Quartz		5	
	Hornblende −biotite gneiss		7	
	Metaultramafite		3	
	Charnockite		9	
	Biotite-hornblende gneiss		7	
Total weight				100

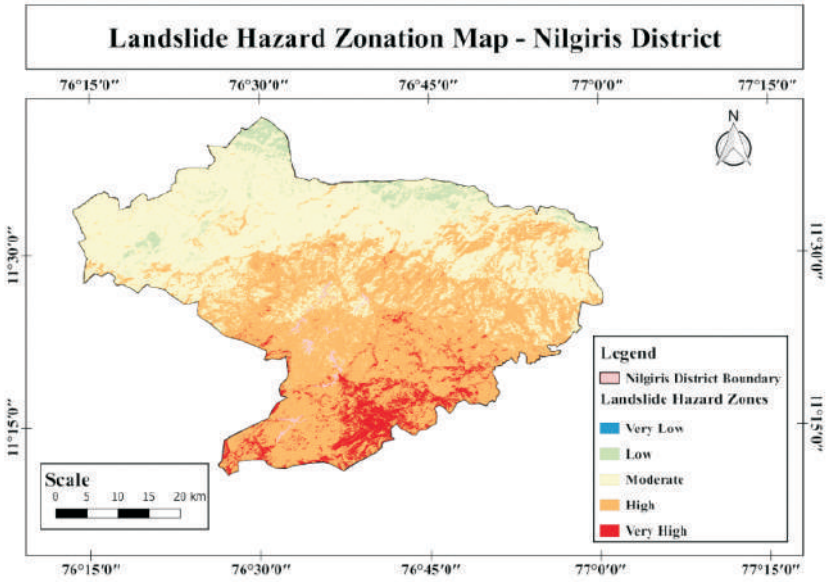

Fig. 4. Landslide Hazard Zonation map – Nilgiris District

Table 4. Comparison of landslides hazard zones and historical landslides data

Landslide classification	No. of landslides	Percentage of landslides
Very low	0	0.00
Low	1	1.47
Moderate	6	8.82
High	52	76.47
Very high	9	13.24

Nilgiris district which can be used by various district authorities to create awareness among the people. Periodical updation of the landslide hazard zonation map and providing periodical awareness can help to reduce the risk of human life in the Nilgiris District. Based on the study, it is also recommended to follow multi criteria decision making analysis such as AHP, Fuzzy logic, etc for updation of LHZ map.

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Weekly Pan-evaporation Simulation using MLP, CANFIS, MLR and Climate-based Models at Pantnagar

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Abstract: This paper explores the potential of multi-layer perceptron (MLP), co-active neuro-fuzzy inference system (CANFIS) and multiple linear regression (MLR) in simulating weekly pan-evaporation at Pantnagar, located in the foothills of central Himalayan region in Uttarakhand, India. In this study, a non-linear modelling tool i.e. gamma test (GT) was utilized to identify the most significant input parameters for MLP, CANFIS and MLR approaches. The simulated pan-evaporation using these techniques was compared with the empirical models such as Stephens-Stewart (SS) and Griffith (G) based on root mean squared error (RMSE), Nash-Sutcliffe efficiency (NS_E) and coefficient of correlation (r). The results of comparison revealed that the MLP model performed superior than the CANFIS, MLR, SS and G models in simulating the weekly pan-evaporation using the available meteorological data for study location.

Keywords: MLP, CANFIS, MLR, Gamma test, Pantnagar

Evaporation, a major component of hydrologic cycle, is affected by various meteorological factors, such as air temperature, relative humidity, solar radiation, wind speed, and vapour pressure deficit occurring in the nature. Simulation of evaporation is useful for determining crop water requirement, irrigation scheduling and sustainable uses of water resources (Lenters et al 2005). Several studies have been conducted by various researchers to simulate the accurate evaporation losses from free water surfaces. In recent time, black box models have been successfully applied in hydrological modelling and water resources management for accurate simulation of pan evaporation (Sudheer et al 2002, Terzi and Keskin 2005, Kisi 2006, Shiri and Kisi 2011, Shirgure and Rajput 2012). Keskin et al (2004) investigated that the fuzzy model and Penman method have good ability for pan evaporation simulation in Turkey. Piri et al (2009) applied ANN and neural network autoregressive exogenous (NNARX) approaches for daily pan evaporation simulation in arid and semi-arid regions of Iran. Tabari et al (2010) simulated daily pan evaporation using MLP and non-linear regression models in Iran, and reported that MLP model characterized by Delta-Bar-Delta learning algorithm gave better simulation of daily pan evaporation. Kisi et al (2012) compared the results of generalized neuro-fuzzy (GNF) to Penman, SS, and Griffith's models in Arizona, USA. Results of comparison revealed that the GNF models performed superior to the Penman, SS and Griffith's models. Tabari et al (2012) used MLP and CANFIS models to predict daily pan evaporation in semi-arid region of Iran, and stated that the MLP model simulate far better than the CANFIS model in the study area. Malik and Kumar (2015) studied the potential of ANN, CANFIS and MLR techniques in daily pan evaporation simulation at Pantnagar, India. The results revealed that the ANN model performs superior to the CANFIS and MLR models.

Keeping the above reviews in mind, this study was conducted with objectives: (i) to select proper input variables combination for MLP, CANFIS and MLR using gamma test and their calibration; (ii) to validate the MLP, CANFIS and MLR models for selected input variables combination; and (iii) to compared the results obtained by MLP, CANFIS and MLR models with that of Stephens-Stewart and Griffith models.

MATERIAL AND METHODS

Study location and data collection: The study was conducted at Pantnagar with longitude of 79° 31′ 0" E and latitude of 29° 3′ 0" N located in Uttarakhand State of India. The location of study area lies in the *Tarai* belt situated in the (Fig. 1) foothills of Indian central Himalayas with an elevation of 243.8m above mean sea level. It has a sub-humid and sub-tropical climate with summer season from February to May, rainy season from June to September, and winter season from October to January. The mean annual rainfall in the study region is about 1400 mm. The observed weekly meteorological data (January, 2004 to December, 2007) including maximum and minimum air temperatures (T_{min} and T_{max}) and relative humidity (RH_{max} recorded at 7:00 AM in the

morning and RH_{min} recorded at 2:00 PM in afternoon), wind speed (U_s), sun-shine hours (SS_h) and weekly pan-evaporation (E_{pw}) were collected from Crop Research Centre (CRC) observatory at G. B. Pant University of Agriculture and Technology, Pantnagar, Uttarakhand, India. The total available dataset was splited into; (i) training dataset: from January 1st, 2004 to December 31st, 2006 was used for model calibration; and (ii) testing dataset: from January 1st to December 31st, 2007 was used for model validation. Table 1 gives the details about statistical parameters of training, testing, and whole datasets. Table 2 represents the cross-correlation matrix between the input (T_{max}, T_{min}, RH_{max}, RH_{min}, U_s and SS_h) and output variable (E_{pw}).

Gamma test (GT): The concept of gamma test was first discovered by Stefansson et al (1997), which was later modified and used by other researchers (Piri et al 2009). Gamma test was used to estimate the minimum standard error for each input-output dataset with continuous nonlinear models. In order to calculate gamma (Γ), a linear regression line is constructed as:

$$y = A\Delta + \Gamma \quad (1)$$

where, y is the output vector of the regression line, A is gradient and Δ is the intercept of the regression line. The value of Γ is corresponding to the output at Δ = 0. The smaller value of Γ (close to zero), is acceptable.

Multi-layer perceptron (MLP): MLP was first introduced by Haykin (1998). The MLP network with single input and hidden layers with one output was used in this study. This environment of MLP was created in Neuro Solutions 5.0 software with error-and-trail procedure.

Co-active neuro-fuzzy inference system (CANFIS): Jang et al (1997) introduced the concept of CANFIS, which belongs to a general class of adaptive neuro-fuzzy inference system. CANFIS has the advantages of both ANN and fuzzy inference systems in a single frame work. CANFIS includes fuzzification layer, rule layer, normalization layer, defuzzification layer and summation layer. The functioning of each layer was described by (Aytek 2008). The architecture of CANFIS was decided using trial-and-error method in Neuro Solutions 5.0 software.

Multiple linear regression (MLR): MLR constructs the linear correlations between a dependent variable and two or more independent variables. Mathematically, linear regression equation (Malik and Kumar, 2015) is written as:

$$Y = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + \ldots + \beta_k X_n \quad (2)$$

where, $\hat{Y}$ *is* the output variable; $X_1, X_2, \ldots\ldots X_n$ are the input variables; and $\beta_0, \beta_1, \beta_2 \ldots\ldots \beta_k$ are the regression coefficients.

Empirical models

Stephens-Stewart (SS) model: Stephens-Stewart (1963) formulated this model for pan evaporation prediction using only two climatic variables. Mathematically, SS model can be written as:

$$E_{pw} = R_s (a + bT_m) \quad (3)$$

where, *a* and *b* are the regression coefficients; R_s is solar radiation (MJ m^{-2} day^{-1}); and T_m is mean air temperature (°C).

Griffith's (G) model: Griffith's (1966) established the relationship between T_m and U_s for estimation of evaporation:

$$E_{pw} = \theta + \propto_1 T_m + \propto_2 U_s \quad (4)$$

where, θ, $\propto_1$ and $\propto_2$ are regression fitting coefficients.

Performance evaluation indices: The performance of MLP, CANFIS, MLR, SS and G models during calibration and validation were evaluated using root mean squared error (RMSE); Nash-Sutcliffe efficiency, NS_E(Nash-Sutcliffe, 1970); and coefficient of correlation (r). These indices are written as:

$$RMSE = \sqrt{\frac{1}{n}\sum_{i=1}^{N}(X_i - Y_i)^2} \quad (0 < \text{RMSE} < \infty) \quad (5)$$

$$NS_E = \left[1 - \frac{\sum_{i=1}^{N}(X_i - Y_i)^2}{\sum_{i=1}^{N}(X_i - \bar{X})^2}\right] \quad (0 < \text{NSE} < 1) \quad (6)$$

$$r = \left[\frac{\sum_{i=1}^{N}(X_i - \bar{X})(Y_i - \bar{Y})}{\sum_{i=1}^{N}(X_i - \bar{X})^2 \sum_{i=1}^{N}(Y_i - \bar{Y})^2}\right] (-r < 1 < 1) \quad (7)$$

where, *X* and $\hat{Y}$ are the observed and simulated values for i^{th} dataset; *N is* the total number of observations; x and y are the mean of observed and simulated values, respectively.

RESULTS AND DISCUSSION

Input variable selection using gamma test: Different combinations (Table 3) of six input variables (T_{max}, T_{min}, RH_{max}, RH_{min}, U_s, and SS_h) were examined using gamma test to assess their influence on weekly pan evaporation simulation. The combination of input variable with the smallest score of Γ was selected as best input variable combination for weekly pan evaporation simulation (Piri et al 2009). Using this criteria, the combination of six variables T_{max}, T_{min}, RH_{max}, RH_{min}, U_s, SS_h, with Γ = 0.497, gradient = 0.009, standard error = 0.115, V_{ratio} = 0.067 and mask = 111111 was selected as best input variable combination for *weekly pan evaporation simulation* using MLP-5, CANFIS-5 and MLR-5 models.

Simulation of E_{pw} using MLP-5 model: Several tests were

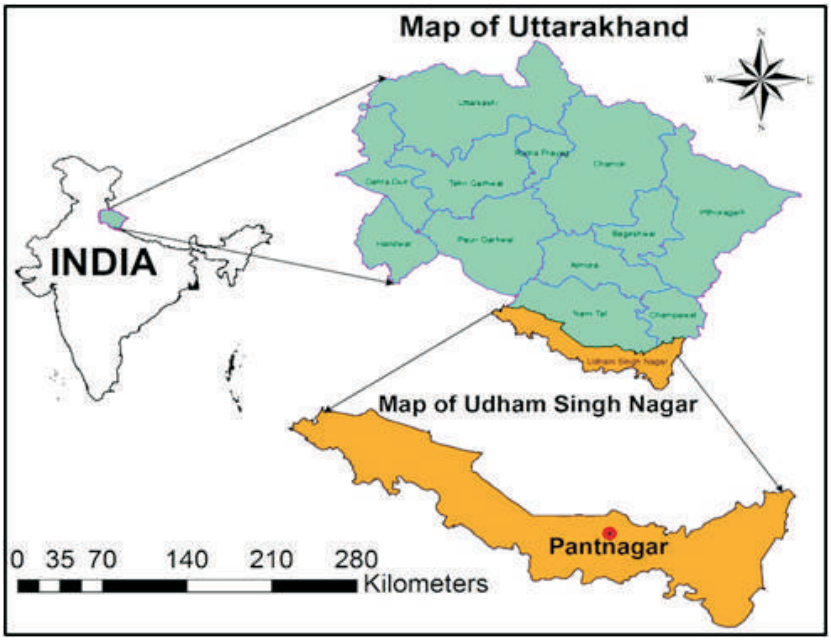

Fig. 1. Location map of study area

Table 1. Statistical analysis of available dataset at Pantnagar

Statistical parameters	Meteorological variables with their units						
	T_{max} (^{0}C)	T_{min} (^{0}C)	RH_{max} (%)	RH_{min} (%)	U_s (km h^{-1})	SS_h (h)	E_{pw} (mm)
Calibration (156 datasets)							
Minimum	14.60	3.70	51.00	15.00	1.00	1.00	0.80
Maximum	41.60	27.90	97.00	78.00	19.80	11.30	17.20
Mean	29.69	17.15	84.45	50.59	5.23	7.21	4.46
Standard deviation	5.86	7.08	10.64	16.08	3.38	2.20	2.82
Coefficient of variation	0.19	0.41	0.13	0.32	0.65	0.31	0.63
Skewness	-0.36	-0.21	-1.49	-0.40	1.57	-0.48	1.33
Kurtosis	-0.34	-1.44	1.32	-0.72	3.03	-0.31	2.46
Validation (52 datasets)							
Minimum	17.30	2.60	53.00	8.00	1.70	1.00	1.30
Maximum	40.50	25.50	95.00	84.00	7.70	11.00	10.90
Mean	29.03	16.88	83.58	51.73	4.66	6.40	3.92
Standard deviation	5.22	7.04	9.68	17.99	1.79	2.24	2.33
Coefficient of variation	0.18	0.42	0.12	0.35	0.38	0.35	0.59
Skewness	-0.16	-0.32	-1.89	-0.27	0.02	-0.18	1.28
Kurtosis	-0.12	-1.22	2.81	-0.56	1.27	-0.25	0.95
Whole (208 datasets)							
Minimum	14.60	2.60	51.00	8.00	1.00	1.00	0.80
Maximum	41.60	27.90	97.00	84.00	19.80	11.30	17.20
Mean	29.50	17.08	84.23	50.88	5.09	7.01	4.32
Standard deviation	5.72	7.07	10.41	16.58	3.07	2.24	2.71
Coefficient of variation	0.19	0.41	0.12	0.33	0.60	0.32	0.63
Skewness	-0.32	-0.24	-1.56	-0.35	1.67	-0.39	1.36
Kurtosis	-0.31	-1.38	1.61	-0.64	4.01	-0.36	2.43

carried out using one and two hidden layers with varying number of neurons in MLP-5 model, but MLP-5 with 6-8-1 architecture (six input variables, eight neurons, and one output) was suitable in E_{pw} simulation for study location. The results of MLP-5 model during validation period gave the value of RMSE as 0.406 mm/week; NS_Eas 0.969; andras 0.991 (Table 4). The temporal variation in the observed and simulated values of E_{pw} by MLP-5 model are plotted in Fig. 2, which clearly indicates that the observed values match fairly with simulated values. Their corresponding scatter plot indicates that the regression line with the coefficient of determination R^2 as 0.983 during the validation phase is fairly close to the exact line (45^{0}line). It is also revealed that the regression and exact lines (Fig. 2) cross each other at 5.7 mm/week evaporation rate, which indicates that the evaporation rate more than 5.7 mm/week are under-predicted by MLP-5 model covering about 17% data, i.e. about 83% data are over-predicted.

Simulation of E_{pw} using CANFIS-5 model: The architecture of CANFIS-5 model was built with two gaussian membership functions per input, Takagi-Sugeno-Kang fuzzy model, hyperbolic tangent activation function and delta-bar-delta

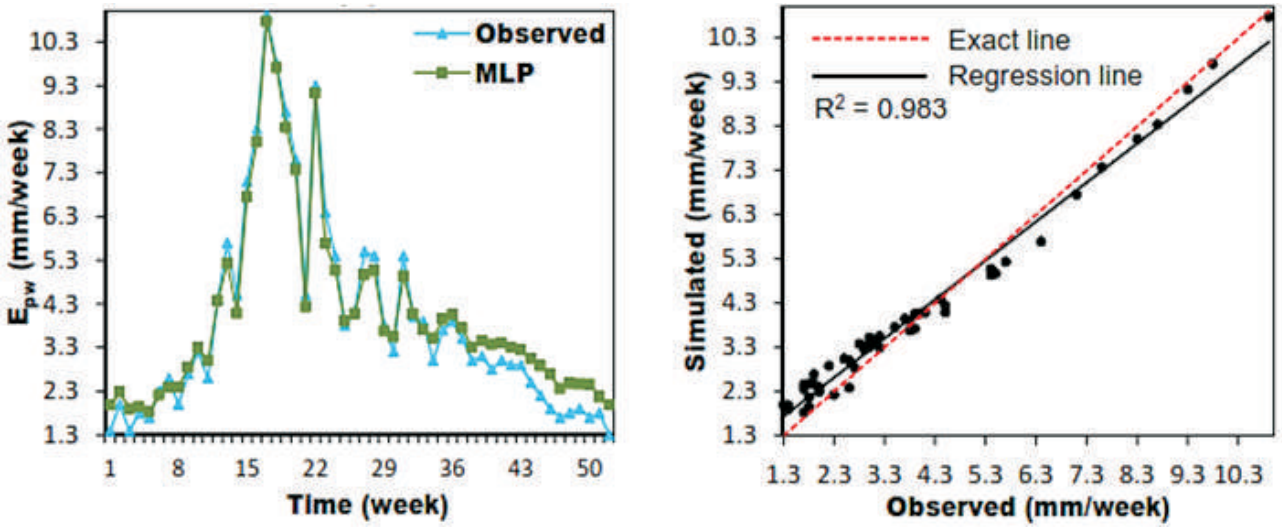

Fig. 2. Temporal variation of observed and simulated values of E_{pw} by MLP-5 model during testing phase and their corresponding scatter plot

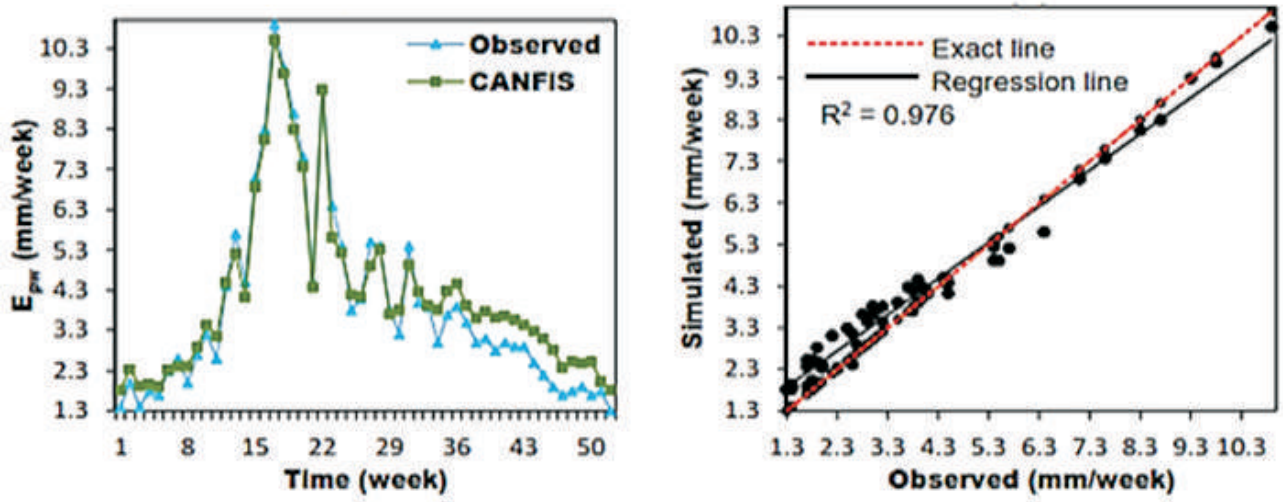

Fig. 3. Temporal variation of observed and simulated values of E_{pw} by CANFIS-5 model during testing phase and their corresponding scatter plot

learning algorithm. There was non−significant improvement in the performance of CANFIS-5 model by changing the number of membership functions. Figure 3 shows the line diagram (left side) and scatter plot (right side) between observed and simulated values of E_{pw} using CANFIS-5 model during validation period. The results of CANFIS model during validation period gave the value of RMSE as 0.456 mm/week; NS_E as 0.961; and r as 0.988 (Table 4). The simulated values also match closely with the observed values of E_{pw}, and well scattered around the exact line with R^2 as 0.976. It is also revealed that the regression and exact lines (Fig. 3) cross each other at 6.4 mm/week evaporation rate, which indicates that the evaporation rate more than 6.4 mm/week are under-predicted by CANFIS-5 model covering about 13% data i.e. about 87% data are over-predicted.

Simulation of E_{pw} using MLR-5 model: The results of MLR−5 model during validation period gave the value of RMSE as 0.913 mm/week; NS_E as 0.846; and r as 0.945 (Table 4). A comparison was made in between observed and simulated values of E_{pw} by MLR-5 model (Fig. 4) during in validation phase, which indicates a clear difference between the predicted and observed values. The scatter diagram (left side) also clearly indicates that regression line with R^2 as 0.893 is fairly above the exact line throughout the whole range of the evaporation data, which indicates that MLR-5 model always over-predicts the evaporation rate.

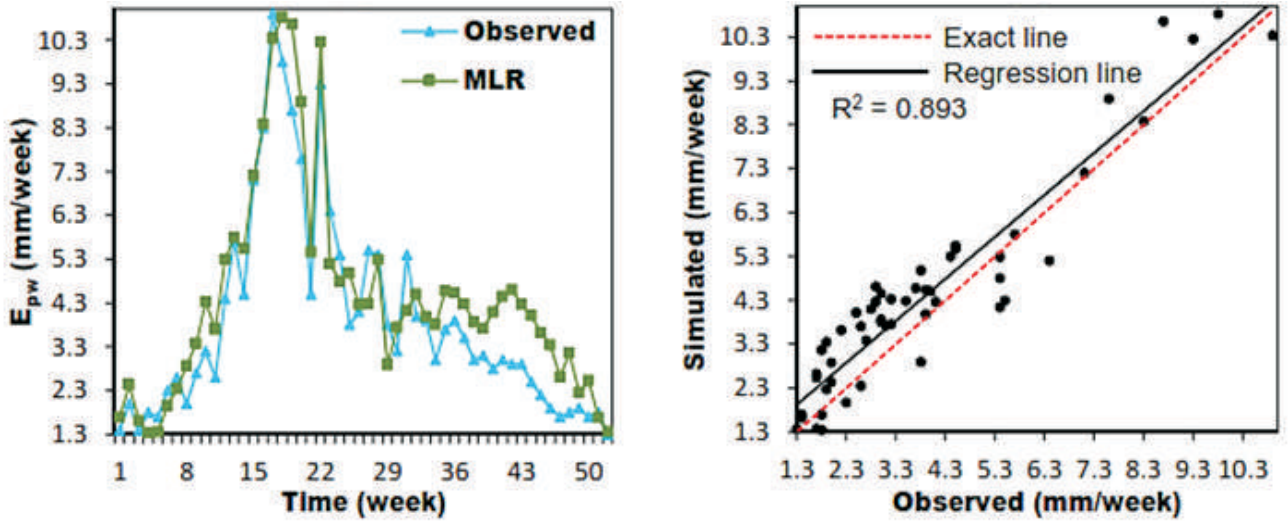

Fig. 4. Temporal variation of observed and simulated values of E_{pw} by MLR-5 model during testing phase and their corresponding scatter plot

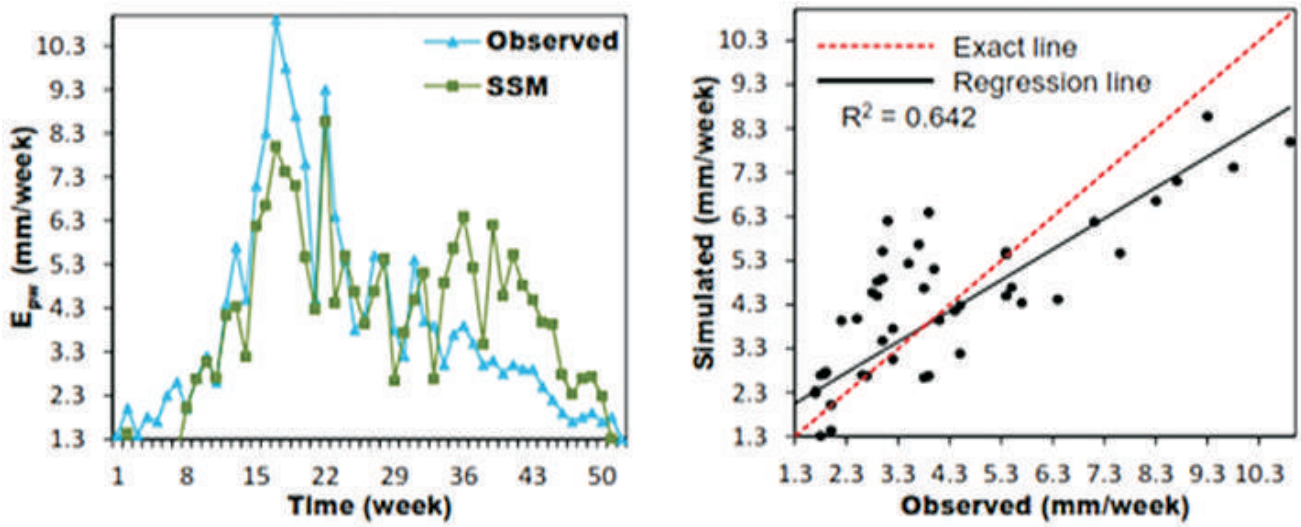

Fig. 5. Temporal variation of observed and simulated values of E_{pw} by SS model during testing phase and their corresponding scatter plot

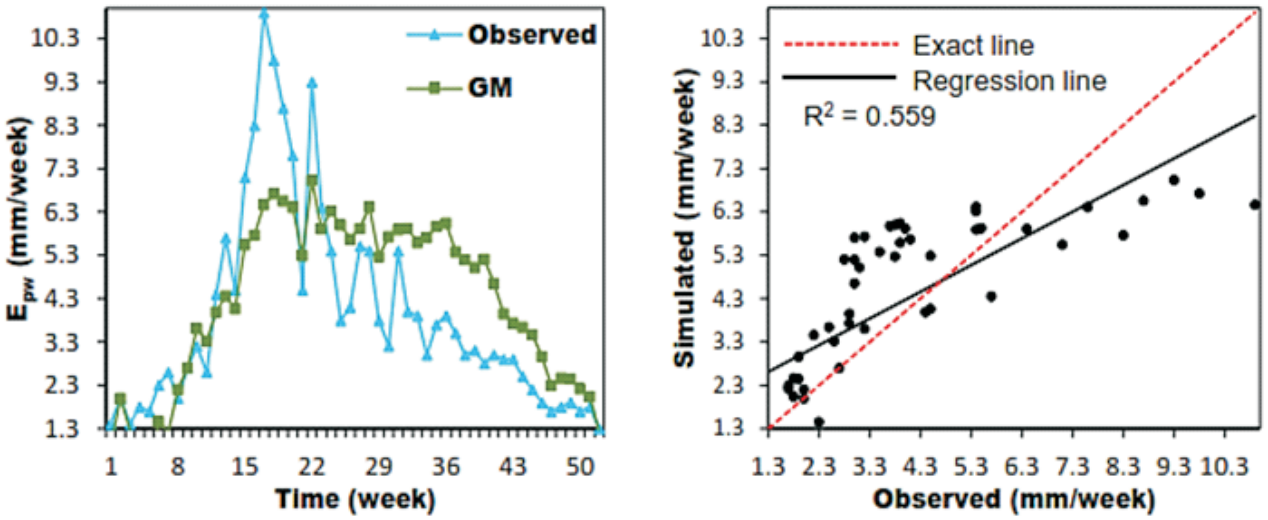

Fig. 6. Temporal variation of observed and simulated values of E_{pw} by G model during testing phase and their corresponding scatter plot

Table 2. Cross-correlation matrix among various input variables at Pantnagar

Variables	T_{max}	T_{min}	RH_{max}	RH_{min}	SS_h	U_s	E_{pw}
T_{max}	1.0						
T_{min}	0.778	1.0					
RH_{max}	-0.741	-0.343	1.0				
RH_{min}	-0.340	0.276	0.691	1.0			
SS_h	0.523	0.049	-0.562	-0.703	1.0		
U_s	0.461	0.554	-0.359	0.014	0.056	1.0	
E_{pw}	0.856	0.589	-0.872	-0.486	0.479	0.574	1.0

Table 3. Gamma test results for various combinations of input variables at Pantnagar

Models No.	Input combinations	Gamma test statistics				
		Gamma (Γ)	Gradient	SE	V_{ratio}	Mask
1	T_{max}	0.883	0.206	0.096	0.119	100000
2	T_{max}, W_S	0.634	0.111	0.115	0.086	100001
3	T_{max}, RH_1, W_S	0.535	0.028	0.061	0.072	101001
4	T_{max}, T_{min}, S_H	0.554	0.099	0.114	0.075	110010
5	T_{max}, T_{min}, RH_1, RH_2, W_S, S_H	0.497	0.009	0.115	0.067	111111

Table 4. RMSE, NS_E and r values for MLP-5, CANFIS-5, MLR-5, SS and G models during testing period at Pantnagar

Model	Performance evaluation indices		
	RMSE (mm/week)	NS_E	r
MLP-5	0.406	0.969	0.991
CANFIS-5	0.456	0.961	0.988
MLR-5	0.913	0.846	0.945
SS	1.399	0.637	0.801
G	1.582	0.537	0.747

Simulation of E_{pw} using SS and G models: Finally, the simulation potential of Stephens-Stewart (SS) and Griffiths (G) models were assessed (Table 4). Both SS and G models used different input variables as explained earlier. For SS model, the results indicated the value of RMSE as 1.399 mm/week; NS_E as 0.637; and r as 0.801; whereas for G model, RMSE was 1.582 mm/week, NS_E was 0.537, and r was 0.747 during the validation period. Figures 5 and 6 illustrate the comparison of observed and simulated values of E_{pw} by SS and G models, respectively. It was indicated that the simulated values by SS and G models did not match at all with the observed values of E_{pw}. Their corresponding scatter

plots also indicated wide variability between simulated and observed values R^2 = 0.642 for SS model, and 0.559 for G model. The results of comparison among the performances of MLP-5, CANFIS-5, MLR-5, SS and G models based on RMSE, NS_E, and r values during validation phase revealed that the MLP-5 model performed better than the CANFIS-5, MLR-5, SS and G models in simulating the weekly pan evaporation for study location. These results are in fair agreement with the results for daily pan evaporation at same location (Malik and Kumar 2015).

CONCLUSION

The MLP-5 model out-performed in simulating weekly pan evaporation using six input variables of minimum and maximum air temperature, minimum and maximum relative humidity, wind speed and sun-shine hours. It has also been confirmed that the gamma test has the potential to select appropriate combination of input variables from a multiple data set with minimum effort and time. Stephens-Stewart and Griffith's models were found to be unfit for weekly pan evaporation simulation at Pantnagar, located in the central Himalayan region of India.

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Landscape Analysis Using GIS and Remote Sensing For Assessing Spatial Pattern in Forest Fragmentation in Shendurney Wildlife Sanctuary, Western Ghats, India

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Abstract: In this study an attempt is made to assess the forest degradation in Shendurney Wildlife Sanctuary, Western Ghats, India by evaluating the land use change and by appraising the rates of forest fragmentation. The study was done using two data sets obtained from Landsat 7 and landsat 8 over a period of fifteen years from 2000 to 2015. The analyses performed in the study includes land use change analysis. Due to climate change and human interruption the barren land has increased by 19 percent and 17 per cent of land cover reduction in Semi Deciduous Forest. Fragmentation analysis resulted with increase in non forest area of 13.94 percent, decrease in area of 250-500 ha is about 168.19% ha and area more than 500 ha is decreased by 15.67% ha. The derived values are then assessed by ground truth, with reference to random point generated using ArcGIS10.4.2. Cohen's Kappa confers us with in close proximity of our classification scheme, 92.25% ha accuracy for land use classification results and 83.27% of accuracy for fragmentation analysis result. The remote sensing and GIS reveals that the area of forest under study is affected by the surrounding areas in varying magnitude.

Keywords: Land use change analysis, Fragmentation analysis, Cohen kappa, Western ghats

Forest degradation and fragmentation are perspicuous but related observable fact. Forest loss is simply the conversion of forest land to some other land use, but forest fragmentation occurs when a large region of forest is broken down, or fragmented, into a collection of smaller patches of forest habitat (Rajanikumari et al 2017). Large-scale fragmentation and destruction of indigenous vegetation is a highly observable outcome of human land-use throughout the world (Bennett and Sunder 2011). When this occurs, three interrelated processes take place: a reduction in the total amount of the original vegetation; subdivision of the remaining vegetation into fragments, remnants or patches; and introduction of new forms of land-use to replace vegetation that is lost. When large continuous forests are divided and sub divided into smaller blocks forest fragmentation occurs. All the same, the factor is inevitable in the up-gradation of the area by roads, agriculture, urbanization etc (Giriraj et al 2010). This process reduces the efficacy of forest's function as a habitat for many flora and fauna. It also reduces the forest's effectiveness in performing other ecological functions, such as water cycling and air purification. The extinction rate of endemic plants in biodiversity hotspots are found to be increasing as a result of habitat loss and fragmentation (Lugo and Scatena 1995). Habitat fragmentation and species loss occur in southern part of Western Ghats as a result of extensive anthropological activities (Jha et al 2005). Intensive human pressure is resulting in increased forest fragmentation and fire frequencies in Western Ghats (Kondapani 2000, Aditya et al 2016). Forest cover change of Western Ghats region in Kerala is high due to anthropogenic and natural reasons, and this leads to forest degradation (Jose 2000).

MATERIAL AND METHODS

The data sets used in the study include Landsat 7 and Landsat 8 images of 7th January 2001 and 23rd February 2015 respectively. The major analyses performed in the study include land use change analysis and fragmentation analysis, the methodology employed for which are detailed herein (Figure 1). Shendurney Wildlife Sanctuary, part of Agasthyamala Biosphere Reserve is a valley of green splendour acclaimed for its rich biodiversity lying on either side of the Shendurney River. The total area of the sanctuary is 171 km^2. The major rivers are Shendurney, Kazhuthurutty

and Kulathupuzha which join together to form the Kallada river. The important tributaries are Umayar, Parappar, Uruliar and Pasmankandamthodu. The Sanctuary is located at 8˚48′ N −8˚57′ N latitude and 77˚4′ E −77˚16′ E longitude. The elevation in the sanctuary varies from 800 to 1920m above MSL with a general slope towards the west. The temperature varies between 20° C and 35° C and the annual rainfall ranges from 2500 to 5000 mm with an average rainfall of 3000 mm. The Sanctuary is drained by the Shenduruny River and its tributaries, Aruviar, Uruliar and Umiar. The Shenduruny River drains into the Kallada Reservoir, formed by the construction of dam across Kallada River at Thenmala. The other rivers that drain into Kallada Reservoir are the Kazhuthurutty and Kulathupuzha. The underlying rocks are of metamorphic type consisting of charnockites and other gneisses. In the ridges and slopes there are intrusions of rocks of granitic nature. In lesser altitudes, it is also found in varying degrees of disintegration from hard rock to fine gravel. The soil along the stream and river banks is of alluvial deposits.

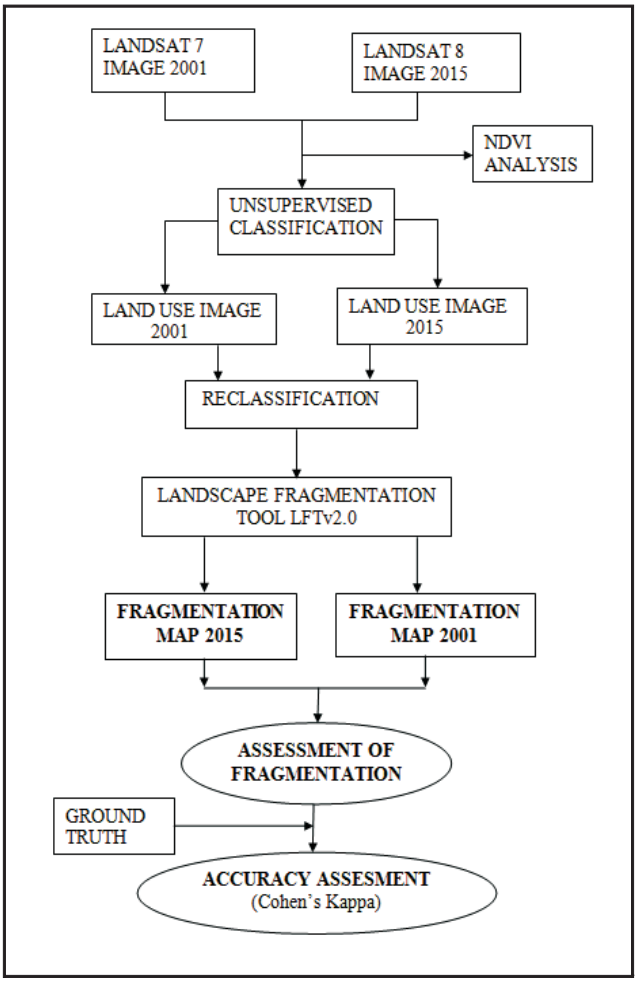

Fig. 1. Methodology followed for fragmentation analysis

The two images were classified using unsupervised classification in Erdas Imagine 9.1. The boundary starts at Thenmala ridge from the north and it passes towards east through Periyamaruthimalai and Karimalai between the state boundary of Kerala and Tamil Nadu. From Karimalai the boundary runs along the Southern boundary of the Division up to 5 kms and then the boundary between natural forests and plantation till it reaches the Kallada Reservoir upto the dam site at its west.

Land use classification: The images were divided into 7 classes namely water body, evergreen forest, semi evergreen forest, semi deciduous, mixed jungle, grassland, hilltop/barren land. The results so obtained were confirmed by ground truthing (using ground control points) for assessing the reliability of the generated outcome. Moreover the results were compared with Google Earth images (after conversion to Kml) and SoI toposheets numbered 58 H1 and H5 of 1:50000 scale. The results obtained from land use classification showed that there has been a decrease in forest cover due to various anthropogenic and physical factors. The dominating land cover of Shendurney wildlife sanctuary is tropical evergreen forest followed by west coast semi evergreen forest. The result from 2001 to 2015 (Figure 2 and 3) shows that there is decrease in the extent of mixed jungle and deciduous forest and there is drastic increase in the extent of barren land. This reveals that the forest of Shendurney wildlife sanctuary has undergone considerable changes during the period.

RESULTS AND DISCUSSION

The results (Table 1) further indicates that the forest type during the study period was degrading which means that the extent of mixed jungle and semi deciduous forest is decreasing and the extent of evergreen forest and barren land are slightly increasing. The increase in evergreen forests might be because of its distance from settlements and other activities. These forests are at the core zone where human interference is almost absent. There is a slight decrease in encroachment / settlement which is due to the

Table 1. Areal extent of land use classes in the study

Land cover	2001 (ha)	2015 (ha)	Difference	Percentage
Water body	551.75	595.25	43.5	7.31
Evergreen	2887.25	3013	125.75	4.17
Semi evergreen	3347.75	3123.5	-224.25	-7.18
Semi deciduous	3310.5	2812.2	-498.25	-17.72
Mixed jungle	3100	2973.5	-126.5	-4.25
Grassland	1961	2039.7	78.75	3.86
Hilltop/barren land	746.5	922.5	176	19.08

loss of settlement area during the construction of dam. The forest cover type change analysis indicates that the forest area of this sanctuary is under degradation.

Forest fragmentation: The results obtained (Fig. 4 and 5) so far revealed the usual pattern of forest fragmentation. LFT v2.0 classifies a land cover type of interest into 4 main categories – patch, edge, perforated, and core (Table 2). It was observed that the small patches which have the tendency to get fragmented are more inside the study area. This is visible from the spatial layout obtained. The study area also showed a trend of perforations inside the thick vegetation which too has a potential to become fragmented patches.

The increase in the number and extent of patches, edges and perforations suggests the increasing tendency of the study area especially the accessible regions in the wildlife sanctuary to become more and more fragmented and isolated. The rates of fragmentation so observed is more in the dam entrance and settlements regions while the other regions inside the sanctuary (except core region) possess tendency of fragmentation. The primary factors of fragmentation could be classified into different clusters of

Table 2. Rate of change in fragmentation

Fragmentaion classes	2001 (Acres)	2015 (Acres)	Differences
Non-forest	7324.52	8510.70	13.94%
Patch	280.33	518.68	45.95%
Edge	3758.59	4324.82	13.09%
Proforated	5799.97	6819.43	14.95%
Core <250 acres	1171.97	1231.25	4.81%
Core 250-500 acres	650.82	242.67	-168.19%
Core >500 acres	19646.91	16985.58	-15.67%

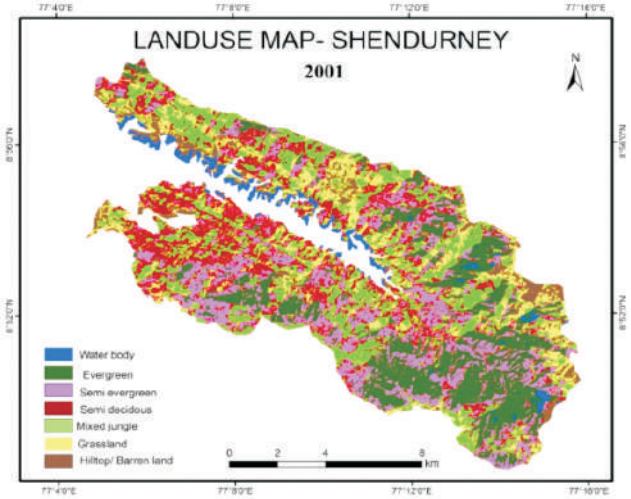

Fig. 2. Land use map of Shendurney, 2001

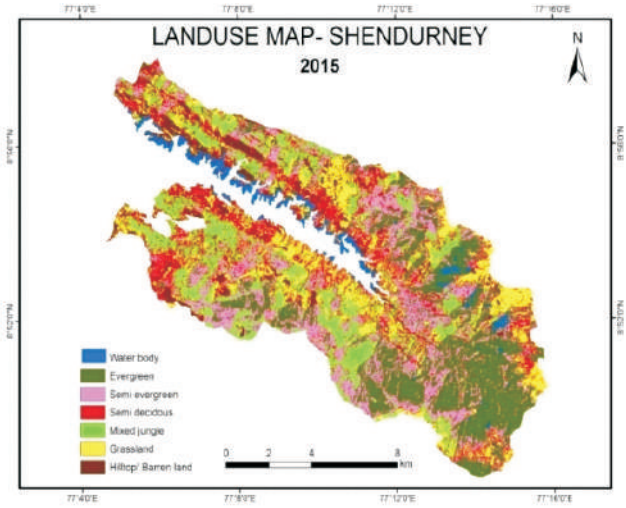

Fig. 3. Land use map of Shendurney, 2015

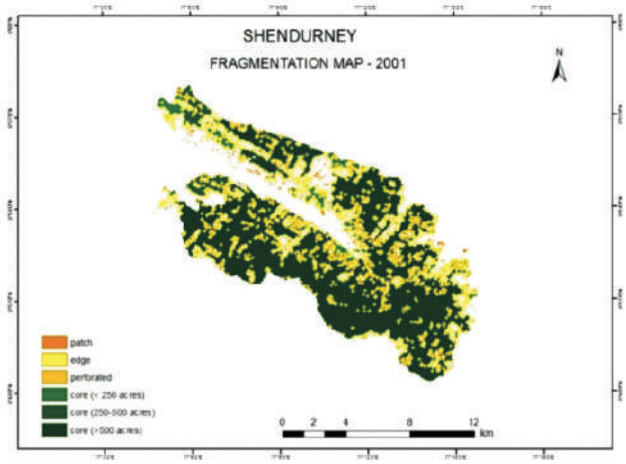

Fig. 4. Fragmentation map of Shendurney, 2001

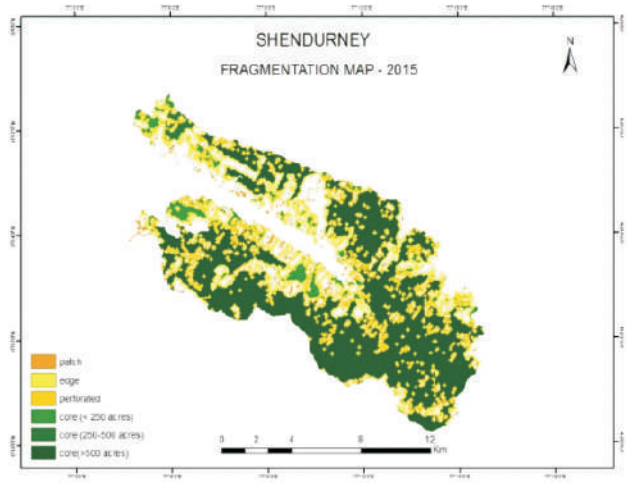

Fig. 5. Fragmentation map of Shendurney, 2015

causes like livelihood dependence of local people for timber, agricultural expansion (plantation), forestry operations, forest fire and various other infrastructure developments.

Accuracy assessment: Assessment of accuracy was analysed over both land use land cover classification and forest fragmentation map resulted using landscape analysis tool. The Kappa coefficient was introduced to the remote sensing community in the early 1980s and has become a extensively used measure for classification accuracy. It was suggested as a standard by Rosenfield and Fitzpatrick-Lins (1986). Kappa increase to one as possibility, agreement decreases and becomes negative as less than chance agreement occurs. A Kappa of zero occurs when the agreement between classified data and verification data equals chance agreement(Congalton et al 1983).

Land use classification analysis: Cohen′s Kappa confers us with in close proximity of our classification scheme and whether or not we accomplished results better than we would have attained rigorously by chance (Pareco et al). The formula for kappa is:

$$\frac{\text{Observation-Expected}}{\text{1-Expected}} \quad \text{(Equation 1)}$$

Observed is percentage between number of samples ground truth and number of random points generated in the map (Table 3), here both are 50 samples and the percentage is 100%. Apply the derived values to (Table 3), which is

$$\text{Observed}=\frac{\text{Total sample – Error sample}}{\text{Total sample}} \quad \text{(Equation 2)}$$

$$\frac{50-3}{50}=0.94$$

Then calculated what would be expected based on chance to apply in (Formula. 2).

$$\text{Expected} = \frac{\text{Product matrix}}{\text{Cumulative sum of product matrix}} \quad \text{(Equation 3)}$$

The product matrix (Table 4) is the sum of the diagonals: 342+56+99+30+20+20+16=563

The Cumulative Sum is the sum of all the values in the Product Matrix= 2500

Apply the derived values in (Equation 3)

$$\text{Expected} = \frac{563}{2560} = 22.52\%$$

Hence,

$$\text{Kappa} = \frac{0.94-0.2252}{1-0.2252}=0.922561$$

Therefore, Kappa= 92.25%

Forest fragmentation analysis: Cohen′s Kappa method is used to assess the accuracy of Forest Fragmentation Result with the On field observed details. The following values are derived from the (Equation 1,2,3) by referring the values from

Table 3. Cross matrix of land use classes

	Classes	Ground truth						
		Evergreen	Semi evergreen	Semi deciduous	Mixed forest	Grassland	Hilltop	Grand total
Unsupervised	Evergreen	18			1			19
	Semi Evergreen		7	1				8
	Semi-Deciduous			9				9
	Mixed Forest				5			5
	Grassland			1		4		5
	Hilltop						4	4
	Grand Total	18	7	11	6	4	4	50

Table 4. Product matrix of land use classes

Classes		Evergreen	Semi−evergreen	Semi−deciduous	Mixed forest	Grassland	Hilltop	Total
	Samples	18	7	11	6	4	4	50
Evergreen	19	342	133	209	114	76	76	950
Semi-evergreen	8	144	56	88	48	32	32	400
Semi-deciduous	9	162	63	99	54	36	36	450
Mixed forest	5	90	35	55	30	20	20	250
Grassland	5	90	35	55	30	20	20	250
Hilltop	4	72	28	44	24	16	16	200
Total	50	900	350	550	300	200	200	2500

Table 5. Cross matrix of forest fragmentation assessment

		Ground Observed Values							
	Classes	250-500 acres	<250 acres	>500 acres	Edge	Non forest	Patch	Perforated	Grand total
Forest Fragmentation Result	250-500 acres	5							5
	<250 acres		13				2		15
	>500 acres			20					20
	Edge			2	7		1		10
	Non forest	1				14			15
	Patch		1				15		16
	Perforated	1		4			1	6	12
	Grand total	7	14	26	7	14	19	6	93

Table 6. Product matrix of forest fragmentation

		Ground observed values							
	Classes		250-500 acres	<250 acres	>500 acres	Edge	Non forest	Patch	Perforated	Grand total
	No of samples		7	14	26	7	14	19	6	93
Forest Fragmentation Result	250-500 acres	5	35	70	130	35	70	95	30	465
	<250 acres	15	105	210	390	105	210	285	90	1395
	>500 acres	20	140	280	520	140	280	380	120	1860
	Edge	10	70	140	260	70	140	190	60	930
	Non forest	15	105	210	390	105	210	285	90	1395
	Patch	16	112	224	416	112	224	304	96	1488
	Perforated	12	84	168	312	84	168	228	72	1116
	Grand total	93	651	1302	2418	651	1302	1767	558	8649

(Table 5 and 6*),* which is same way as calculated the Accuracy assessment of Land Use Classification above.

To least Observed Value = 0.860215054

Product Matrix= 1421

Cumulative Sum of Product Matrix= 8694

Expected Value= 0.16429645

Kappa = 0.832733813

Therefore, Fragmentation analysis result derived using Landscape Fragmentation Tool (LFT v. 2) is 83.27 % of accuracy.

CONCLUSION

Increased pressure in the sanctuary particularly in the tourist zone has resulted in high fragmentation rate leading to a decline in floral and faunal life. The result also coincides with the decrease in area for different classes. It is supported by clear evidences that forest cover decrease is due to illegal anthropogenic activities and cultivations of agriculture crop which has supplemented to fragmentation. Deforestation is mainly attributed to shifting cultivation and commercial logging of timber in the settlement regions. Changes between fragments and within fragments, and their surroundings, involve full consequences of landscape change. It can be concluded that settlement, tourism, shift cultivation and over grazing has a role to play in forest fragmentation.

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Harmonization and Comparative Evaluation of Evapotranspiration Estimates in Data Scarce Conditions

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Abstract: For efficient irrigation water management and hydro-meteorological studies at both the field and catchment scales, a need exists to evaluate the existing evapotranspiration (ET) estimation methods under varied physiographical and data availability conditions. With the limited availability of meteorological variables at basin-scale in many remote areas, ET estimation is becoming a challenging task. There is a scope to test the ET methods by FAO-56 PM method, the benchmark method with Hargreaves raw model. All of them were inter-compared by taking its basin average. Further, FAO-56 PM and Hargreaves raw model were harmonized by daily and monthly correction factor (C_f) for five year period and was verified by using statistical indicators namely, index of agreement (d) and Pearson correlation coefficient (r) as well as graphical indicators. The harmonized estimators of less data intensive methods relative to FAO PM provides satisfactory results in all six stations after applying the correction factor.

Keywords: FAO-56 PM, Hargreaves model, Harmonization

Evapotranspiration (ET) has the largest contribution in the hydrological water balance components, it is necessary to measure and quantify it under varied data types that accounts for the meteorological variables, remote sensing based energy variables and land uses. The ET prediction plays crucial role in weather and climate forecast, efficient irrigation water management, agricultural envisions and other water resources management (National Research Council 2010). Despite of the necessity of taking decisions on sectoral water distributions, irrigation scheduling, groundwater recharge, reservoir management at both the spatial and temporal scales, ground observations of ET are still hypothetical (Sheffield et al 2008). The reference ET (ET_o) is estimated in reference to a standard (alfalfa) grass surface, 12 cm in average height with a fixed surface resistance of 70 s/m and albedo of 0.23 (Allen et al 1989). Now-a-days, the standard FAO-56 ET estimation method is utilized in various regions (Allen et al 1998) as the keystone for irrigation system and various other water supply systems (Srivastava et al 2017). Depending on varied data availability conditions, different ET estimation methods exist in the literature which has varied accuracy levels when compared with the benchmark FAO-56 Penman Monteith method. Evapotranspiration is the process of returning water back to the atmosphere through evaporation from open water, soil, and plant surfaces, and transpiration from plants. Theoretically, evaporation is a diffusive process that follows the Fick's first law and can be written as a function of the vapour pressure deficit between the evaporating surface and overlying air; and the wind speed. It is accompanied by heat loss from the evaporating surface in the form of latent heat, that is compensated by radiative or sensible-heat transfer or by heat transfer from within the evaporating body to the surface. The importance of ET in the water cycle and hydrological management, in addition to the expensive and sensitive measuring equipment, has led to extensive efforts for modeling the ET mechanism.

Many methods have been developed, revised, and proposed for the estimation of ET in different climatic conditions using different predictor variables and reviewed the evolution of different types of ET estimation methods. Belaineh et al (2014) harmonized multiple methods in a seamless reconstruction of historical Potential evapotranspiration (PET) and Reference evapotranspiration (RET) by quantifying and eliminating the biases of the simple Hargreaves-Samani method relative to the more complex and accurate Priestley-Taylor and Penman-Monteith methods. The common period was 1995-2009. This harmonization process is used to generate long-term, internally consistent, spatiotemporal databases of PET and RET. Based on the discussions, the following research gaps are identified depending on varied data availability conditions: different ET estimation methods exist in the literature which has varied accuracy levels when compared with the FAO-56 Penman Monteith method.

MATERIAL AND METHODS

Description of study area: In order to carry out the framed objectives, the Kangsabati River basin has been chosen as the study area. The Kangsabati river basin is located in the Indian state of West Bengal with 86°00′ E and 87°40′ E longitude and 22°20′ N and 24°40′ N latitude and having an area of approximately 5796 km^2. The Kangsabati river flows in south-easterly direction before becoming the last contributing river to the Ganges river in India. The elevation of the Kangsabati river basin ranges from 19 m to 656 m above mean sea level. The hilly area is predominantly in the northeast region of the basin. Paddy is the major crop grown in the cultivable land. The river basin receives an average annual rainfall of 1400 mm. Normal rainfall season is for from June to October. The basin has been traditionally considered a drought prone basin with erratic rainfall, high summer temperature, high evapotranspiration rates and low water holding capacity of the lateritic soil (Saxena 2012). At the same time, due to high average annual rainfall and hardpan geology the basin is prone to flood as well. The changes in the extremes of temperature and precipitation will further worsen the situation in the basin. There are five rainfall stations namely, Jhargram, Mohanpur, Kharagpur, Midnapore, Purulia and Bankura. Daily maximum and minimum air temperatures data were collected for the period 2011 to 2015. This was used in order calculate the Hargreaves ET so that is could be used for harmonization.

ET estimation using the FAO-56 Penman-Monteith equation: The FAO-56 PM equation used for estimating the reference evapotranspiration is given as (Allen et al 1998)

$$ET_o = \frac{0.408\Delta(R_n - G) + \gamma \frac{37}{T_{hr}+273} u_2[e^o(T_{hr})(1-Rh)]}{\Delta + \gamma(1+0.34u_2)} \quad (1)$$

where R_n= net solar radiation at the reference grass surface (MJ m^{-2} hour^{-1}); G = soil heat flux density (MJ m^{-2} hour^{-1}); T_{hr}= mean hourly air temperature (°C); ¯ = saturation slope of vapour pressure curve at T_{hr} (kPa °C^{-1}); $e^o(T_{hr})$= saturation vapour pressure at air temperature T_{hr} (kPa); u_2 = average hourly wind speed at 2 m height (m s^{-1}); *Rh* = relative humidity; and γ = psychrometric constant (kPa °C^{-1}).

ET estimation using the Hargreaves temperature equation: The Hargreaves temperature equation is one of the simplest and most accurate equations used to estimate (ETo) in mm/day (Jensen et al 1997; Zhai et al 2010), which is expressed as (Hargreaves and Samani 1985)

$$ET_0 = 0.0023\, R_a\, (T_{mean} + 17.8) \quad (2)$$

where R_a = Extraterrestrial radiation (mm=day), (1 MJ/m^2/day=0.408 mm=day), T_{max} and $T_{min.}$ are maximum and minimum temperature.

Harmonization of ET estimates: In this study, the evapotranspiration estimates using the HS method were harmonized with FAO PM method to produce unbiased HS estimators for the six different stations in the given study area. Harmonization was achieved by computing the mean biases between HS_{Raw} and FAO-56 PM and. The flowchart showing the steps involved in harmonization is shown in Fig. 1.

Performance evaluation indicators: The comparison of model simulated values with the observed values determines how well a model fits the study area. The graphical representation of the results could be easily interpreted if calibration is done for only one watershed at one stream gauge location. Continuous time series plot of the recorded and simulated series and a scatter gram of recorded data plotted against simulated flows were therefore used in this study for model calibration and validation.

Pearson correlation coefficient: Pearson product-moment correlation coefficient was obtained by the division of the covariance of the two variables by the products of the standard deviations. If there are n observations and n model simulated values, then the correlation coefficient measure is used to estimate the correlation between the two:

$$r = \frac{\sum_{i-1}^{n}\left[(O_i - \bar{O})(P_i - \bar{P})\right]}{\sqrt{\left[\left(\sum_{i-1}^{n}(O_i - \bar{O})^2\right)\left(\sum_{i-1}^{n}(P_i - \bar{P})^2\right)\right]}} \quad (3)$$

where $\bar{P}$ and $\bar{O}$ are observed and simulated mean value.

The interpretation of the measure is also equally important. It ranges between +1 to −1. A correlation of +1 show perfectly increasing linear relationship and −1 show a perfectly decreasing linear relationship, and the values in between indicates the degree of linear relationship between modeled and observational data. Whereas, a correlation coefficient of 0 indicates that there is no linear relationship between the variables.

Index of agreement: To evaluate each ETo estimation method, index of agreement (d) are used. The index of agreement is given by (Willmott 1982)

$$d = 1 - \frac{\left\{\sum_{i=1}^{N}(P_i - \bar{O}_i)\right\}^2}{\left\{\sum_{i=1}^{N}(P_i - \bar{O}_i) + (O_i - \bar{O}_i)\right\}^2} \quad (4)$$

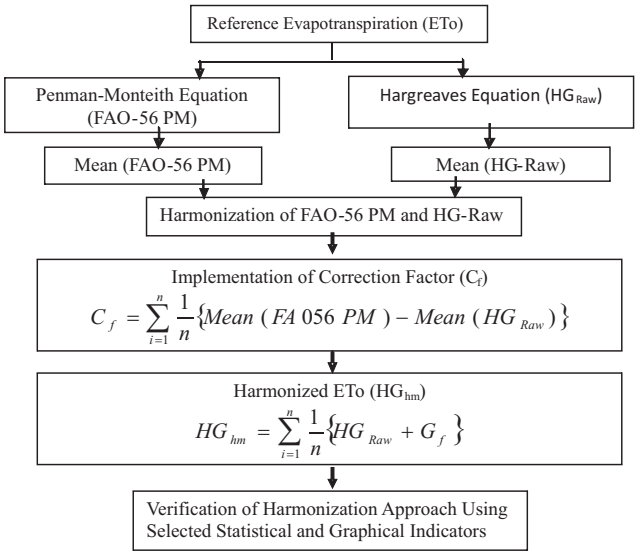

Fig. 1. Flowchart showing major steps involved in harmonization of Et_0 methods

where Pi = ETo estimates by the existing model; Oi = ETo estimates by the benchmark FAO-56 PM model; = mean ETo value calculated using the FAO-56 PM model; and N = number of observations. A value of d = 1 indicates perfect agreement and a value d = 0 indicates poor agreement. A model is accepted if r ≥0.5 and d ≥0.5, else rejected.

RESULTS AND DISCUSSION

Comparison of ET estimation methods: ET was estimated by different methods, namely, FAO- 56 PM method and Hargreaves Radiation model. All of them were inter-compared by taking its basin average. The results were plotted and these ET estimation methods were evaluated with each other by various performance evaluation measures such as correlation coefficient (r) and index of agreement (d). ETo was estimated using the FAO 56 PM and Hargreaves methods. ET_o for six stations namely Mohanpur, Bankura, Purulia, Kharagpur, Midnapore, and Jhargram was evaluated using Hargreaves method and compared with FAO-56 PM method (Fig. 2) without using correction factor.

Although the FAO-56 method is the benchmark method but, it require several meteorological variables for the computation of the ETo. So, in data scarce conditions we could not use it. To overcome this problem there are several methods to estimate ETo out of which the Hargreaves model was taken and compared with the benchmark FAO-56 PM equation. To, see the deviation from the FAO-56 method and then applying correction factor to Hargreaves method will result in the application of Hargreaves model in data scarce condition. So, in this way we can Hargreaves model overestimated throughout the whole time span of study as it considers only the effect of radiation whereas in former method large number of weather variables is contemplated. Accordingly, Hargreaves model was refined using a correction factor given by Bandyopadhyay et al (2009), which gave better correlation as compared to the correlation without considering the correction factor (Fig. 3). The estimates of r and d values show that after incorporating the correction factor in Hargreaves model the performance has been improved for all six stations (Table 1). As it is evident from the table, the stations namely, Bankura, Midnapore and Mohanpur have shown extremely good improvement in the ET estimation after the application of correction factor. While on the other hand, Jhargram does not show good agreement after application. These stations showed correlation coefficient ranging between 0.66 to 0.80 and index of agreement varying in between 0.7 to 0.8 without the correction factor applied. Once the correction factor was applied, these values surged from 0.75 to 0.85 (r) and 0.75 to 0.88 (d).

Table 1. Performance evaluation for the comparison of Hargreaves model with respect to FAO Penman Monteith equation for all six stations during 2011-2015 with and without applying correction factor

Stations	Without correction factor		With correction factor	
	r	d	r	d
Jhargram	0.80	0.74	0.75	0.80
Bankura	0.66	0.84	0.72	0.83
Purulia	0.73	0.83	0.75	0.86
Kharagpur	0.72	0.73	0.75	0.83
Midnapore	0.69	0.76	0.73	0.84
Mohanpur	0.61	0.79	0.82	0.87

CONCLUSIONS

ET is a complex and non-linear phenomenon as it depends on several interacting factors such as temperature, humidity, wind speed, radiation, and type and growth stage of crop. The direct measurement of ET using lysimeter or water balance approach is a time consuming method and needs precisely and carefully planned experiments. Due to wide application of ET data, because it is the most important components of water cycle which is considered as loss. Though a number of indirect methods for estimation of ETo have been developed by several researchers based on the easily available location characteristics (elevation and latitude) and meteorological data (temperature, humidity, wind speed, solar radiation, etc.). However, not only data requirement varies from method to method, but also each method′s performance varies with climatic condition. Therefore, accurate estimation of evapotranspiration is a

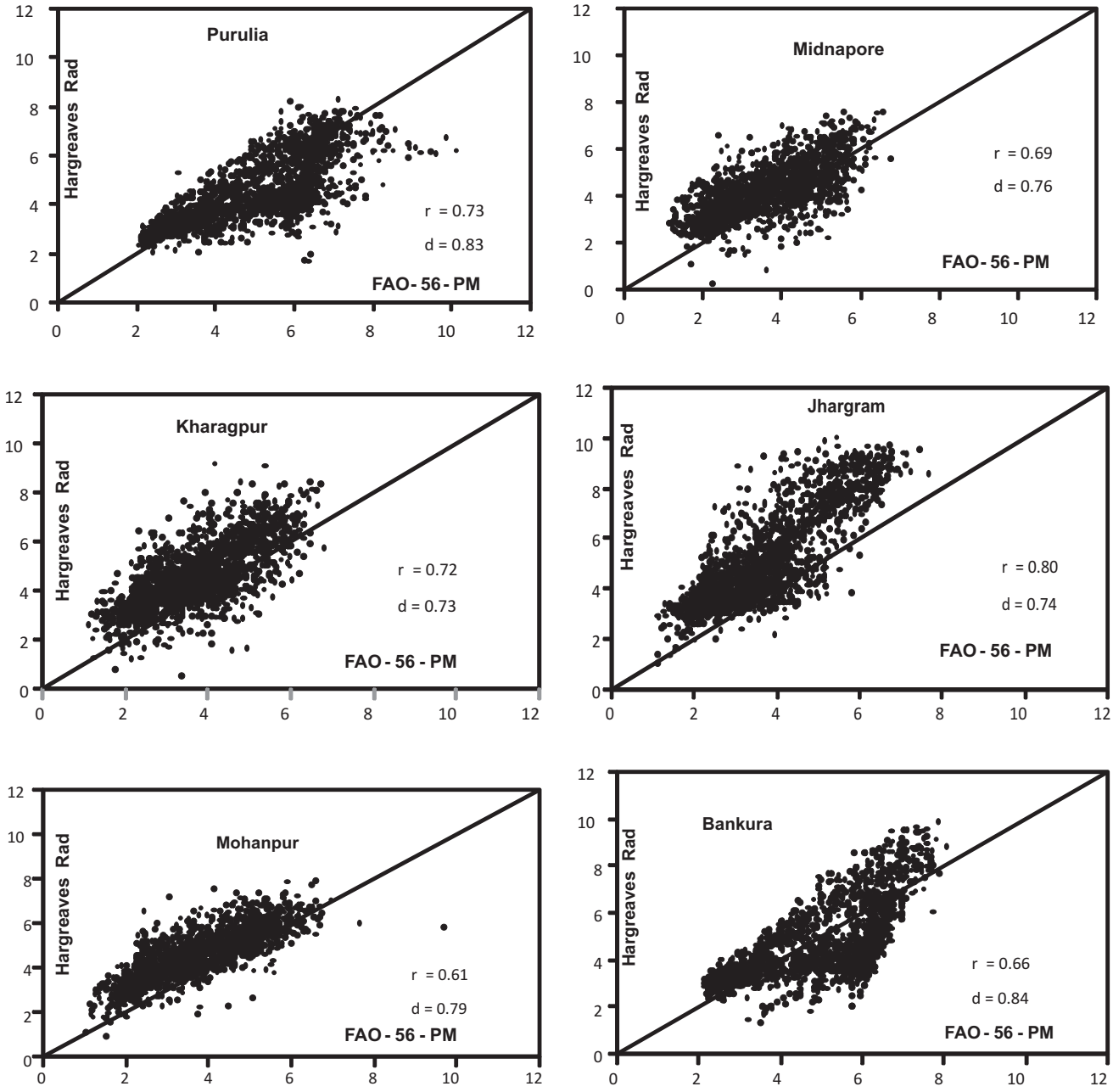

Fig. 2. Comparison of ETo estimated using Hargreaves model with respect to FAO Penman-Monteith equation for all six stations during 2011-2015 without applying correction factor

challenging task. To overcome this problem a methodology for evaluating ET was conducted in this study in order to test the accuracy of limited data based ET estimates. Hargreaves ET was standardized by using correction factor and tremendous results was obtained for all the six stations. Altogether it is an efficient methodology for the water resources management perspective and for irrigation scheduling for the crops. Apart from that at catchment-scale where there is limited data availability for ET calculation accuracy of harmonized based ET estimation is very useful in order to estimate the losses.

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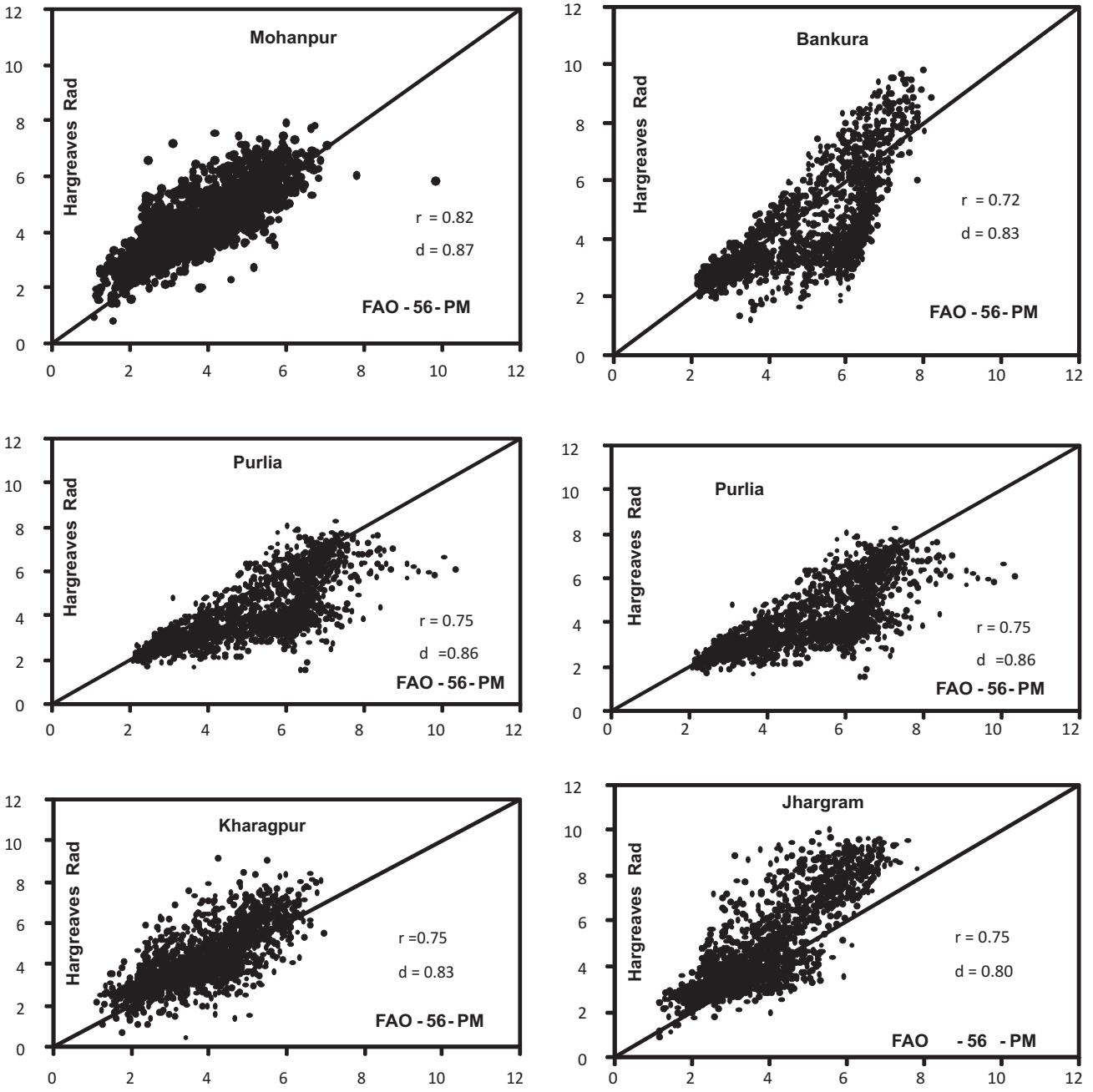

Fig. 3. Comparison of ETo estimated using Hargreaves model with respect to FAO Penman Monteith equation for all six stations during 2011-2015 after applying correction factor

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Effect of Real Time Nitrogen Management on Productivity of Rice (*Oryza sativa* L)

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Abstract: The present study was done at farmer field of Katihar district during the two consecutive years 2014 and 2015 to find out the effect of real time nitrogen management on productivity of rice. The soil is non-calcareous light gray flood plain belongs to the alluvial gangetic plain (Agro climatic zone II) with normal in physico-chemical properties except fertility status. One of the recently introduced nitrogen management approach was estimating the leaf nitrogen concentration by the measurement of leaf greenness. The application of nitrogen with the help of CLCC significantly increase in yield attributes i.e. plant **h**eight, number of tillers, panicle length, filled kernel/plant, productive tiller /m^2, grain and straw yield in comparisons to farmers practice. Hence, the B: C ratio increase from 2.08 (farmers practices) to 4.14 where CLCC used for nitrogen application. Therefore, inexpensive customized leaf color chart (CLCC) has proved quick and reliable tools to decide the time when nitrogenous fertilizer needs to be applied to the crop. With CLCC, farmers can apply N at the right time, thereby increasing the productivity and profitability of rice and reduction in nitrogen fertilizer.

Keywords: Rice, CLCC, Nitrogen

The adequate nutrient supply plays a vital role in soil and crop management system. Knowing the required nutrients for all stages of growth and understanding the soil′s ability to supply those needed nutrients are critical to profitable crop production (Nedunchezhiyan and Laxminarayan 2011). Increase fertilizer inputs, especially N fertilizer, results in significant increases in rice crop production (Peng et al 2010). Nitrogen is the major nutrient limiting the high yield potential of rice cultivars, Farmers generally apply nitrogenous fertilizer in several split applications that results in high pest and disease incidence and serious lodging. Precise application of nitrogen fertilizer based on plant need and location in the field greatly improves fertilizer use efficiency in rice. Farmers generally apply fertilizer N in several split applications, but the number of splits, amount of N applied per split, and the time of applications vary substantially. The apparent flexibility of rice farmers in adjusting the time and amount of fertilizer application offers potential to synchronize nitrogen application with the real-time demand of the rice crop (Alam 2005). Farmers generally apply too much N (and little P and K and other nutrients) that results in high pest and disease incidence and serious lodging. The consequence of high N application is associated with the high pesticide use to control pests, more expenditure on pesticides, and reduced yield and poor grain quality due to lodging (Nath et al 2013). Site specific nitrogen management has the potential to increase fertilizer use efficiency as well as grain yield in the farmers′ fields (Ravi 2007). Precise application of N fertilizer based on plant need and location in the field greatly improves fertilizer use efficiency in rice. Farmers generally use leaf color as a visual and subjective indicator of the rice crop′s nitrogen status and need for N fertilizer application. Leaf color intensity is directly related to leaf chlorophyll content which, in turn, is related to leaf N status. The concept is based on results that show a close link between leaf chlorophyll content and leaf N content (Nath et al 2013). One of the recently introduced N management approach was estimating the leaf N concentration by the measurement of leaf greenness through CLCC. Among the different tools available to measure the leaf greenness, the non destructive measurement of leaf green color intensity using customized leaf color charts (CLCC) is gaining importance (Kumar and Haefele 2013). The customized leaf color chart (CLCC) is an easy-to-use and inexpensive diagnostic tool for monitoring the relative greenness of a rice leaf as an indicator of the plant N status. Therefore, a field experiment was conducted to find out the optimize the right time of nitrogen application on performance of rice with CLCC tools for increase the productivity and profitability of rice and reduction the used nitrogen fertilizer.

MATERIAL AND METHODS

An experiment was conducted during kharif 2014-15 at

farmer fields of Katihar adopted by Krishi Vigyan Kendra, Katihar under Bihar Agriculture University, Sabour, Bhagalpur. The experiment was in randomized block design with split plot arrangement in net plot size was 10 x 10 m having ten replications and three treatments. Nursery of medium duration rice cultivar Sahbhagi was sown in the first week of June and transplanted in the age of twenty one days. The treatment was T_1–farmer practices (80:40: 20:: N: P: K basal + 50 kg N at 25 DAT+ 50 kg N at 50 DAT), T_2 –RDF (basal 60:60:40 kg N: P: K + 45 kg N at 30 DAT+ 45 kg N at 60 DAT) and T_3–RDF (basal 60:60:40 NPK + real time application of balance N by using customised leaf colour chart. The seedlings of rice cultivar Sahbhagi was transplanted on second week of July with spacing of 20 x 20 cm. The full dose of phosphorous, potash and half dose of nitrogen were applied at the time of transplanting and remaining half of nitrogen was top dressed as urea as par requirement of treatment to correct deficiency of nitrogen. Data was recorded on leaf color chart with an interval of ten days, starting from two weeks after transplantation up to flower initiation. The leaf color chart value for semi dwarf high yielding rice varieties is 4.0; if the average value fell below 4.0; nitrogenous fertilizer was top dressed @ 30 kg ha^{-1} to correct the nitrogen deficiency. The plant height and tillers were measured at tillering, flowering and harvesting stages and panicle length, grains per panicles at harvesting stage. The rice crop was harvested at physiological maturity stage. After harvesting grains were separated from each plot and were dried under sun light for three days then winnowed, cleaned and taken test weight of rice and computed yield. Straw from each plot was dried under sun for 10 days and weight was recorded after complete drying. The benefit cost ratio was worked out after price value of grain with straw and total cost included in crop cultivation. The soil samples are collected randomly from all experimental sites before start the experiment and post harvest. The important properties of soil samples are analyzed; organic carbon content was determined by the Walkley and Black method (1934), available nitrogen was determined by the alkaline $KMNO_4$ method (Subbaiah and Asija 1956), available phosphorous (Olsen′s method, 1954) and available potash were determined using 1 N neutral normal ammonium acetate solution (Tandon 1993), pH and EC with soil suspension (1:2.5) using electrode (Chopra and Kanwar 1999). The collected data on different parameters under the experiment were statistically analyzed to obtain the level of significance using the computer MSTAT package program developed by Russel (1986).

RESULTS AND DISCUSSION

Soil Physico-chemical Properties

pH, EC and Organic carbon: Reduction in electro chemical properties in farmers practices might be due to continues use of more amounts of chemical fertilizers over the years reduced soil pH and EC over applied treatment. This marginal increase in pH and EC might be due to the moderating effect of recommended dose of chemical fertilizers and also less amount of organic matter in treatment T_1. The soil organic carbon one of the gracious factor in sustaining agricultural production and also improve physical, chemical and biological properties of soil. Non significant improvement of organic carbon content in treatment T_3 might be due to addition of fertilizers that improve the root and shoot growth might have increase the organic carbon content (Sharma and Subehia 2014).

Available nitrogen: The significant and positive changes was observed in available soil nitrogen in T_3 where nitrogen was applied accordance to CLCC and significant negative relationship in farmer practices with indiscriminate fertilization at par with T_2. The higher available nitrogen content which might be due to higher use efficiency of nitrogen and might be lowest losses of organic and inorganic nitrogen from soil (Stalin et al 2000). The lowest value of available nitrogen in T_1 may be due to mining of available nitrogen with continuous cropping without balance fertilization over the year. The increase was maximum in T_3 where 60:60:40 NPK + real time nitrogen management were applied. It may be due to sufficient supply of nutrients by applied NPK fertilizers (Varlakshmi et al 2005).

Available phosphorous: Significant difference in the available phosphorous of the soil was observed during two consecutive years after final harvesting of crop (Table 1). The available P content of the soil was found to be significantly lower in the treatment T_3 than T_2 and control. The phosphorous uptake by the plant increased due to increased biomass production towards maturity (Table 3). Johnkutty et al (2000) also documented similar results from increased P due to higher nitrogen application.

Available potash: Significant variation in the available potash content of the soil was observed due to application of different treatments in this study. The decreased available potash in this treatment might be due to the abundant release of potash by soil and maximum utilized by plant. Among the treatment T_3 showed highest available potash utilization. It is possible due to the uses of nitrogen on real time in balanced amount and its possible due to synergetic effect of nitrogen on potash and others macro and micro nutrients (Varlakshmi et al 2005).

Growth attributes of rice: Amongst various application method of nutrients the treatment T_3 where after application of basal doses of nitrogen fertilizers through broad casting after that on real time whenever nutrients required by plant and its measure through CLCC tools was significantly superior over top dressing of nitrogen fertilizers at different days interval (T_2) and indiscriminate uses of fertilizers (T_1) with respect to all growth parameters. This might be due to increase nitrogen use efficiency with addition of nitrogen at real time whenever plants required. Salman (2012) also reported that application of nitrogen in split according to the plant needs in CLCC practices might be the reason for better rice growth parameters. Effective tillers per square meter increase successively with CLCC practices due to increased plant population per unit area (Table 3). Panicle length was significantly higher T_3 as compared to T_2 and T_1. The grain per panicle and test weight were significantly higher in CLCC practices as compared to recommended dose of fertilizers and farmers practices because maximum utilization of nitrogen fertilizers at required stages of crop and higher nutritional status helped the production of panicle number and lengthier panicles too with more number of filled grains and grain weight (Arumugaperumal 2000). The CLCC practices produced higher panicle number and lengthier panicle respectively over indiscriminate top dressing of fertilization. Increase number of nitrogen application in splits synchronied with the nutritional demand of rice at all the stages resulted in longer panicle and weighted grains. Nayak and Patra (2000) reported that the increased thousand grain weight due to nitrogen application at flowering could be attributed to increase filled grains.

Yield of rice: The farmer practices reduce the rice yield from 44 and 91 per cent in comparison to T_2 and T_3. The grain number per panicle and 1000 grains weight had significant difference compared to T_3. The maximum grain and straw yield were observed with T_3 followed by recommended doses (T_2) and minimum with farmers practices (T_1). The yield of rice with CLCC practices were significantly higher over farmer practices and recommended dose of fertilizers. The maximum grain filling can be one prime reason for the yield differences. The CLCC practices have maximum filled grains and reduced unfilled grains so that the increase yields. Stalin

Table 1. Effect of different treatments on physico-chemical properties of soil (Pooled data of 2014–15)

Treatments	pH (1 : 2.5)		ECe (d Sm^{-1})		OC (%)		N		P		K	
							Available nutrients (Kg ha^{-1})					
	Initial	Final	Initial	Final	Initial	Final	Initial	Final	Initial	Final	Initial	Final
T_1	6.92	6.81	0.24	0.26	0.42	0.41	181.2	162.4	16.8	18.2	238.2	199.4
T_2	6.95	6.98	0.27	0.31	0.44	0.45	176.4	183.6	16.2	16.5	247.4	212.4
T_3	6.88	6.91	0.27	0.28	0.45	0.45	185.5	194.2	16.6	15.4	244.5	236.2
CD (p=0.05)	0.02	0.04	NS	0.01	0.2	NS	1.2	1.5	NS	0.7	2.1	4.2

Table 2. Effect of different treatments on paddy yield attributes (Pooled data 2014 –15)

Treatments	Plant height (cm)	Tillers $plant^{-1}$	Panicle length (cm)	Kernels $plant^{-1}$	Filled kernels $plant^{-1}$	Productive tillers (m^{-2})
T_1	106.00	9.20	23.21	187.0	145.0	172.2
T_2	115.00	12.60	26.20	206.0	178.0	188.4
T_3	123.00	14.72	32.40	231.0	202.0	201.4
CD (p=0.05)	5.30	1.40	1.50	8.2	12.8	12.4

Table 3. Effect of different treatments on paddy yield and economics (Pooled data of two 2014–15)

Treatments	1000-kernel weight (g)	Paddy yield (t ha^{-1})	Straw yield (t ha^{-1})	Harvesting Index	Cost of cultivation (Rs ha^{-1})	Gross income (Rs ha^{-1})	Net Income (Rs ha^{-1})	BC ratio
T_1	14.80	3.69	4.14	0.47	75532	176220	100688	2.33
T_2	15.87	5.32	6.22	0.46	78613	193716	115103	2.46
T_3	17.22	7.06	8.24	0.46	78714	218025	139311	2.77
CD (p=0.05)	1.20	1.40	1.20	–	–	–	–	–

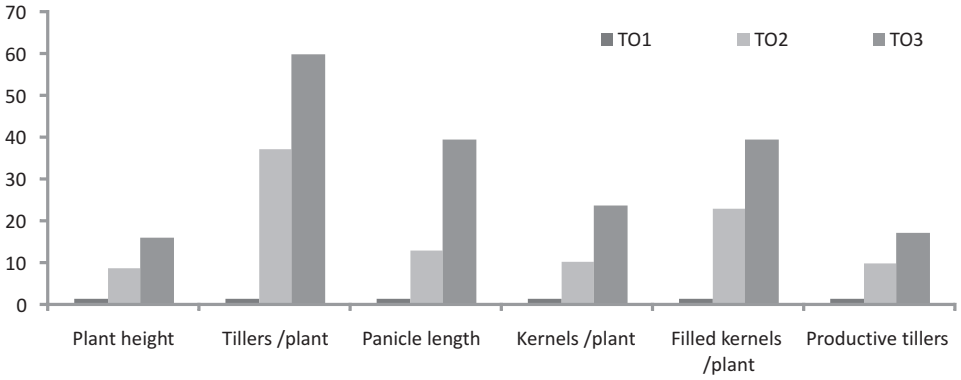

Fig. 1. Percentage increase of paddy growth attributes (pooled data 2014–15)

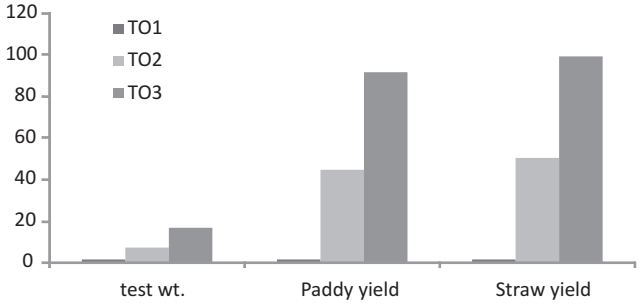

Fig. 2. Percentage increase yield of paddy (pooled data 2014–15)

et al (2000) reported that the N doses should be applied only after careful assessment of plant requirement through CLCC and not by predetermined crop calender timings, because the need based application help in increase filled grain per cent and thousand grain weight. CLCC is easy to use and an inexpensive diagnostic tool for monitoring the relative greenness of rice leaf as an indicator for the plant N status (Sen et al 2011). Similarly, Sathiya and Ramesh (2009) observed that nitrogen management with LCC produced significantly higher tillers, plant height, dry matter and grain yield.

Economics: Among the nutrient applied the application of nitrogen as basal 80 kg nitrogen 60 kg phosphorous 40 kg phosphorous and remaining nitrogen with the help of real time nitrogen required by plant with the help of customised leaf colour chart registered highest net return (Rs 84240 ha^{-1}) as well as benefit: cost ratio (3.66). This might be due to maximum nitrogen use efficiency and higher number of productive tillers, grains filled in kernels, test weight ultimately higher total production of paddy compared to other treatments applied in this experiment. Reduction in cost of cultivation with CLCC result more benefit than recommended dose of fertilizers and farmer practices. The lower net return (Rs 29080 ha^{-1}) and benefit: cost ratio (1.98) in farmers' practice might be due to indiscriminate and untimely uses of nitrogen so that the cost of cultivation increases. The results are accordance with Gobi et al (2006) states that split application of nitrogen increase net return and B: C ratio.

CONCLUSION

Based on results of present study it can be concluded that real time nitrogen management increase growth attributes, yield attributes, yield of rice and minimize the cost of cultivation and maximize the profit of rice cultivator.

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Effect of Weed Control by Containment and Weeding Frequency on the Growth and Yield of Cucumber in Abakaliki, Southeastern Nigeria

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***Abstract*:** Growth and yield response of cucumber to weed control by containment technique (plant density and weeding frequency)was observed in 2014 and 2015 planting seasons at the Ebonyi State University, Abakaliki southeastern Nigeria. The design was a 5x3 factorial experiment in a randomized complete block design. Factor A was five weeding frequencies [0, 2, 4, 6 and 8 weeks after planting (WAP)], while factor B was three plant densities (41,667, 33,333 and 27,778 plants ha^{-1}). The highest fresh weed weight (93.62g $plot^{-1}$) was at 0WAP on the lowest plant density, showing that critical period of weed infestation in cucumber is not localized in this study. Two WAP significantly influenced growth and yield parameters. The highest plant density (41,667) suppressed weed growth earlier and also gave the highest fruit yield (1.11 kg $plant^{-1}$), having a weed suppression ability of 52.86 in2014 and 43.75 per cent in 2015. Eight WAP gave the highest fruit yield (1.17 kg $plant^{-1}$). The highest plant density weeded 2WAP produced 1.60 kg, 1.20 kg at 8WAP and 0.93 kg $plant^{-1}$ at 0WAP. Therefore, high plant density and a single weeding at 8WAP will reduce cost of production without adverse effect on growth and yield in cucumber at a zero threat to the environment. Hence, weed control by containment technique is sustainable and is highly recommended in cucumber production among the smallholder farmers of developing nations of the world.

***Keywords*:** Containment technique, Plant density, Weeding frequency, Critical weed period

The battle against weeds is a never ending one, and its control is often the costliest agronomic input in terms of the farmers′ time, labour and money. It has been recognized as the greatest hazard hampering sustainable crop production and hiking the cost of food supply in developing countries since man started domesticating plants and animals around 10,000 BC. Weeds are injurious naturally occurring common or noxious annual, biennial or perennial plants of various plant families rightly defined as 'plants out of place' in agricultural systems. They are problem plants which harbor or serve as alternative hosts to insects and disease organisms and increasing their damage to crops and harm the health of animals that may feed on them. Weeds compete with crops for light, water, nutrients and space thereby leading to reductions in crop yield and quality or total failure. A recent estimate showed that weeds account for 37% of the total annual yield loss in India, varying from as low as 10% to as high as 100% in certain crop situations and the annual loss could be nearly 45%. Also, yield reduction of 15-30% was recorded in wheat, 30-35% in rice, 18-85% in maize, sorghum, pulses and oilseeds and they also remove on average 30-40 Kg N, 10-15Kg P_2O_5 and 20-40 Kg K_2O/ha (Das 2008). Weeds may also be parasitic on crops, poisonous to man and animal, less palatable to animals, poor in nutrition, its thorns or spines may be injurious, may block drainage ditches, irrigation channels, railways and roads, but yet a rich source of medicinal values (Das 2008).

Cucumber (*Cucumis sativus* L.*)* is a monoecious plant (Adetula and Denton 2003) with a chromosome number 2n = 14 (Grubben and Denton 2004). It is a tender annual vine creeper or climber on stakes or trellises, with indeterminate or determinate growth habits (Hector et al 2000), being the most important and popular member of the Cucurbitaceae family. It is of Indian or Chinese origin and its cultivation dates back to 5,000 years (Wehner and Guner 2004). It is fourth in importance after tomato, cabbage and onion in Asia, second after tomato in Western Europe, less sugary but a good source of vitamins A, C, K, B6, potassium, magnesium, phosphorus, copper, manganese, pantothenic acid, caffeic acid and dietary fibre (Grubben and Denton 2004). Without herbicides and other control methods, very significant part of the physical farming process is devoted to weed control, yet the uncontrolled and unregulated use or misuse of herbicides when affordable creates health hazards in developing countries. It is therefore against this backdrop that the effects of weed control by containment on cucumber growth and yield was studied in Abakaliki.

MATERIAL AND METHODS

The study was conducted at Ebonyi State University, Abakaliki, in 2014 and 2015 planting seasons. The site is lying on latitude 06° 19′ 407″ N and longitude 08° 07′ 831″ E and at an altitude of about 447m above sea level, southwest of the derived savanna zone of the southeast agro-ecology of Nigeria. It has a pseudo-bimodal rainfall pattern from April to November with a total average annual rainfall of about 1700–2060mm. The site receives abundant sunshine during the day with a maximum mean daily temperature ranging from between 27°C –31°C all through the year. The humidity is high with the lowest levels obtained during the dry season. The soil is a shallow hydromorphic type with unconsolidated parent material (shale residuum) within 1m of the soil surface, classified as Dystric leptosol (Anikwe, Okonkwo and Aniekwe 1999). The design of the experiment was a 5x3 factorial in a randomized complete block design in three replications. Factor A was five weeding frequency regimes [2, 4, 6, 8 weeks after planting (WAP) and a control (0WAP), while factor B was three plant densities (41,667, 33,333 and 27,778 plants ha^{-1}) on a cucumber cultivar (Poinsett 76), a popular open-pollinated cultivar developed for tropical climates by East-West Seed Company (van Luijk 2004). These gave rise to 15 treatment combinations that were randomly planted out in each of the three blocks or replicates. Each replicate was separated by 1m and measured 52 x 2m made up of 15 plots each separated by 0.5m and measured 3 x 2m to give a total area of 52 x 11m or 0.0572ha for the experiment. Each plot was made up of flat beds manually constructed with large blade short Indian hoe, one meter apart and two meters long.

First year field experiment, began in May and was terminated in September, whereas it started in June and ended in October in the second year. In each case, application of N.P.K (15:10:10) at the recommended rate of 700kg/ha (van Luijk 2004) was carried out to augment the native soil fertility of the soil and to aid proper establishment. Data were collected on the vegetative growth parameters [vine length (cm), number of leaves and leaf area (cm^2)] yield parameters (number of fruits $plant^{-1}$, weight of fruits (kg $plant^{-1}$) and weed growth parameters [fresh and dry weights (g $plot^{-1}$)]. Four plants from the two innermost rows in a plot were used for data collection. From each plots, fresh and dry weights were taken at every weeding frequency for the weed growth data. However, the weeding frequency control (0WAP) was weeded as the last fruit harvest was carried out for weed data measurement.

RESULTS AND DISCUSSION

Plant spacing which gives rise to plant population density significantly regulated the fresh and dry weights of weed under the different plant densities in both years (Table 2). The fresh weed weight of 51.87 g $plot^{-1}$and the corresponding dry weight of 19.34g $plot^{-1}$ (2014) and 55.03g $plot^{-1}$ and 29.11g $plot^{-1}$ (2015) were obtained under 41,667 plants ha^{-1}, it was 71.57g $plot^{-1}$ fresh weight and 38.24g $plot^{-1}$ dry weight (2014) and 61.34g $plot^{-1}$ fresh and 31.03g $plot^{-1}$ dry (2015) under 27,778 plants ha^{-1}. The heavier the plant density, the lighter the fresh and dry weed weights in the two years. At the early growth stage of plants, weeds tend to thrive better in the widest plant spacing (60cm x 60cm) as expected. High plant density enables the plants form leaf covers in a shorter time than in lower densities. Also, it was observed that plant density significantly affected the growth and yield parameters positively, except the leaf area, vine length and number of fruits $plant^{-1}$ (2014) and number of leaves, leaf area, vine length, number of fruits and weight of fruits in 2015. Obtaining higher fruit weight (2.15 kg $plant^{-1}$) of cucumber at the intersection between the heaviest density (41,667 plants ha^{-1}) and the least density (27,778 plants ha^{-1}) did not agree with yields of crops in the vegetative phase that show an asymptotic curve relationship with unit area of land.

Table 1. Plant density derived from each of the plant spacing

Plant spacing	Plant population ha^{-1}	Feeding area $plant^{-1}$
60x40cm	41,667	2400 cm^2
60x50cm	33,333	3000 cm^2
60x60cm	27,778	3600cm^2

The fresh weight and dry weight of weeds increased progressively from low fresh weight of 50.28 g $plot^{-1}$ and dry weight of 17.62 g $plot^{-1}$ at 2WAP to as high as 76.86 g $plot^{-1}$ (fresh weight) and 39.90g $plot^{-1}$ (dry weight) when weeding was delayed till the last fruit harvest (0WAP) (Table 3). If at 4WAP, weed fresh weight was 56.56 g $plot^{-1}$, and leaf area of cucumber was 293.14 cm^2 while the number of fruits was 9.63 and fruit weight 7.33 kg $plant^{-1}$, then it could be concluded as the critical weed period in cucumber. This is because these values stood in the middle of values observed between 2WAP above it and 6WAP below it. This is the period after which weeding in cucumber may not be economical (Anil 2000). In this instance, the weed suppression ability of cucumber is 52.86% in 2014 and 43.75% in 2015, showing a significant potential in weed management by containment technique (Aniekwe and Mbah 2011). The vegetative parameters were significantly depressed sequentially as the weeding frequency was delayed, except the leaf area which shot up to 296.17cm^2 at 0WAP but was 253.75 cm^2 at 8WAP and vine length was longer at 4WAP (107.17 cm) than at

0WAP (89.36 cm) in 2014. In 2015, it was a little bit as expected but not in a perfect sequence of depression. It was also evident that delayed weeding till 0WAP did not reduce the weight of fruit yield of cucumber being 9.64 kg plant^{-1}, while it was 11.11 kg plant^{-1} at 2WAP in 2014. It is however difficult to explain why the fruit weight was as low as 5.75kg plant^{-1} at 8WAP but 9.64 kg plant^{-1} at 0WAP. It may however be suggested that the 9.64 kg plant^{-1} at 0WAP was a demonstration of the competitive superiority of cucumber over weed infestation. But the quantum jump of 11.11 kg plant^{-1} at 2WAP is akin to what was observed in 2015 with 1.14 kg plant^{-1} at 2WAP.

Weed growth in a cucumber plot was significantly influenced by plant density and weeding frequency interaction on the basis of fresh weed weight in 2014 (Table 4).It showed that the heaviest weed growth (93.62g plot^{-1}) was observed on the plots with the lowest plant density (27,778 plants ha^{-1}) and where weeding was delayed up to the last fruit harvest (0WAP) and at 8WAP (90.39 g plot^{-1}). The lightest fresh weed weight (32.24 g plot^{-1}) was observed on the plot with the lowest plant population and where weeding was delayed to 4WAP. On the other hand, heavier fresh weed weights (76.86 g plot^{-1} and 71.57 g plot^{-1}) occurred at 0WAP and where plant density was lowest (27,778 plants ha^{-1}) respectively. The 38.39g plot^{-1} of fresh weeds observed on the high plant density plot (41,667 plants ha^{-1}), 2WAP was in order as Ngouajio and Mennan (2005) observed that cover cropping has been a common practice in weed control management among the smallholder farmers who are affected by declining workforce. Mbah and Aniekwe (2013) concluded that cucumber was able to keep weeds in check while its fruit yield was little affected by weed infestation.

Table 2. Effect of plant density on weed growth, growth and yield of cucumber

Plant density	Fresh weed weight (g plot^{-1})	Dry weed weight (g plot^{-1})	Number of leaves	Leaf area (cm^2)	Vine length (cm)	Number of fruits plant^{-1})	Weight of fruits (kg plant^{-1})
2014							
41,667	51.87	19.34	15.67	286.05	96.28	8.78	1.79
33,333	61.57	29.23	16.42	278.73	86.85	7.75	2.15
27,778	71.57	38.24	17.48	295.03	91.45	7.58	1.59
F-LSD (p<0.05)	9.74	1.78	0.95	29.67	17.62	1.67	0.23
2015							
41,667	55.03	29.11	7.65	255.41	79.56	11.40	1.11
33,333	60.12	32.26	7.23	252.64	73.55	8.73	0.97
27,778	61.34	31.03	7.33	247.02	73.60	8.67	0.95
F-LSD (p<0.05)	0.14	0.10	1.00	44.79	12.90	4.97	0.33

Table 3. Effect of weeding frequency on weed growth, growth and yield of cucumber

Weeding frequency	Fresh weed weight (g plot^{-1})	Dry weed weight (g plot^{-1})	Number of leaves plant^{-1}	Leaf area (cm^2)	Vine length (cm)	Number of fruits plant^{-1}	Weight of fruits (kg plant^{-1})
2014							
2WAP	50.28	17.62	21.25	305.50	92.47	7.97	11.11
4WAP	56.56	27.03	18.30	293.14	107.17	9.63	7.33
6WAP	61.96	27.44	16.58	285.14	90.47	8.73	6.42
8WAP	62.70	32.54	15.33	253.75	78.16	6.14	5.75
0WAP	76.86	39.90	11.14	296.14	9.36	7.72	9.64
F-LSD (p<0.05)	16.23	2.30	4.77	38.31	22.74	1.67	0.81
2015							
2WAP	52.34	27.12	7.81	226.30	73.08	10.33	1.14
4WAP	53.44	28.14	7.25	247.74	74.64	9.89	1.02
6WAP	59.50	29.33	7.58	270.89	78.28	10.67	0.92
8WAP	67.92	30.24	2.25	288.22	81.78	8.67	1.17
0WAP	75.24	41.40	7.19	225.27	70.08	8.44	0.80
F-LSD (p<0.05)	0.11	0.10	1.65	34.69	9.99	3.85	0.26

Aniekwe and Mbah (2011) recommended close planting and a single weeding at 6WAP as a beneficial practice because it increased tuber yield in sweet potato and reduced cost of production.

Plant density x weeding frequency interaction significantly influenced the vine length, number of fruits and fruit yield of cucumber (Tables 5, 6 and 7). During first year, vine length was maximum (138.42cm) at the lowest plant density (27,778 plants ha^{-1}) when weeding was delayed till the final fruit harvest (0WAP), which further proved that cucumber plants can withstand weed infestation without adverse effect on the vine length. Also, at 8WAP vine length was 103.67 cm at the lower plant density (33,333 plants ha^{-1}) and 103.42 cm at the highest plant density (41,667 plants ha^{-1}) at 6WAP, which showed that the growth of the vines of cucumber thrived irrespective of plant density or time of weeding. Nevertheless, the highest plant population had the shortest (84.85cm), while the lowest plant population had the longest vine length (97.52 cm). On the other hand 0WAP had the longest vine length (106.92 cm) followed by 8, 6, 4 and 2WAP. During 2015, the number of fruits $plant^{-1}$ (Table 6) showed that the effect of interaction of the highest plant density and weeding frequency at 6WAP produced the highest number of fruits per plant (17.00) but the least number of fruits per plant (4.33) at the lower plant density (33,333 plants ha^{-1}). This result did not represent any trend in 2014 report and may be difficult to suggest the possible cause of the low number of fruits. Plant density x weeding frequency interaction however, favoured higher number of fruits per plant in 2015 than in 2014. Moreover, the main effect of plant density showed a good improvement at the highest plant density in the mean number of fruits per plant of cucumber. Zero weeding depressed the number of fruits per plant (7.00) at the lowest plant density.

At 2WAP, 1.60 kg of fruits per plant was produced under plant density of 41,667 plants ha^{-1}, while 1.13 kg and 1.07 kg were produced at 4WAP under 33,333 and 27,778 plants ha^{-1} respectively (Table 7). This means that plant density in combination with weeding schedules can promote cucumber yield. It was also observed that the interaction effect of plant density and weeding frequency had equal influence on weight of fruits per plant in all the three plant densities studied 8WAP. The implication is that with weeding or without weeding, cucumber can thrive (Mbah and Aniekwe 2013).

Table 4. Plant density and weeding frequency interaction on the fresh weed weight (g $plot^{-1}$)

Plant density	2 WAP	4 WAP	6 WAP	8 WAP	0 WAP	Mean
41,667	38.39	52.89	73.11	35.48	59.50	51.87
33,333	47.06	84.55	36.55	62.23	77.45	61.57
27778	65.39	32.24	76.23	90.39	93.62	71.57
Mean	50.28	56.56	61.96	62.70	76.86	

F-LSD ($p<0.05$) = 9.74, 16.23 and 9.74 – for comparing two plant density means, for comparing two weeding frequency means and for comparing two plant densitiesx weeding frequency interaction means

Table 5. Plant density and weeding frequency interaction on vine length (cm $plant^{-1}$) 2014

Plant density	2 WAP	4 WAP	6 WAP	8 WAP	0 WAP	Mean
41,667	71.67	81.92	103.42	83.33	83.92	84.85
33,333	74.42	92.50	92.08	103.67	98.42	92.22
27,778	82.25	86.42	85.25	95.25	138.42	97.52
Mean	76.11	86.95	93.58	94.08	106.92	

F-LSD ($p<0.05$) = 17.62, 22.74 and 17.62 – for comparing two plant density means, for comparing two weeding frequency means and for comparing two plant densities x weeding frequency interaction means

Table 6. Plant density and weeding frequency interaction on the number of fruits $plant^{-1}$

Plant density	2 WAP	4 WAP	6 WAP	8 WAP	0 WAP	Mean
41,667	13.33	7.00	17.00	9.33	10.33	11.40
33,333	8.33	10.67	4.33	9.33	8.00	8.73
27,778	9.33	9.00	10.07	7.33	7.00	8.67
Mean	10.33	9.89	10.67	8.67	8.44	

F-LSD ($p<0.05$) = 1.66, 4.96 and 1.66 – for comparing two plant density means, for comparing two weeding frequency means and for comparing two plant densities x weeding frequency interaction means

Table 7. Plant density and weeding frequency interaction on the weight of fruits (kg plant^{-1}) 2015

Plant density	2 WAP	4 WAP	6 WAP	8 WAP	0 WAP	Mean
41,667	1.60	0.87	0.93	1.20	0.93	1.11
33,333	0.67	1.13	0.87	1.17	0.80	0.97
27,778	0.97	1.07	0.90	1.13	0.67	0.95
Mean	1.14	1.02	0.90	1.17	0.80	

F-LSD ($p<0.05$) = 0.33, 0.26 and 0.33 – for comparing two plant density means, for comparing two weeding frequency means and for comparing two plant densities x weeding frequency interaction means

In view of its growth habit as a creeper as well as a climber, effects of weeds can relatively be put to a serious check as a soil cover (un-staked) and as a biological weed control measure void of environmental disruption and pollution. This weed control approach (containment) involving manipulating production factors that favour good crop establishment, choice of cultivars, land preparation, time of sowing, crop density and the use of fertilizers proves to be sustainable. Although, cucumber plants are poor competitors with weeds at early stages of growth, but can completely cover the ground within 2WAP for these factors to show significant interactions on these growth and yield parameters. Some studies agree that prostrate crops like sweet potato, cucumber, egusi melon can suppress weeds and reduce early weeding in maize intercrop (Mbah and Aniekwe 2013) and plant population trials (Aniekwe and Mbah 2011).

CONCLUSION

In spite of the importance of weed control, there is a strong reason to do it in an environmental friendly way in view of the obvious hazards presented by other previous methods, such as environmental pollution, soil degradation and climate change. Against this background, biological weed control by containment is a sustainable alternative to chemical weed control which is being advocated for in this paper using cucumber solely or as an intercrop. Apart from controlling weeds, cucumber provides a suitable source of minerals and vitamins for man′s well being. As high cucumber plant density and a single weeding at 8WAP will reduce cost of production without adverse effect on growth and yield in cucumber at a zero threat to the environment, weed control by containment technique is sustainable and a recommendable for cucumber production among the smallholder farmers of developing nations of the world. Based on this, we highly recommend that cucumber should be used as an intercrop with cereal crops that grow erect for effective ground cover, weed suppression, provision of additional food nutrients and reduction of cost of production especially in this age of declining labour force and climate change.

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Effects of Paclobutrazol on Growth and Yield Attributes of Groundnut (*Arachis hypogaea* L.)

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Abstract: A field experiment was carried out to investigate the effect of paclobutrazol (PBZ) as a growth retardant on excessive vegetative growth and yield of groundnut (*Arachis hypogaea* L.) at District Seed Farm, under Bidhan Chandra Krishi Viswavidyalaya, Nadia, West Bengal during *kharif* season in 2013 and 2014. The experiment was in split-plot with 6 main-plot treatments (PBZ @ 0, 50, 100, 150, 200 and 250ppm) and 3 sub-plot treatments (single spraying at 30 and 50 days after emergence (DAE) and double spraying at 30 and 50 DAE). During reproductive stage significantly shorter plants (upto 28% less plant height) were observed due to PBZ application as compared to control. At harvest significantly higher dry matter production was recorded from PBZ @ 250ppm (232.1 g m^{-2}) and from double spraying at 30 and 50 DAE (231.1 g m^{-2}). The number of pod $plant^{-1}$ and sound mature kernel (%) had showed positive impacts and finally increased the dry pod and haulm yield. The maximum dry pod yield was 1745 kg ha^{-1} and 1610 kg ha^{-1} with PBZ @ 250ppm and double spraying at 30 and 50 DAE, respectively. The highest benefit: cost ratio was also from PBZ @ 250ppm and double spraying at 30 and 50 DAE. A highly positive correlation among different attributes were recorded except plant height which was negatively correlated with other attributes i.e. dry matter production, number of pods $plant^{-1}$ and yield was recorded. Therefore, PBZ @ 250ppm with double spraying had considerable positive influences on number of pod $plant^{-1}$, total dry pod yield (Kg ha^{-1}) of groundnut as well as on the benefit: cost ratio.

Keywords: Groundnut, Paclobutrazol, Plant height, Dry matter distribution, Yield, Correlation matrix

Among the nine oilseeds, groundnut (*Arachis hypogaea* L.) is most important in India and takes up a significant place in the Indian agricultural economy (Madhusudhana 2013). Despite being a tropical plant, it can be grown in all seasons. But the main problem during *kharif* season is the growth of vegetative parts become rapid which induce the disturbance in reproductive growth as well as incidence of pest and diseases. Since its vegetative stage continues along with reproductive stage, the partition of assimilates is severely affected with excessive dry matter distribution to stems and results in low pod yield. For the same reason, yield during *kharif* is also lesser than other seasons (Gatan and Gonzales 2015). Considering the above facts application of growth retardant can be an approach to increase the production of groundnut by dropping the excess vegetative growth and proper partitioning of assimilates in the whole plant body during *kharif* season. Paclobutrazol (PBZ) [(2RS–3 RS)-1-4(chlorophenhyl)-4, 4-dimethyl-2-1, 2,4-triazol-1yl-penten-3-ol], a member of the triazole family encourages different morphological changes such as shoot inhibition by the inhibition of gibberellin biosynthesis, increase in the chlorophyll content and also altered carbohydrate status (Jaleel et al 2006, Kishorekumar et al 2006). So, PBZ can be used in order to maintain the balance between vegetative and reproductive growth by reducing the competition for assimilate. As a result, more distribution of assimilates to pods during reproductive stage help in increment of yield (Arzani and Roosta 2004). Hence, the objective of present study was to study the effects of different concentrations of foliar spray of paclobutrazol applied at various times on growth and yield of groundnut during *kharif* season.

MATERIAL AND METHODS

The field experiment was carried out at Bidhan Chandra Krishi Viswavidyalaya, Nadia, West Bengal during *kharif* season in the year of 2013 and 2014. The farm is situated at 23.5°N latitude and 89.0°E longitude with an average altitude of 9.75 metres above mean sea level. The soil of the experimental field was alluvial and sandy loam in nature with good water holding capacity. The fertility status of soil was almost medium (organic carbon= 0.5%, nitrogen= 231 kg ha^{-1}, phosphorus= 21.63 kg ha^{-1} and potash= 190.7 kg ha^{-1}) and neutral in reaction (pH= 7.2). The fertilizers were applied as per recommended doses (N: P_2O_5: K_2O @ 20: 60: 40 kg ha^{-1}).

The experimental design, adopted for this research work was spilt-plot with six different doses of PBZ as main-plot treatments and three different times of application of PBZ as sub-plot treatments, which were replicated three times.

Different doses of PBZ were 0, 50, 100, 150, 200 and 250 ppm as T_0, T_1, T_2, T_3, T_4 and T_5; the sub-plot treatments were viz. single spraying at 30 and 50 days after emergence (DAE) as S_1 and S_2, respectively and double spraying at 30 and 50 DAE (S_3). The variety used in this experiment was TG51 (Mutant derivatives of TG26 x Chico, Bhaba Atomic Research Centre, Mumbai) with about 90 days crop duration. The source of paclobutrazol was CULTAR (23%W/W SC 25% W/V). Different growth attributes such as plant height (cm) during vegetative stage and reproductive stage i.e. at 45 DAE and 75 DAE, respectively; dry matter production (g m^{-2}) at 30, 45, 60, 75 DAE and at harvest; number and dry weight (g) of nodules per plant at 45 and 60 DAE; different yield attributes like number of pods per plant and sound mature kernel (%) [Sound mature kernel (%) = {Total weight of mature kernel (g)/ Total weight of kernel (g)}× 100]; dry pod and haulm yields (kg ha^{-1}) were recorded during this experiment. Testing of hypothesis related to correlation among growth parameters, number of pods per plant and yield (dry pod and haulm) was implemented by calculating correlation matrix which was done using software 'R'.

RESULTS AND DISCUSSION

Effect of PBZ on plant height (cm): Application of PBZ in *kharif* groundnut had the positive influences to reduce the plant height (Table 1). With increasing doses of PBZ at 45 DAE, significantly shorter plant height (21.9 cm) (PBZ @ 200 ppm) was statistically at par with PBZ @150 and 250 ppm. In case of different time of applications of PBZ either single and / or double spraying at 30 and 50 DAE did not influence the plant height significantly. The significantly shorter plant height (45.3 cm) at 75 DAE was with PBZ @ 150 ppm which was statistically at par with T_4 and T_5. However there was no significant difference in case of double spraying at 30 and 50 DAE (S_3) as compared to single sprayings. The inhibition of gibberellin biosynthesis due to PBZ application might have resulted in declining in plant height. Cheng et al (2006) showed that by application of PBZ the twig length and stem height of groundnut were reduced. Sankar et al (2014) also reported that PBZ treatment decreased the stem length upto 68.53% over control on 80 days after sowing.

Effect of PBZ on dry matter production (g m^{-2}): Paclobutrazol had no positive influence on dry matter production at initial stage i.e. at 30 DAE. The dry matter production at 45 and 60 DAE increased significantly upto the application of PBZ @ 200ppm, thereafter, decreased with further increase the doses (PBZ @ 250 ppm) (Table 1). But at 75 DAE and at harvest PBZ upto 250 ppm had the positive response and significantly maximum dry matter production (196.8 g m^{-2} at 75 DAE and 232.1 g m^{-2} at harvest) was in the treatment T_5. The PBZ @ 150 to 250 ppm were statistically at par among each other and were significantly superior to control. Double spraying at 30 and 50 DAE (S_3) showed the significantly higher results at 45 DAE (104.6 g m^{-2}) and at harvest (231.1 g m^{-2}). Despite the reduction in plant height, the dry matter production was increased and that was might be as PBZ stimulates the root elongation by inhibiting gibberellin synthesis and also increases the chlorophyll content in leaves (Jaleel et al 2006, Kishorekumar et al 2006) for which more assimilates are produced and partitioned

Table 1. Effect of PBZ on growth attributes and nodulation (Pooled over two years)

Treatments	Plant height (cm)		Dry matter production (g m^{-2})					Number of nodules $plant^{-1}$		Nodule dry weight (g) $plant^{-1}$	
	45 DAE	75 DAE	30 DAE	45 DAE	60 DAE	75 DAE	At harvest	45 DAE	60 DAE	45 DAE	60 DAE
Doses of paclobutrazol (T)											
T_0: control	30.4	62.8	70.5	93.1	114.5	166.7	194.8	95.3	194.5	0.300	0.491
T_1: PBZ@50 ppm	31.3	51.4	71.7	99.0	129.3	162.3	208.3	92.1	167.1	0.304	0.290
T_2: PBZ @100 ppm	25.0	45.8	75.1	102.7	136.7	163.2	224.8	101.2	174.2	0.351	0.398
T_3: PBZ @150 ppm	24.1	45.3	77.4	103.6	132.3	183.3	225.1	98.7	213.7	0.328	0.432
T_4: PBZ @200 ppm	21.9	45.9	75.8	108.1	136.9	185.9	224.3	107.8	203.6	0.316	0.376
T_5: PBZ @250 ppm	22.4	48.8	73.6	103.3	135.5	196.8	232.1	112.1	183.3	0.292	0.488
CD (p=0.05)	2.53	4.51	NS	2.60	12.23	19.73	10.52	NS	NS	NS	NS
Time of application (S)											
S_1: single spraying at 30DAE	25.0	50.65	70.6	89.3	127.0	169.7	208.1	93.7	169.0	0.319	0.349
S_2: single spraying at 50DAE	26.8	49.7	74.1	101.2	129.8	178.5	215.5	105.7	206.8	0.321	0.398
S_3: double spraying at 30 and 50DAE	25.8	49.55	77.3	104.6	135.8	180.9	231.1	104.2	192.4	0.306	0.490
CD (p=0.05)	NS	NS	NS	1.73	NS	NS	7.04	NS	NS	NS	NS

between vegetative and reproductive portions. Kumar et al (2012) found that PBZ treatments were effective in shortening plant height along with increasing the number of stems and stem thickening which finally also contributed to the total dry matter production. Same result also obtained by Senoo and Isoda (2003).

Effect of PBZ on number and dry weight of nodules: There was no significant result of PBZ application on both number and dry weight (g) of nodules per plant (Table 1). That means PBZ had no effect on nodulation of plants.

Effect of PBZ on pod number per plant: The significantly higher pods per plant (12.1) was in PBZ @ 150 ppm, which was statistically at par with PBZ @ 100 and 200 ppm but significantly superior to control. In case of time of application of PBZ, number of pods per plant varied significantly with double spraying at 30 and 50 DAE (S_3). The maximum pod number per plant was in S_3 (11.9) which were statistically at par with S_2 (11.1). The foliar application of PBZ at early stage had no significant influence to increase the pods in groundnut but at later stage i.e. 50 DAE had the positive response. The retardation of plant height during reproductive stage might have resulted in better partitioning of assimilates between vegetative and reproductive parts which improved the pod number per plant. Similar finding was attained by other researchers (Lubis et al 2011, Zhang et al 2013).

Effect of PBZ on sound mature kernel percentage (SMK %): Due to application of different concentrations of PBZ, SMK (%) did not vary significantly. But single spraying at 50 DAE (88.0%) as well as double spraying at 30 and 50 DAE (88.0%) showed significant result. It can be assumed that the increase in sound mature kernel percentage mainly depended on the alteration of dry-matter distribution to kernels due to restrain over stem elongation (Senoo and Isoda 2003).

Table 2. Effect of PBZ on yield attributes, yield and B: C ratio (Pooled over two years)

Treatments	Number of pods plant^{-1}	Sound mature kernel (%)	Yield (kg ha^{-1})		B:C ratio
			Dry pod	Dry haulm	
Doses of paclobutrazol (T)					
T_0	8.5	86.5	1140	1993	1.62
T_1	9.8	87.5	1331	2089	1.78
T_2	11.3	87.5	1474	2303	1.91
T_3	12.1	87.8	1639	2330	2.05
T_4	11.9	87.8	1693	2402	2.06
T_5	10.8	87.9	1745	2457	2.06
CD (p=0.05)	1.14	NS	72.5	105.34	
Time of application (S)					
S_1	9.2	86.3	1400	2157	1.79
S_2	11.1	88.0	1502	2215	1.92
S_3	11.9	88.0	1610	2415	2.03
CD (p=0.05)	1.06	1.45	48.4	70.42	

Effect of PBZ on dry pod and dry haulm yield (kg ha^{-1}): Among the different concentrations of PBZ, 250 ppm gave significantly higher dry pod yield (1745 kg ha^{-1}) which was statistically at par with PBZ @ 200 ppm. In addition, significantly superior dry pod yield (1610 kg ha^{-1}) was observed with the double spraying at 30 DAE and 50 DAE i.e. S_3. Therefore, PBZ application at later stages along with early application had positive consequence to increase the pod yield of groundnut. Lubis et al (2011) and Zhang et al (2013) also found that PBZ spraying significantly increases pod yield via increasing the pod number per plant and percentage of double kernel. Similar kinds of influences of PBZ concentrations as well as time of applications were observed for dry haulm yield (aerial portions + roots). Maximum dry haulm yield i.e. 2457 and 2415 kg ha^{-1} were obtained from T_5 in case of doses and S_3 in case of time of applications, respectively. The increase in total dry matter production at harvesting stage ultimately increased the total dry haulm yield of plant.

Effect of PBZ on benefit: cost (B: C) ratio: The benefit: cost was higher in case of PBZ treatments compared to control. Maximum B: C ratio (2.06) was recorded from both T_4 and T_5 treatments and those were 27% more than T_0. Besides, double spraying of PBZ (S_3) presented higher B: C ratio (2.03) than both single treatment i.e. S_1 and S_2. Despite the extra expenditure of higher dose and double application of PBZ, the B: C ratios were more and that might be due to additional yield of dry pod and dry haulm in case of the treatments.

Correlation analysis: In case of different concentrations of PBZ (Table 3), it can be observed that plant height at 75DAE was negatively and significantly correlated with other parameters except with number of pods per plant (r= -0.949) that was negatively significant at 1% level. Hence, the reduction in plant height was advantageous to improve the yield. In addition, positively significant at 1% level correlation was found regarding dry pod yield with dry matter production (r= 0.948) and also with dry haulm yield (r= 0.978). For different times of application of PBZ (Table 4), there was no significant correlation but plant height was negatively and highly correlated with other observations. The correlation result also revealed that dry pod yield had highly positive correlation with dry matter production at harvest (r= 0.983), number of pods plant^{-1} (r= 0.969), sound mature kernel % (r= 0.858) and dry haulm yield (r= 0.958).

Table 3. Pearson's product-moment correlation matrix of yield (pod and haulm) with growth parameters and yield parameter for different doses of PBZ

Parameters	Plant height	Dry matter production	Number of pod plant^{-1}	Dry pod yield	Dry haulm yield
Plant height	1	-0.893*	-0.949**	-0.825*	-0.817*
Dry matter production	-0.893*	1	0.867*	0.948**	0.971**
Number of pod plant^{-1}	-0.949**	0.867*	1	0.856*	0.843*
Dry pod yield	-0.825*	0.948**	0.856*	1	0.978**
Dry haulm yield	-0.817*	0.971**	0.843*	0.978**	1

(*= significance at 5% level and **= significance at 1% level)

Table 4. Pearson's product-moment correlation matrix of yield (pod and haulm) with growth parameters and yield parameters for different times of application of PBZ

Parameters	Plant height	Dry matter production	Number of pod plant^{-1}	Sound mature kernel (%)	Dry pod yield	Dry haulm yield
Plant height	1	-0.825	-0.986	-0.992	-0.916	-0.761
Dry matter production	-0.825	1	0.907	0.747	0.983	0.995
Number of pod plant^{-1}	-0.986	0.907	1	0.957	0.969	0.858
Sound mature kernel (%)	-0.992	0.747	0.957	1	0.858	0.674
Dry pod yield	-0.916	0.983	0.969	0.858	1	0.958
Dry haulm yield	-0.761	0.995	0.858	0.674	0.958	1

CONCLUSION

The foliar application of paclobutrazol in different concentration had been proved better in reducing excessive vegetative growth and increased the pod yield up to 12 to 41% over control. Significantly highest pod yield was with the application of 250 ppm of paclobutrazol with double spraying at 30 and 50 DAE which was economically viable for groundnut.

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Performance of Groundnut (*Arachis hypogaea* L) Varieties as Affected by Weeding Frequencies

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Abstract: The field experiment was conducted at Ebonyi State University , Abakaliki during 2014 and 2015 farming seasons to investigate the effect of weeding regime on the growth and yield of three groundnut varieties. The experiment was laid out in 3 x4 factorial in a randomized complete block design. The majority of weeds in the experimental site were the broad leaves (dicotyledons), while grasses (monocotyledons) were in a lesser density. The dominant weeds flora infesting groundnut during growing season were *Physalis angulata*, *Spigelia anthelma* and *Cleome viscosa* with relative weed density of 27, 21 and 11 per cent, respectively. Samnut 21 produced the lowest number of branches, number of leaves and days to 50 per cent flowering while Samnut 10 produced the tallesst plant, heaviest pods and seeds, highest number of seeds and total yield .Weeding at 3 weeks produced the tallest plant, highest leave area index, number of seeds, 100 seed weight and total yield. The plots without weeding (control) produced the lowest in all the parameters showing that weeds has negative effect on the crop yield. The result of this research work showed that Samnut 10 with 3 weeks weeding intervals demonstrated highest seed yield and can be recommended for the farmers in the study area.

Keywords: Groundnut, Dicotyledons weeding, Frequencies, Samnut 21

Groundnut is a major oil seed crop grown in tropics and sub-tropic parts of the world. Nigeria is the fourth largest producer of groundnut after China, India and USA (USDA 2009). It occupies the fourth place among the oil crops in the world both in area and production next to soybean, sunflower and cotton (FAO 2015, Garko et al 2015). In United States of America groundnut yield is as high as 3000 kg ha^{-1}, while the average yield in tropical Africa is about 800 kg ha^{-1} (El Niam et al 2010). Use of appropriate varieties for a particular ecology is very vital in groundnut production. Farmers using improved varieties have derived significant yield gains of 23, 43 and 31 percent over local variets in Mali, Niger and Nigeria, respectively (ICRISAT 2011). Again, use of aggressive groundnut varieties can be effective cultural practice for weed growth suppression. In Nigeria, groundnut yield loss due to weed infestation could be as high as 51 percent (Etejere et al 2013). The main problems limiting production of peanut are poor cultural practices, lack of improved varieties and inadequate weed management. Page et al (2002) reported that groundnut cannot compete effectively with weeds, particularly 3–6 weeks after sowing; therefore, early removal of weeds is important before flowering and pegging. The degree of damage caused by the weeds is a function of their leaf area index (LAI) as compared to the crop they are competing with (El-Naim and Ahmed 2010). Weed leads to direct yield losses through competition with the crop for water, nutrients, lights, space and/or of carbon dioxide. This degree of damage is mainly a function of their number and biomass as compared with that of the crop (El Naim et al 2013). Weeds have different competitive abilities which determines their performance and potential of damage in a given situations; most important are vigor, growth habit, **seed production**, regenerative capacities and time of germination which is mainly a function of their leaf area index, as compared with that of the crop (Bedry 2007, Alam 2007).

Weeds constitute a major production problem which faces farmers in West Africa. In Nigeria, uncontrolled weeds caused 40-90% yield loss in cereals, 53-60% loss in legumes, 50-55% loss in oil seeds and 65-91% loss in root and crops (Etejere et al 2013). Therefore, the objectives of this study were to investigate the performance of groundnut varieties as affected by weeding frequencies.

MATERIAL AND METHODS

The field experiments were conducted at Ebonyi State University, Abakaliki, during the rainy season of 2015 and 2016. The treatments were four weeding frequencies (no weeding (control), weeding at 3 weeks, weeding at 6 weeks, and weeding at 9 weeks and three groundnut varieties (Samnut 10, 11 and 21) which were laid out in 3x 4 factorial experiment in a randomized complete block design (RCBD) with three replications. Each replication contained 12 plots

giving a total of 48 plots in the experiment, each plot measured 2 x 2 m (4 m^2) allowing 0.5 m between adjacent plots, while 1.0 m separated each replicate. The field was tilled manually with hoe, while seeds were sown at 2–3 cm depth at the spacing of 50x50 cm. Weed richness, proportion, diversity and evenness were calculated using Shannon′s Wiener Diversity Index. Shannon′s Wiener Diversity Index which is represented by H is calculated using the formula : $H = \Sigma \{P(i) \times \ln P(i)\} \times -1$. The species evenness ranges from zero to one. The agronomic parameters were also measured and recorded and were analysed using the General linear Model in Minitab and the treatment means were compared using Turkey´s test while the residual effects of treatments were also tested using Anderson Darling´s test.

RESULTS AND DISCUSSION

The majority of weeds in the experimental site were the broad leaves (dicotyledons), while grasses (monocotyledons) were found in a lesser density (Table 1). The dominant weeds flora infesting groundnut during growing season were *Physalis angulata*, *Spigelia anthelma* and *Cleome viscosa* with relative weeds density of 27, 21 and 11 percent respectively. *Physalis angulata* had the highest frequency of 83, proportion (0.111) and diversity (Table 1). The lowest frequency (02), proportion (0.027) was of *Dactyloctenium aegyptium*. Species richness, evenness and Shannon Weiner Diversity index for this community were 26, 0.929 and 3.028. This indicate that, the community is moderately diverse. The diversity of species in a particular

Table 1. Weed identification, classification, species richness ,shannon wiener diversity index and eveness in the experimental site

Scientific name	Common name	Classification	Frequency	Proportion
Physalis angulata	Wildcape gooseberry	Broad Leave	83	0.111
Laportea aestuans	Tropical nettleweed	Broad Leave	32	0.043
Euphorbia heteropylla	Spurge weed	Broad Leave	26	0.035
Amaranthus spinosis	Thorny pig weed	Broad Leave	37	0.500
Ageratum conyzoides	Goat weed	Broad Leave	51	0.068
Commelina benghalensis	Wandering jew	Broad Leave	45	0.060
Tridax procumbens	Tridax	Broad Leave	45	0.060
Peporomia pellucida	Shiny bush	Broad Leave	35	0.047
Cleome viscosa	Consumption weed	Broad Leave	48	0.064
Solenostemon monostachyus	Golden shrimp plant	Broad Leave	41	0.055
Scoparia dulcis	Broom weed	Broad Leave	17	0.023
Spigelia anthelma	Worm bush	Broad Leave	51	0.068
Senna abtusifolia	Sickle pod	Broad Leave	46	0.062
Cleome rutidosperma	Fringed spider	Broad Leave	32	0.043
Aspilia africana	Wild sunflowrer	Broad Leave	22	0.030
Ghomphrena celosioides	Soft khaki weed	Broad Leave	27	0.036
Ludwigia abyssinica	Water primrose	Broad Leave	25	0.034
Kyllinga erecta	Creeping sedge	Broad Leave	10	0.013
Mariscus altermifolius	Angel′s wing	Sedges	7	0.009
Kyllinga squamulata	Asian spike sedge	Sedges	18	0.024
Ctperus iria	Rice flat sedge	Sedges	9	0.012
Cyperuus esculentus	Yellow nut sedge	Sedges	6	0.008
Fimbristylis littoralis	Fringe rush	Sedges	15	0.020
Panicum maxmiun	Guinea grass	Grasses	11	0.015
Dactyloctenium aegyptium	Bachelor′s button	Grasses	2	0.003
Paasspalum scrobiculatum	Bahama grass	Grasses	4	0.005

Species richness (X) =26, Shannon Weiner′s diversity index H=3.028, Evenness =0.929

area depends not only on the number of species found but also in their numbers.

Effect of varieties and weeding frequenices on growth parameters of groundnut: The varieties used in this experiment exhibited consistent significance difference in their growth characters such as plant height, number of leaves and branches and days to 50 per cent flowering (Table 2). The tallest plant observed in Samnut 21 is attributed to its erect growth habit and competition by crops to intercept greater solar radiation and accumulate greater dry matter per unit area and per unit time. The widest canopies observed on plots where samnut 11 were planted indicated that the variety made adequate use of the soil nutrients to grow and spread out in conformity with its growth habit. The increase in the leaf area index, number of branches and leaves of samnut 10 were attributed to the available nutrients to crops and its ability to intercept radiation. This is in agreement with Kamara et al (2011) who reported that groundnut has the ability to utilize soil nutrients that may be relatively unavailable to other crops and therefore can make good use of residual fertility. The variations of the varieties by days to anthesis and maturity could be attributed to genotypes differences. The shortening of the days to maturity promote rapid cell division as reported by Brady and Weil (2002). Samnut 11 produced the highest leave area index and the lowest leave area index produced by Samnut 10. The difference in the mean leaf area index was as a result of the various varieties which may be attributed to the difference in the genetic composition of the individual varieties. Variety had significant effect on number of branches which recorded its highest at Samnut 11. The lowest number of branches was produced by samnut 21. There was a deviation as samnut 21 which had a spreading growth habit had lesser number of branches while samnut 11 and 10, which have semi –erect growth habit had higher number of branches. The result is in agreement with the findings of Ahmad and Mohammad (1997) who reported that number of branches in groundnut is a varietal characteristics, controlled largely by plant genetic factors. The maximum days to 50 per cent flowering were recorded by Samnut 11.

Weeding at three weeks had a highest plant height. Weeding facilitates plants to have more resources for growth, these results agreed with Joshi (2004), Mubarak (2004) and Bedry (2007) observed that increasing weeding frequency increased plant height, due to efficient weed control. Weeds decreased the number of branches per plant. The highest number of branches per plant was obtained at weeding at three weeks. This result may be attributed to vigorous plant with less competition for light, nutrients, and free space in weed free environment. Increased weeding frequencies increased leaf area index. This was due to better control of weeds. The reduced competition and increased availability of resources like nutrients, soil moisture and light which paved way for higher leaf area per plant (leaf area index). These results are conformity with the findings of El Naim et al (2010).

Effect of variety and weeding frequency on the yield and yield component of groundnut: The seed yield of the different varieties was significantly different at the 5 percent probability (Table 3). Samnut 10 had the higher yield in both years than Samnut 11 and Samnut 21. Bala et al (2011) observed that Samnut 10 is inherently higher yielding variety than Samnut 11 which implies that the variety is more efficient in the manufacture of assimilate and partitioning of same to the reproductive sink. This may explain the superiority in seed yield production of samnut 10 over other varieties as reported by Kamara et al (2011). Samnut 10 significantly produced the highest number of pod and pod weight. The variation in the number of pods per plant were as a result of the variation in the potential productivity of the groundnut

Table 2. Effect of weeding frequencies on the growth parameters of groundnut varieties

Treatments	Plant height (cm)	Numbe rof leaves	Leaf area Index	Number of branches	Days to 50% flowering
Variety					
Sammaz 10	39.19 b	21.00b	0.69b	5.25b	30.38b
Sammaz 11	38.41c	21.19a	0.74a	5.30a	30.38b
Sammaz 21	39.99a	20.69c	0.72c	5.17c	34.25a
Weeding frequency					
Unweeded (Control)	37.01b	17.83d	0.37d	4.46d	30.33c
3 weeks	39.75a	24.50a	0.75a	6.13a	32.25a
6 weeks	40.16a	21.00b	0.70b	5.25b	32.66a
9 weeks	39.85a	20.50c	0.53c	5.12c	31.42b

Means followed by same letter (s) within same column and treatment group are notstatistically different at 5% level of probability using Duncan Multiple Range Test (DMRT)

Table 3. Effect of weeding frequencies on the yield and yield components of groundnut varieties

Treatments	Pod weight (g plant $^{-1}$)	Number of seed	Seed weight (g plant^{-1})	100 Seed weight (g)	Total yeild (kg ha^{-1})
Variety					
Samnut 10	11.94a	65.46a	0.27a	14.44a	1181.25a
Samnut 11	10.06b	54.56b	0.21c	13.75c	984.38b
Samnut 21	9.119c	54.25c	0.23b	14.25b	934.38b
Weeding Frequency					
Unweeded (Control)	7.08d	9.83d	0.20b	9.33d	564.58c
3weeks	12.08a	81.92a	0.24a	17.75a	1172.32a
6 weeks	10.42c	81.67b	0.24a	16.25b	1002.08ab
9 weeks	12.00b	58.94c	0.25a	13.25c	993.75ab

Means followed by same letter (s) within same column and treatment group are not statistically different at 5% level of probability using Duncan Multiple Range Test (DMRT)

varieties as reported by Patel et al (2005) who indicated the spreading and semi-spreading groundnut varieties differ in their potential productivity. Weeding significantly affected yield parameters. Weeding at three weeks recorded significantly the more pod, 100 seed weight, had the highest number of seeds and total yield while the control treatment had the least in all the yield parameters. Weeding significantly affected the 100-kernel weight. Increased weeding frequencies decreased 100-kernel weight. Weeding treatments significantly affect the pod yield per plant. Weeding at three weeks increased pod yield per plant and improved total yield (t/ha).Weeding increased number of pods per plant, 100 kernel weight, pods yield per plant and final pods yield (ton ha^{-1}). This is because hand-weeding resulted in a better performance of growth and yield components. Similar results observed by many workers, Mubarak (2004), Bedry (2007) and Kumar (2009) in groundnuts and concluded that pod yield increased with weeding treatments, which encouraged early flowering, increased flowering, developed higher leaf area index, increased number of pods and branches per plant and finally maximized pod yield. Weeding at three weeks resulted in increased 100-kernel weight. This may be due to better availability of nutrients and better translocation of photosynthates from source to sink and may be due to higher accumulation of photosynthates in the seeds. Weeding at three weeks had the highest harvest index. This may be due to better translocation of photosynthates from source to sink area and may be due to higher accumulation of photosynthates in the seeds (economical yield).

CONCLUSION

The varieties significantly influenced some of the growth and yield parameters while weeding regime influenced almost all the parameters .Samnut 10 with weeding regime at three weeks produced maximum seed yield which may be attributed to the varietal characteristics as controlled by genetic factors on the part of the varieties and reduced competition for resources and space, efficient dry matter accumulation for weeding regime.

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Delineation of Rice-wheat Cropped Area using Geo-spatial Techniques

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Abstract: Rice and wheat are the most important food crops of India in term of area, production and consumer preference. India is world's second largest producer of rice and wheat crop and Punjab, Haryana are the most productive states of rice wheat cropping system. But due to over exploitation of groundwater resources to irrigate both the crops in these areas, sustainability of rice–wheat cropping is under high threat. In this paper, rice-wheat cropped area was delineated for Agro Climatic Region (ACR-VI) comprising Punjab, Haryana by using remote sensing and GIS analysis. Landsat ETM+ and IRS LISS III images were analyzed to delineate area under rice-wheat cropping system during *kharif* and *Rabi* season. Spatial analysis on effective rainfall varied within 230-466 mm during monsoon period in ACR-VI. Based on the rainfall distribution, groundwater table depth and soil type, potential areas under rice and wheat crops were identified so that most of the crop water requirement could be met through rainfall and there will be check in use of groundwater to maintain sustainable use of natural resources.

Keywords: Agro Climatic Region-VI, Rice-wheat cropped area, GIS, Remote sensing, Landsat ETM+

Rice and wheat are the major cereals grown all over the world. In India, rice and wheat production is 103.04 million tonnes and 94.88 tonnes respectively. Punjab is one of the most productive states for rice and wheat cropping, which contributes 12 and 20% to India's rice and wheat production respectively from only 1.5% of the geographical area. The expansion of rice–wheat cropping system under the green revolution turned Punjab and Haryana states into the food bowl of India, has led to degradation of the natural environment. More than 90% area in northern states like Punjab and Haryana is irrigated through groundwater resources and groundwater decline, rising groundwater table and salinity is the major concern. Hence sustainability of rice–wheat cropping system is a big challenge. Global positioning system (GPS) and geographic information system (GIS) technologies have been adopted for better management of land and other resources for sustainable crop production. Acquiring spatial data in GIS platform and remote sensing (RS) plays a major role in information management systems. RS is an accurate, efficient, economical and reliable technique to prepare a comprehensive inventory of the natural resources of an area (Palaniswami et al 2011, Dhanasekarapandian et al 2015). Many studies demonstrated the effectiveness of using remotely sensed data as a powerful tool to detect land use change for critical environmental areas, vegetation dynamics and urban expansion breakthrough in the method of acquiring information on land resources, agriculture, forestry, ocean resources and other studies (Yasodharan et al 2011, Wulder et al 2012, Crews-Meyer 2004, Laney 2004). The integration of remote sensing data into monitoring frameworks has the potential to standardise monitoring approaches across different spatial scales (Vanden et al 2011). Spectral and contextual information from remote sensing images and thematic data processed together resulting in delineation of polygons that is used to support mapping in field surveys (Schiewe 2002). In object-based image analysis, region-based multi-resolution segmentation approach is commonly used. This is a bottom up region−merging technique in which pixels are merged into homogeneous land parcel units based on the parameters defined by homogeneity criteria for different colours and shapes. However, the algorithms used can lack objective and reproducible means for defining the parameter values (Ouyang et al 2011, Tian and Chen 2007). A plethora of research reports have corroborated the suitability of mapping and monitoring land cover as an important scientific goal (Collins et al 2001). Land suitability analysis of Anjarakandi River basin was carried out using various topographic maps and satellite imagery. Satellite data from Landsat ETM+ were

used for preparing land use, drainage and contour maps. It used a weighted overlay methodological approach to integrate all thematic layers for achieving the designed objectives (Gopal Krishna and Regil 2014). In this paper, remote sensing and GIS was used to delineate rice-wheat coverage areas in ACR-VI region of India and to perform suitability of rice-wheat cropped area based on soil properties, cropping pattern and rainfall distribution in ACR-VI.

MATERIAL AND METHODS

Study area: The study was undertaken in Agro Climatic Region-VI, which covers the major portion of Punjab and Haryana state, located between 27.63 ^{0} N 72.64 ^{0} E and 32.47 ^{0} N 77.59^0 E and covers the area of 11.4 million ha. Rice during *Kharif* and wheat during *rabi* season are widely grown in this region. The region has three distinct seasons, viz. winter (November–March), summer (April–June) and rainy season (July–October). Average annual rainfall varied within 600-900mm, out of this 80% occurs during monsoon season of July–September. The normal annual rainfall is 720 mm in the Haryana districts and 628 mm in the Punjab districts. The climate is semi-arid to dry and sub-humid and the soil is alluvial. Over 80% of the land is sown and over 80% of the sown area is irrigated (Verma et al 2006).

Remote sensing image analysis: A total of 12 Landsat ETM+ images with distinctive paths and rows from website http://glcf.umd.edu for ACR-VI (the states of Punjab and Haryana) were downloaded for rice area delineation. Out of 12 scenes, acquisition period of three images were in the month of September 2000 (paddy crowing season) and rest nine images were for October 2000 (paddy harvesting season). Similarly, all total 14 IRS LISS III images in January 2012 (8 images) and February 2012 (6 images) were used for wheat area delineation. ERDAS 9.2 software was used for data analysis. As acquisition of all the images were not for the single date so pixel values of each image was different. So while comparing the images, crop coverage in particular locations were identified and then analyzed. Then all the images were processed for mosaicing due to variation in pixel values and individual districts were clipped out of the images. False colour composite of band combinations 2,4,7 and 2,3,4 bands of Landsat ETM+ images were considered for better identifications of land category. For wheat area, false colour composite was prepared using green, red, and near infra red bands of the satellites scenes of IRS LISS III sensor. In order to assist these image interpretation elements like shape, size, tone, texture, association and pattern were used. Published crop pattern map developed by Space Application Centre, Indian Space Research Organization was used as secondary data to compare the classified image. All the images were compared to identify the rice cultivated areas for the months of September and October. Similarly wheat areas were identified for the month of January and February. Then delineated rice and wheat areas were compared with the published report of the state.

GIS (Geographic Information System) analysis: Topographic maps of Punjab and Haryana were geo referenced to real World Geodetic Co-ordinate System (WGS 1984). District wise polygon shape file was generated to delineate the study area of ACR-VI with attributes containing the districts name and geographical area. In first phase, a snapshot was taken from Harmonized world soil database (HWSD) viewer indicating the ACR-VI boundary with its all districts boundary. Appropriate soil classes were selected to cover the entire ACR-VI. The snapshot as image file was saved and imported to geographic information system (GIS) interface. With reference to survey of India (SOI) topo-sheets, the image was geo-referenced, and then digitized to get a polygon shape file with attributes containing the soil parameters. The basic soil properties (types) of ACR-VI were obtained from the HWSD and database was prepared. Later using the soil texture triangle, soil textural classes were obtained and map was prepared. Soil texture map was chosen as first thematic layer for analysis. Then cropping pattern map of Punjab and Haryana published by Space Application Centre, Indian Space Research Organization was taken, geo-referenced and overlaid over district wise polygon shape file of ACR-VI. The dominant crop pattern for each district and the same was inserted in the attribute table of ACR-VI shape file. On this basis, cropping pattern map was developed. Daily rainfall data of 37 locations within the ACR-VI was acquired from Indian Meteorological Department (IMD) for the period from 1994 to 2010. The mean monthly rainfall depths were calculated for each location and the monthly effective rainfall depths were estimated by adopting the USDA SCS method using the FAO CROPWAT ver. 8.0 software. Rainfall depths occurring during the pre-monsoon (March, April, May, and June), monsoon (July, August, September) and post-monsoon (October, November, December, January and February) were estimated besides the effective rainfall depths during these periods. Geographically, to visualise and observe the distribution pattern over ACR-VI, point shape file was created importing the coordinates of those 37 locations, attribute table was created putting the effective rainfall values in the columns. Interpolation technique was adopted for getting the values at unknown locations within ACR VI. Krigging technology was applied to get the effective rainfall range and their spatial distribution pattern in the study area. Finally,

spatial mapping of effective rainfall was carried out. Then overlay of thematic layers were performed to identify the suitability of growing rice and wheat crop in ACR-VI.

RESULTS AND DISCUSSION

Mapping of rice-wheat area using remote sensing image analysis: Rice-wheat cropping area was delineated for ACR-VI by using remote sensing and GIS. Landsat ETM+ and IRS LISS III data with maximum likelihood classifier approach in image classification were used for delineation of crop coverage in the study area. It was observed that out of total area, 2.63 and 1.05 million ha area is under rice in Punjab and Haryana respectively. In ACR-VI, about 3.68 million ha area is under rice area (Fig. 1). Similarly wheat area was delineated for ACR-VI. Resourcesat-2 LISS III data with two stage classification approach i.e. unsupervised iso-data followed by maximum likelihood supervised classification methods were used for delineation of wheat crop coverage areas. Wheat area was estimated at 3.51 and 2.46 million ha in Punjab and Haryana respectively. A total of 5.9 million ha wheat area was delineated in ACR VI region (Fig. 2). Areas under rice-wheat crop sequence were 2.053 million ha, which is around 49.06 % of state's total cultivated area. Similarly combined rice-wheat cultivated areas were estimated at 4.16 million ha (more than 90% of cultivated areas).

Image analysis showed that maximum rice areas were delineated in Punjab. District wise analysis showed that Ludhiana and Sangrur districts in the Central Plain Zone (CPZ) of Punjab showed the maximum areas under rice. More than 60% of the total cultivated area in the state in the *kharif* season is occupied by rice. In sub-montane undulating zone and undulating plain covering large parts of districts Ropar, Hoshiarpur, Gurdaspur and Patiala of Punjab state, rice area has virtually spread to occupy all of the plain land. Availability of canal and tube well irrigation supplemented by rain makes large-scale growing of rice quite feasible and available in the undulating plain zone. Agro climatologically, the CPZ falls in the low rainfall zone of 400–800 mm. There is good network of canal system in the state, apart from that minor irrigation census 2011 showed that Punjab, Haryana and UP state of India account for 55 per cent of the tube wells in India. On an average there are 28 tube wells per sq. km. of net sown area in Punjab alone. The area irrigated by government canals covers only 29 per cent of the total irrigated area of the state. On the other hand, net area irrigated by wells covers 71 per cent of the total irrigated area of the state. The problem of overexploitation of groundwater resources is most severe in central Punjab, usually called sweet water zone and dominated by rice crop in the *kharif* season. While the average annual fall in groundwater table in the central Punjab was about 17 cm during the 1980s and about 25 cm during the 1990s, it was alarmingly high at 91 cm per annum during 2000– 2005 (Singh 2011). Analysis revealed that rice and wheat remained the dominant crops which occupy 57.8 and 64.9% of total agricultural area, respectively (Choudhury et al 2013). Similarly, Haryana state is also dominated by rice crop during the *kharif* season. Eastern zone of Haryana including districts of Ambala, Yamunanagar, Kurukshetra, Karnal, Sonipat, Faridabad, Gurgaon and parts of Rohtak comprises the major rice-growing area of Haryana. The Kurukshetra-Karnal-Sonipat-Gurgaon-Faridabad belt is famous for *Basmati* rice production. Groundwater quality in this area is poor and marginal; hence most of the area is dependent on canal system of irrigation (Narang and Virmani 2001). Landsat ETM+ satellite image was also used to delineate and estimate rice crop areas in Haryana state. Remote sensing and GIS analysis resulted an area of 1051,000 ha under rice crop, where as the published report indicated an area of 1049,000 ha under rice for the state of Haryana (Sethi et al 2014). In Haryana rice is grown in 18 districts out of 21 districts under irrigated condition only. This has been well represented in the delineated map of ACR-VI (Table 1). Satellite image analysis showed that nearly 2626000 ha is under rice in Punjab, where as published report showed 2611000 ha area is under rice. Similarly, area under rice in Haryana is 1051,000 ha as per image analysis, whereas it is 1049,000 ha as per the published report.

Hence, there was good agreement on delineation of total rice area in both the states; however, district wise analysis showed variation on rice area for these states. Remote sensing approach was used in other areas for delineating rice areas. Supervised classification was carried out to make clusters of pixel values of similar rice crop with same spectral signature (Dhumal et al 2013). Similarly simplified approach was used to map rice area in the Indo-Gangetic Basin (IGB) by combining remotely sensed imagery, national census and meteorological data. The statistical rice cropped area and production data were synthesized to calculate district-level land productivity, which is then further extrapolated to pixel-level values using MODIS NDVI product based on a crop dominance map. (Cai and Sharma 2010).

GIS analysis for ACR-VI

Soil analysis: Rice-wheat is the major cropping pattern of ACR-VI (Fig. 3) followed by cotton-wheat. Mostly, Indo-Gangetic Plain (IGP) is under continuous deposition of alluvium from the hills and mountains from both sides of the plains – the Himalayas in the north and Deccan Plateau in the south. So, soils of the IGP are Ustochrepts, Aquents, Naturstalf, and Hapludolls (Tarai region). There are large

Table 1. Comparison of rice and wheat cropped area

State	No. of districts	Area (Govt. records) '000 ha	Area (Image classification analysis) '000 ha
Rice			
Punjab	23	2611	2626
Haryana	21	1049	1051
Wheat			
Punjab	23	3528	3511
Haryana	21	2522	2464

lowland patches of heavier soils (silty clay loam to clayey) in almost all states in the IGP where rice-wheat cropping system is practiced (Prasad 2007). While delineating soil map of ACR-VI, all total thirty two numbers of polygons representing uniform land parcel units were created by digitization, which comprised of ten number of soil groups. Major soil groups were presented in Fig. 4 and details of soil characteristics were shown in Table 2. The sand, silt and clay percentage varied within 16-89, 6-47 and 5-53 respectively. The organic carbon content varied within 0.4 to 1.4. The area is mainly dominated by loamy texture soil. On superimposing the soil texture map with the cropping pattern map, it was found that rice-wheat cropping pattern is mainly dominated in loam soil (Fig. 5). In the loamy soils, the soils were neutral to alkaline in nature (pH ranged from 6.2 to 8). Organic carbon content varied within 0.6 to 1.4%. The Leptosol-LP, Lixisol-LX, Regosol-RG and Cambisol-CM were high in soil organic carbon content whereas the rest of the soil groups were low to medium in soil organic carbon content.

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Rainfall analysis: Monsoon rainfall varied within 51 to 651 mm in the study area but the rice-wheat areas receive 195 to 484 mm of rainfall with effective rainfall of 156 to 300 mm (Fig.5). Major crops grown during *kharif* season in these areas are rice. Water requirement of *kharif* rice in Punjab and Haryana is 730 mm (ENVIS Centre, Punjab 2013). This showed that maximum water requirement is met through rainfall if rice is grown in *kharif* season only. Similarly pre-monsoon rainfall varies within 0-67 mm with effective rainfall between 7-64 mm. Post monsoon rainfall varies within 3-32 mm with same amount of effective rainfall. On superimposing

Table 2. Details of soil characteristics of the study area

Id	Soil Group	Sand (%)	Silt (%)	Clay (%)	Organic carbon content (% weight)	Bulk density (kg/dm^3)	pH	Soil texture
1	Luvisol-LV	81	9	10	0.57	1.41	6.20	Loamy sand
2	Fluvisol-FL	35	47	18	0.60	1.39	8.00	Loam
3	Sand dunes-DS	89	6	5	0.40	1.50	6.40	Sand
4	Calcisol-CL	40	37	23	0.56	1.31	7.90	Loam
5	Solonchak-SC	16	31	53	0.58	1.25	8.30	Clay
6	Leptosol-LP	43	34	23	1.40	1.30	7.60	Loam
7	Arenosol-AR	89	6	5	0.40	1.50	6.40	Sand
8	Lixisol-LX	47	32	21	0.82	1.42	6.20	Loam
9	Regosol-RG	47	34	19	0.97	1.21	6.40	Loam
10	Cambisol-CM	42	36	22	1.00	1.37	6.60	Loam

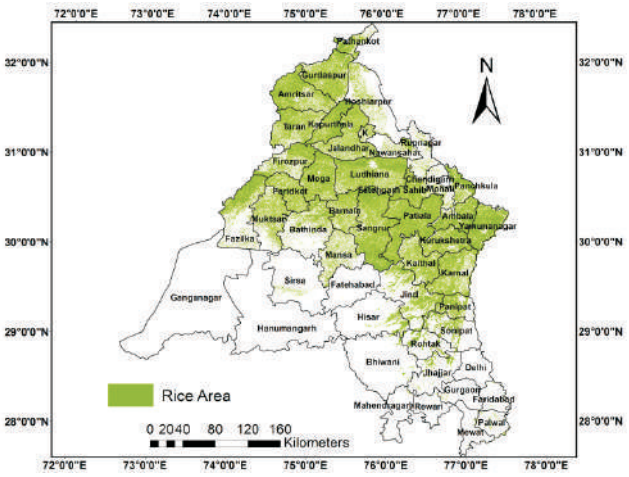

Fig. 1. Delineated rice area in Agro-climatic Region VI (Satellite Image Analysis)

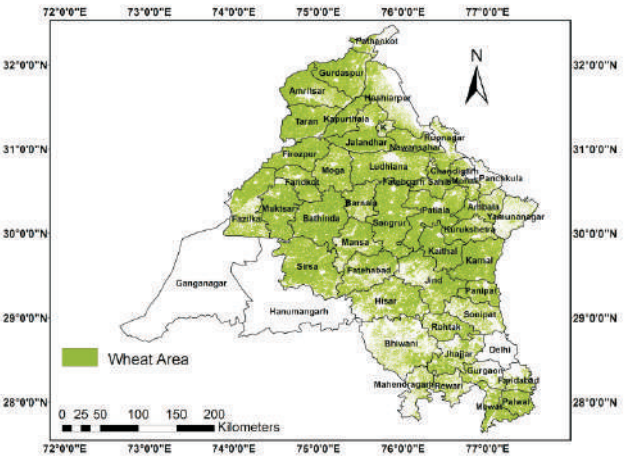

Fig. 1. Delineated wheat area in Agro-climatic Region VI (Satellite Image Analysis)

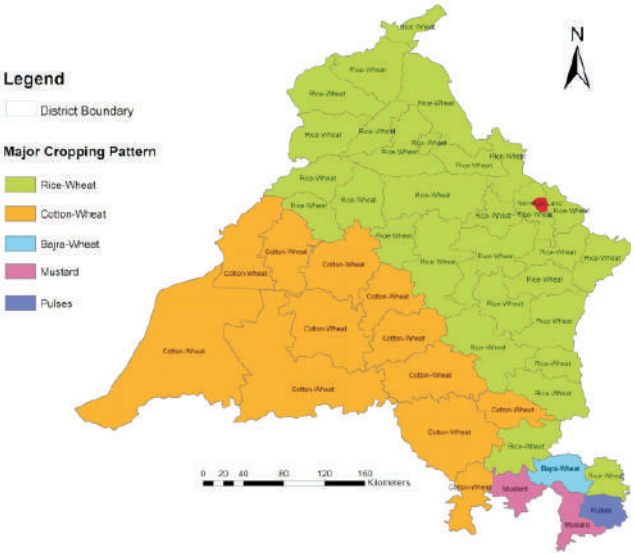

Fig. 3. Major cropping pattern of ACR-VI

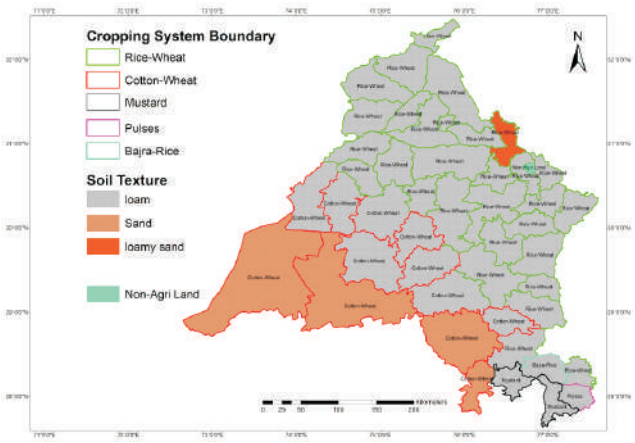

Fig. 4. Cropping pattern with soil texture in ACR VI

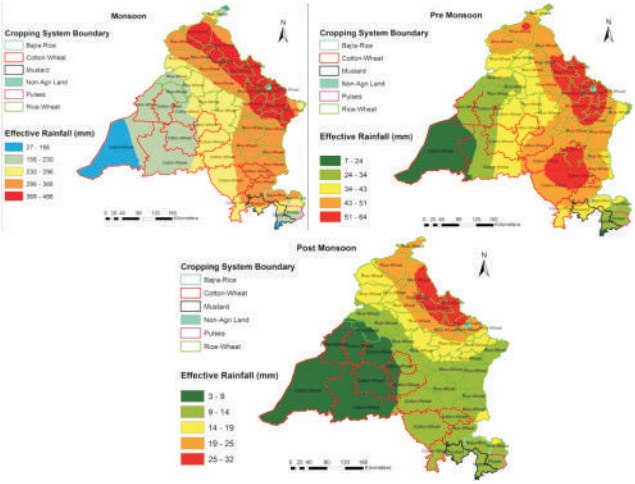

Fig. 5. Effective rainfall distribution pattern with respect to cropping system

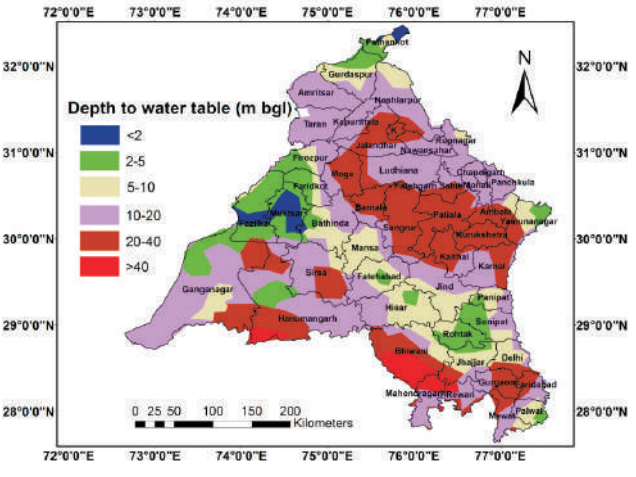

Fig. 6. Status of groundwater table depth in ACR-VI

major cropping pattern of ACR-VI with effective rainfall distribution, it showed that effective rainfall for rice-wheat cropping system varied within 230-406, 34-64 and 9-32 mm during monsoon, pre monsoon and post monsoon season respectively.

Groundwater table depth: Spatial variation of depth to water table as per *ground water year book* in ACR-VI is presented in Fig. 6. In rice-wheat cropping system maximum area (24.67 million ha) lies under the water table depth of 10-20 m followed by 19 million ha under 20-40 m depth to groundwater (Fig. 6). It has been reported that overexploitation of groundwater resources is most severe in central Punjab. The average annual depletion in groundwater table in the central Punjab was about 17 cm during the 1980s and about 25 cm during the 1990s; it was alarmingly high at 91 cm per annum during 2000-2005 (Singh 2011). Out of 142 blocks in the state, water table is declining in 110 blocks due to over-extraction of water than the proportionate recharge. By the year 2023, the water table depth in central Punjab is projected to fall below 21 m in 66 % area, below 30 m in 34 % area and below 40 m in 7 % area (Sidhu et al 2010).

CONCLUSION

The rice-wheat area of ACR-VI was mapped through remote sensing analysis using Landsat ETM+ and IRS images respectively. There was a good correlation in terms of quantitative estimation of rice and wheat area between the analyzed data and the reported information by respective government departments under the study area. From rice-wheat delineated areas, the major part of crop water requirement is not met through rainfall. Hence groundwater is being extensively used in most part of ACR-VI. Hence choice of low water requirement crops, appropriate cropping pattern to fitting the rainfall, improved soil-water-crop management technologies as well as water saving irrigation methods should be promoted inorder to sustain the agriculture system within the limited available water resources.

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Effect of Flucetosulfuron on Soil Health in Rice Ecosystem

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Abstract: The present investigation was undertaken to study the impact of the herbicide flucetosulfuron, on soil microbial load during *Kharif* (2016) and *Rabi* (2016-17) in Kalliyoor Panchayat (8.4455^0 N and 76.9918^0 E at an altitude of 29 m above MSL) Kerala, India. Flucetosulfuron @ 20, 25 and 30 g/ha applied at 2-3, 10-12 and 18-20 days after sowing (DAS) along with two control treatments *viz.,* hand weeding at 20 and 40 DAS and unweeded control comprised the treatments. Microbial count was taken 6 days after spraying the herbicide, using serial dilution technique. The application of herbicides increased the microbial population in herbicide treated plots which may be because herbicides act as carbon source for these microorganisms. No significant variation in the microbial population was observed among the herbicidal treatments and was significantly lower in unweeded control. This indicate that flucetosulfuron is safe to the environment providing healthy and conducive environment for the microorganisms and the bioindicators of soil quality and health.

Keywords: Earthworms, Flucetosulfuron, New generation herbicides, Soil health, Soil microorganisms

Soil health is the capacity of soil to function as a vital living system, within ecosystem and land use boundaries, to sustain plant and animal productivity and promote plant and animal health (Doran and Zeiss 2000). A healthy population of soil micro and macro organisms can stabilize the ecological system in soil due to their ability to restore nutrients to support plant growth (Chauhan et al 2006). The organisms (bacteria, fungi, actinomycetes, protozoa, nematodes, earthworm etc.) residing in the soil play important role in successful functioning of agricultural ecosystems. Singh and Ghoshal (2012) also reported that for sustainable agroecosystem, soil microbial biomass and biological productivity are most essential. Population size of microorganisms *viz.,* bacteria, fungi and actinomycetes serves as the bioindicators of the impact of herbicide application in the agroecosystem (Radosevich et al 2009). Any change in their populace and activity may affect the cycling and availability of nutrients which indirectly affect productivity and other soil functions (Wang et al 2008). Herbicides have a tremendous role in controlling weeds, since no viable alternative is presently available to shift the chemical dependence for weed management in rice (Juraimi et al 2013). The efficacy of herbicide is evident, but ever mounting civic concern over the real or perceived impact of herbicides on public health and environment (Phuong et al 2005) and its effect on soil microbial population (Ayansina and Osa 2006) has renewed the interest to alternate the use of herbicide molecules with different mode of action. Among herbicides, use of low dose, high efficacy herbicides (LDHE) is becoming more popular due to its high efficacy and environmental safety. Flucetosulfuron is one of the latest additions to this array, which is a broad spectrum, systemic herbicide, inhibiting acetolactase synthase (ALS) enzyme, thus causing chlorosis of the plant, leading to death of apical meristems (Paranjape et al 2014). Application of flucetosulfuron followed by bispyribac sodium (25 g/ha each) showed excellent control of broad spectrum weeds (WCE-91-92 %) in wet direct sown and transplanted rice (CRRI, 2013). It is essential to have knowledge of the behavior of herbicides in the soil to avoid soil pollution and their side effect on soil macro and micro-organisms. Therefore, in the present study, an attempt has been made to assess the effect of flucetosulfuron on soil microbial population *i.e.,* total count of bacteria, fungi and actinomycetes and earthworm population under wet seeded system of rice cultivation.

MATERIAL AND METHODS

In order to find out the impact of flucetosulfuron on the population of soil microbes and earthworm, field investigations were conducted during *Kharif* (2016) and *Rabi* (2016-17) in Kalliyoor Panchayat (8.4455^0 N and 76.9918^0 E at an altitude of 29 m above MSL), Kerala, India. A warm, humid, tropical climate was experienced in the experimental area. The experiment was laid out in randomised block design with 12 treatments replicated thrice (Table 1). The soil was Typic haplaustalf under the order *Alfisols*. Kanchana

(PTB 50), a short duration rice variety, was selected as the test crop. The size of the experimental plot was 5 m x 4 m (gross) and 4.7 m x 3.7 m (net). Herbicides were applied on to the surface of soil using knapsack sprayer with flood jet nozzle (spray volume 500 L ha^{-1}). The crop was fertilized with 70:35:35 kg/ha N, P and K, where one third N and K and half P was applied at 15 DAS, one third N and K and half P was applied at 35 DAS and remaining one third N and K was applied at 55 DAS. Basal dose of organic manure was supplied with well decomposed farm yard manure (FYM) with an analytical value of 0.49, 0.2, and 0.46 % N, P_2O_5 and K_2O respectively. Soil was acidic in reaction, high in organic carbon (0.83), available phosphorus (25.98 kg/ha) and available potassium (293.96 kg/ha) and medium in available nitrogen (291 kg/ha). At the time of sowing, a thin film of water was maintained in the field and it was gradually increased to 5 cm at tillering and maintained till 2 weeks before harvest. Just before herbicide application, the field was drained, and reflooded 48 hours after application. Just before lime application also the field was drained and was repeatedly washed 2 days after application. In order to estimate the total count of bacteria, fungi and actinomycetes in the experimental plots, soil samples were collected with soil auger just before herbicide application (JBHA) and 6 days after herbicide application (DAHA). From each treatment plot, four samples were collected to a depth of 15 cm and mixed thoroughly to form a composite sample. The total count of bacteria, fungi and actinomycetes were assessed by serial dilution plate technique (Johnson and Curl 1972) using Nutrient agar, Martin's Rose Bengal agar and Kenknight's agar respectively. Observations were taken on the colonies after 24,72 and 168 h for bacteria, fungi and actinomycetes.

Count of earthworm in soil was taken before and after each field experiment. Before *Kharif* 2016, one composite sample was taken by collecting soil randomly from different parts of the experimental field. After harvest of each crop earthworm population was enumerated by collecting two representative samples from each plot. One metre square wooden frame was used to plot the sampling area. Soil samples were drawn up to 10 cm depth (Bano and Kale 1991). The soil lumps were broken and the soil was passed through the fingers to sort out the worms. By passing through a sieve of 3-4 mm size, the smaller worms were collected. The worms were then counted.

RESULTS AND DISCUSSION

Microbial population: The herbicide application could result in significant changes in bacterial population (Table 1). Just before herbicide application, during both the crop seasons, the population was non-significant. During *Kharif* (2016) and *Rabi* (2016–17), application of flucetosulfuron @ 25 g/ha at 10–12 DAS recorded the highest bacterial population. During Kharif (2016), this treatment was on par with its application @ 20 g/ha at 18–20 DAS whereas, during *Rabi* (2016–17), it was on par with flucetosulfuron @ 20g/ha at 10–12 DAS. Unweeded control and hand weeding twice recorded significantly lower bacterial population during both the seasons though these treatments were not comparable with each other. The significantly higher bacterial population was observed in herbicide applied plots. Less inhibitory effect of sulfonyl urea herbicide on microbial population especially bacteria was reported by Latha and Gopal (2010). The

Table 1. Effect of weed management treatments on bacterial population (x 10^6cfu/g soil) in soil

Treatments	Before treatment application		Six days after treatment application	
	Kharif (2016)	*Rabi* (2016–17)	*Kharif* (2016)	*Rabi* (2016–17)
T_1-flucetosulfuron @ 20 g/ha at 2-3 DAS	4.33	4.67	105.33 (10.27)	82.00 (9.06)
T_2–flucetosulfuron @ 25 g/ha ,,	6.33	5.67	101.00 (10.05)	95.67 (9.77)
T_3–flucetosulfuron @ 30 g/ha ,,	6.33	5.00	97.00 (9.84)	92.33 (9.60)
T_4–flucetosulfuron @ 20 g/ha at 10–12DAS	4.67	5.00	104.33 (10.22)	135.67 (11.65)
T_5–flucetosulfuron @ 25 g/ha ,,	5.67	4.67	122.67 (11.07)	136.00 (11.65)
T_6–flucetosulfuron @ 30 g/ha ,,	4.67	4.67	90.33 (9.50)	108.00 (10.39)
T_7–flucetosulfuron @ 20 g/ha at 18-20 DAS	4	4.33	114.33 (10.70)	112.60 (10.60)
T_8–flucetosulfuron @ 25 g/ha ,,	5.67	3.67	111.33 (10.55)	106.67 (10.32)
T_9–flucetosulfuron @ 30 g/ha ,,	3.67	4.67	99.33 (9.96)	95.33 (9.76)
T_{10}-bispyribac sodium @25 g/ha at 15DAS	5.67	5.67	97.33 (9.86)	91.00 (9.53)
T_{11}-hand weeding at 20 and 40 DAS	4.67	5.33	52.00 (7.21)	56.33 (7.48)
T_{12}-unweeded control	5.67	4.67	27.67 (5.24)	29.67 (5.43)
CD (p=0.05)	NS	NS	(0.40)	(0.67)

cfu–colony forming units. The data were subjected to square root transformation and the values given in parentheses are transformed

increased microbial population upon herbicide application might be due to increased supply of nutrients available as carbon source from the herbicides (Vandana et al 2012, Kaur et al 2014). Significant differences existed among the treatments due to herbicide application (Table 2) on fungal population also. Before herbicide application the fungal population was non-significant. Similar to the observations on bacterial population, application of flucetosulfuron @ 25 g/ha at 10–12 DAS recorded the highest fungal population during both the seasons. However, this treatment was on par with its application @ 30 g/ha at 10–12 DAS during *Kharif* (2016) and during *Rabi* (2016–17) it was comparable with the application of flucetosulfuron @ 20 and 25 g/ha at 18-20 DAS. Even though the herbicide applied treatments exhibited significantly higher fungal population than unweeded control, these treatments were comparable with the hand weeding treatment. Baboo et al (2013) reported increased fungal count in the case of pyrasosulfuron ethyl, a sulfonyl urea herbicide, from 7th to 28th day after herbicide application. Besides this, herbicides can influence fungal count directly or indirectly by affecting the interaction of fungi with other microorganisms (Arajuo et al 2003).

The herbicide application exerted significant effect on the actinomycetes population (Table 3). Before herbicide application, no significant variation was observed for actinomycetes population among the treatments. During *Kharif* (2016) flucetosulfuron @ 30 g ha^{-1} at 2–3 DAS recorded the highest actinomycetes population, whereas during *Rabi* (2016–17), its application @ 25 g/ha at 2–3 DAS recorded the highest population. Actinomycetes population from the treatment hand weeding twice was on par with that of herbicide applied plots during both the seasons. Unweeded control recorded the lowest population during both the seasons. Kaur et al (2014) reported that actinomycetes were less affected as compared to bacteria and fungi and found to be relatively resistant to herbicides. However, Santric et al (2016) reported that the effect of herbicide on actinomycetes population depends on the type of herbicide, application rate, duration of activity and actinomycete isolate. The constant population in soil is extremely useful as these microbes play a major role in the biodegradation of pesticides in the soil (Yadav 2006).

Enhancement in the bacterial and fungal count at five days after sowing over the application of azimsulfuron, a sulfonyl urea herbicide was reported by Nishan (2012) and Rajagopal (2013). The present study also conforms the findings of Priya et al (2017) who reported that the increase in microbial populations might be due to the capability of utilizing the applied herbicides as carbon source. Bacterial and fungal population were found significantly and positively

Table 2. Effect of weed management treatments on fungal population (x 10^{3}cfu/g soil) in soil

Treatments	Before treatment application		Sixdays after treatment application	
	Kharif (2016)	*Rabi* (2016–17)	*Kharif* (2016)	*Rabi* (2016–17)
T_1	1.00	1.00	13.00	7.33
T_2	2.33	1.33	12.33	8.67
T_3	1.67	2.33	15.67	6.67
T_4	1.33	1.67	12.67	11.67
T_5	1.33	2.33	20.33	18.00
T_6	1.33	1.67	18.00	7.67
T_7	1.33	1.67	15.33	17.67
T_8	2.00	2.33	12.33	14.33
T_9	1.67	2.00	15.67	12.33
T_{10}	1.00	1.33	13.67	12.33
T_{11}	2.00	1.33	11.67	6.33
T_{12}	1.33	2.00	4.67	2.00
CD (p=0.05)	NS	NS	3.26	3.72

See Table1 for details

Table 3. Effect of weed management treatments on actinomycetes population (x 10^{4}cfu/g soil) in soil

Treatments	Before treatment application		Six days after treatment application	
	Kharif (2016)	*Rabi* (2016–	*Kharif* (2016)	*Rabi* (2016–17)
T_1	0.67	1.00	2.33 (1.64)	1.67 (1.46)
T_2	0.33	0.67	2.67 (1.77)	3.67 (2.02)
T_3	0.67	0.33	3.67 (2.03)	1.67 (1.44)
T_4	1.00	1.00	1.33 (1.35)	3.00 (1.84)
T_5	1.00	1.00	1.33 (1.35)	2.33 (1.68)
T_6	0.67	0.67	2.33 (1.68)	2.00 (1.53)
T_7	0.33	0.33	1.33 (1.35)	2.00 (1.56)
T_8	0.67	1.00	1.67 (1.44)	2.33 (1.64)
T_9	0.33	0.33	1.67 (1.44)	1.67 (1.44)
T_{10}	0.67	1.00	1.67 (1.44)	2.33 (1.68)
T_{11}	0.33	0.33	1.33 (1.35)	1.67 (1.44)
T_{12}	0.33	0.33	0.33 (0.88)	0.33 (0.88)
CD (p=0.05)	NS	NS	0.46	0.46

See Table1 for details

Table 4. Effect of weed management treatments on earthworm population in soil (number/m^2)

Treatments	After I crop	Before II crop	After II crop
T_1	6.67	6.67	6.67
T_2	5.33	6.67	2.67
T_3	5.33	4.00	5.33
T_4	8.00	9.33	8.00
T_5	9.33	8.00	6.67
T_6	6.67	6.67	9.33
T_7	8.00	5.33	5.33
T_8	4.00	2.67	5.33
T_9	6.67	6.67	5.33
T_{10}	5.33	4.00	4.00
T_{11}	5.33	6.67	8.00
T_{12}	10.67	9.33	9.33
CD (p=0.05)	NS	NS	NS

See Table1 for details

Table 5. Correlation coefficients of microbial count and earthworm population with organic carbon

Parameter	Organic Carbon	
	Kharif (2016)	*Rabi* (2016-17)
Bacterial population	0.531**	0.600**
Fungal population	0.412*	0.510**
Actinomycetes population	0.008	0.230
Earthworm population	0.011	0.082

**and *-correlation is significant at 0.01 and 0.05 level respectively (2-tailed), n=36

correlated with organic carbon during both the seasons (Table 5). Even though actinomycetes population exhibited non-significant correlation with organic carbon content, it exhibited a positive trend. Islam and Borthakur (2016) also reported similar results where soil organic carbon was highly correlated with microbial biomass.

Earthworm population: Critical appraisal of the data (Table 4) revealed that herbicide application did not cause any significant alterations in the earthworm count before and after the crop. The earthworm species observed in the experimental area was *Perionyx sansibaricus* (Family: Megascolecidae). Before *Kharif* (2016) average earthworm count recorded was 7.33 whereas during *Rabi* (2016-17) before the crop the average count was 6.33. After harvest during *Kharif* (2016), 6.77 was the average earthworm count whereas during *Rabi* (2016-17) after harvest no change was observed with average count of earthworm. The average count of earthworm is lower after harvest of *Kharif* (2016) crop, compared to its initial count. Dry condition of field at the time of harvest might be one of the reasons for this reduction. Even though a slight reduction in the average count of earthworm could be seen compared to the same before starting the crop in the field, no alarming reduction due to herbicide application can be found out in the study. The results corroborated the findings of Giesy et al (2000) in which no adverse effects were observed when earthworms were exposed to glyphosate residues in soil at rates equal to or greater than labelled rates. Yadav (2006) also observed that the application of pyrasosulfuron ethyl did not cause any significant and harmful effect on earthworm population in wetland rice ecosystem.

CONCLUSION

Flucetosulfuron @ 20, 25 and 30 g/ha applied at 2-3, 10-12 and 18-20 days after sowing (DAS) did not show any inhibitory effect on microbial population, whereas herbicide application significantly increase the microbial population. Unweeded control always reported significantly lower microbial population and earthworm count and it was not significantly influenced by any of the treatments. Hence, it can be concluded that application of flucetosulfuron does not cause any inhibitory effect on microbial population and earthworm count irrespective of its dose and time of application.

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Towards Unsustainable Resource use in Punjab Agriculture

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Abstract: This paper makes an attempt to develop a composite index to measure sustainability of resource-use for Punjab state. Sustainability in agriculture has evolved overtime. In present perspective, its definition has been centred on optimal resource-use, maintaining environment quality. In consequence, the indexis based on three resource components, namely, land, water and air. The data were deployed on five indicators pertaining to these components from 1970 to 2015. The overall index shows decline in resource sustainability in entire Punjab. Majorly, districts in central and south-western region have become highly unsustainable overtime. Thus, a regular assessment of sustainability of resource-use is required and this index can be useful for effective policy decision making. The overall index highlights the nature of resource sustainability. It raises awareness and understanding of district level differences in sustainability. It aims to trigger interventions leading to sustainable solutions in agriculture for Punjab.

***Keywords*:** Land productivity, water deficit, air pollutant emissions, unsustainability, Punjab

Natural resources, specifically land, water, soil, climate and ecosystem services are essentially required for efficient functioning of agricultural systems. Historically, agricultural sustainability largely focused on increasing agricultural productivity; it did not take into account the adverse effects of rising productivity on the natural resources (Faeth 1993, Lockeretz 1988, Ruttan 1988). The agricultural sustainability definition was revisited after the World Commission on Environment and Development published a report "Our Common Future", it proposed a much wider scope of defining sustainability while including economic, social, political and ecological dimensions (Brundtland 1987). Later studies emphasized sustainable agriculture "as enhancing the environment quality and resource base on which agriculture depends, is economically viable and enhances the quality of life for farmers and society as a whole". Subsequently, integrated natural resource management was conceived as the most important component for improving livelihoods, agro-ecosystem resilience, agricultural productivity and environmental services particularly for developing countries (Douglass1984, Allen et al 1991, Pretty 2008).

In India, agriculture plays a dominant role in improving rural livelihoods and farm incomes. The green revolution since late-1960s accelerated the cereal production faster than the rate of population growth during 1965-2000 (Swaminathan 1993; 1996b; 1999). The success of green revolution was largely visible in the northern parts of India, particularly Punjab, as the state was able to reap its benefits more effectively as compared to the other Indian states. Unfortunately, though, the success came at the expense of natural resources such as land, water and air and the results, like depletion of groundwater table, deterioration of soil quality, stagnating productivity and declining farm incomes, are clearly visible (Sidhu 2002, Singh 2009, World Bank 2010). These adverse impacts on land, water and air resources have mostly been assessed subjectively, but quantification of such impacts, which can be extremely useful for analysing the status of agricultural sustainability has not really been explored. The current study addresses the multi-dimensional nature of sustainability of resources such as land, water and air in Punjab agriculture by developing a composite index for all such indicators.

MATERIAL AND METHODS

Study area: The study was carried out for the state of Punjab, situated between 29˚30´- 32˚32´´N and 73˚55´ - 76˚50´´E, with the geographical area of 50,362 sq.km, accounting for 1.54 per cent of the total geographical area of the country.

Indicators of resource sustainability: Globally, assessing the sustainability of natural resources largely examined the changes in soil fertility, land productivity, water management, and the use of chemical fertilizers. Within India, several studies have measured the sustainability of agriculture by separately using indicators such as productivity, fertilizer consumption, soil fertility, declining in water depth etc. But, most of them do not integrate natural resources such as land, water and air in evaluating the sustainability of agricultural systems, primarily due to lack of data on appropriate indicators and unavailability of data at district level. In this

study, we have attempted to evaluate the resource sustainability by examining the trends of indicators on land, water and air resources. The list of indicators and corresponding variables selected for the study has been listed in Table 1.

Development of resource sustainability index: In this paper, spatial aspects of resource sustainability have been emphasized by proposing a composite index of resource sustainability at the district level. A total of four key indicators were shortlisted for which sufficient and credible time-series data were available. The data were obtained from the Statistical Abstracts of Punjab, were normalized and a composite index was developed using the Iyengar and Sudershan method (Iyengar and Sudershan 1982). The resource sustainability index was estimated for four periods i.e. triennium ending 1980-82, 1990-92, 2000-02, 2009-11 and 2014-15 to study and compare decadal changes. The methodology is convenient for the development of composite index of sustainability.

Let X_{id} represent the size or value of the i-th sustainability indicator in the d-th district of a state (i=1,2,……m, d =1,2…..n say). If X_{id} is negatively associated with sustainability, as for example fertilizer consumption or cropping intensity is high then the district tends to move towards unsustainability then it is written as equation 2.1: -

$$yid = \frac{Max\ X_{id} - X_{id}}{Max\ X_{id} - Min\ X_{id}} \qquad \text{(Equation 2.1)}$$

Where Min X_{id} and Max X_{id} are respectively the minimum and maximum of ($X_{i1}, X_{i2}, \ldots\ldots\ldots X_{in}$). If however X_i is positively related to sustainability, then it equation 2.2 is use: -

$$yid = \frac{X_{id} - Min\ X_{id}}{Max\ X_{id} - Min\ X_{id}} \qquad \text{(Equation 2.2)}$$

From equation 2.1 and 2.2 we have obtained scales values of y_{id} which vary from zero to one. From the matrix of scaled values, $Y = ((y_{id}))$ we construct a measure for the stage of sustainability for different districts as follows: -

$$\overline{yd} = w_1 y_{id} + w_2 y_{2d} + \ldots\ldots + w_m y_{md} \qquad \text{(Equation 2.3)}$$

Where the w's ($0<w<1$ and $w_1+w_2+\ldots\ldots\ldots,w_m = 1$) are weights which reflects the relative importance of the individual indicators.

It is assumed that the weights vary inverse y as the variation in the respective indicators of development. More, specifically, we assume: -

$$W_i = \frac{k}{\sqrt{var(y_i)}} \qquad \text{(Equation 2.4)}$$

$$\text{where } k = \left[\sum_{i=1}^{m} \frac{1}{\sqrt{var(y_i)}}\right]^{-1} \qquad \text{(Equation 2.5)}$$

The weights were obtained for overall sustainability and were multiplied with the standardized values and find indices were obtained for sustainability. The choice of the weights in this manner ensured that large variation in any one of the indicators will not dominate the contribution of rest of the indicators, so that inter-district comparisons are not distorted. For the purpose of classification, a simple ranking of district indices (yd) could done, but for more meaningful characterization of the different stages of sustainability, suitable fractile classification from an assumed distribution is needed. The probability distribution which is widely used in this context is β-distribution. This distribution is defined by equation 2.6: -

$$f(z) = \frac{x^{a-1}(1-x)^{b-1}}{b(a,b)},\ 0 < x < 1 \text{ and } a, b > 0 \qquad \text{(Equation 2.6)}$$

The distribution has two parameters *a* and *b* which can be estimated by comparing the following equation 2.7 and 2.8

$(y-m)a-mb = m-y$ (Equation 2.7)

$(1-y)a-yb = 0$ (Equation 2.8)

Where y is the mean of district indices

$m = sy^2 + y^2$ (Equation 2.9)

sy^2 is variance of district indices. Once the values of a and b are obtained, they are distributed with 20% interval and finally five classes are obtained and districts were ranked accordingly: (i) least, if $0 < y_d < z_1$; (ii) less, if $z_1 < y_d < z_2$; (iii) moderate, if $z_2 < y_d < z_3$; (iv) high, if $z_3 < y_d < z_4$; and (v) higher, if $z_4 < y_d < 1$.

The paper develops an overall resource sustainability index, land productivity, cropping intensity, fertilizer use, water deficit and emission index. It indicates that high index values show lower consumption of resources, whereas lower index shows higher or greater exploitation of resources.

RESULTS AND DISCUSSION

Land productivity, cropping intensity and fertilizer use indices: Land productivity has been a dominant indicator of the agricultural growth and sustainability and is defined usually as crop output per unit of land (Zhen and Routray 2003, Pretty 2008, Mellor 2001, World Bank 2008). Figure 1 reveals that Punjab had lower land productivity during early 1970s, but it increased considerably after that, slowing down during 1990s. Districts lying in the central and south-western region registered further shift towards higher land productivity during 1990s and 2000s. The index of land productivity increased tremendously from 0.4 in 1970s to 0.6 in 2000s with slight decline in 2010 (i.e. 0.5). This is mainly due to stagnant growth in irrigation and cropping intensities (GOP 2013). However, in 2015 some improvement is seen in land productivity as more districts showed an increased

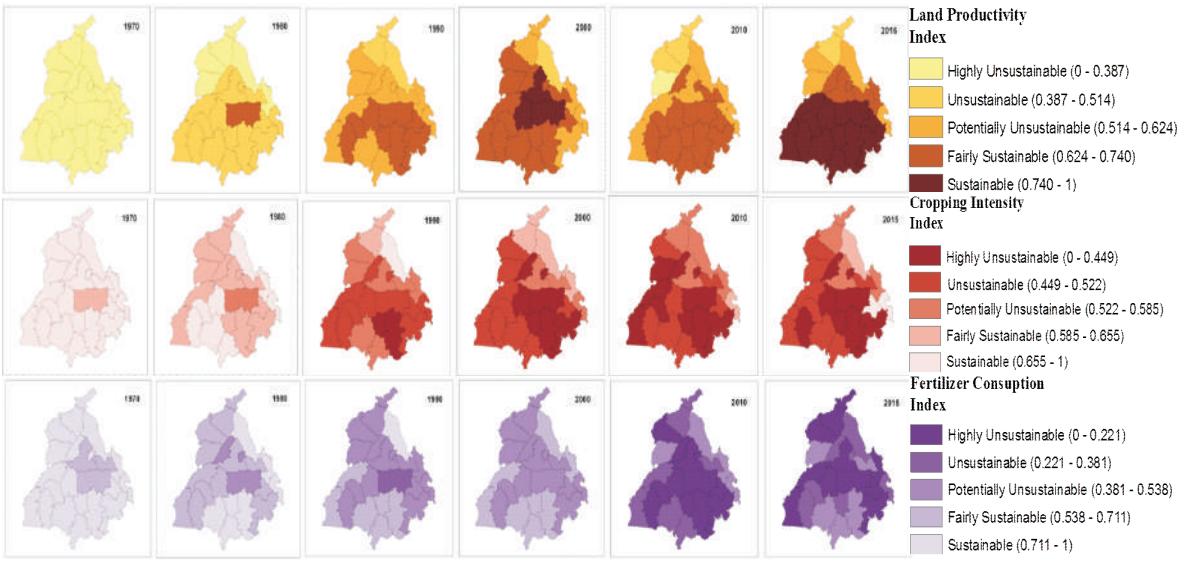
value of the index. Cropping intensity index indicates the intensification of land resource in the five decades. During 1970s and 1980s almost entire Punjab region was sustainable. The degree of RW intensification increased in 1990s as almost half of the districts in the region became unsustainable. By 2000 and 2010, all the districts became unsustainable as the index declined to 0.449 from 0.7 in 1980s Kapurthala, Ludhiana, Sangrur and Patiala are highly unsustainable districts, since the cropping intensity remained more than 190%in the last two decades (Fig. 1). The situation hasn't seen much change in 2015.

Another important factor affecting the land resource is the high use of chemical fertilizers. The fertilizer use index shows aless fertilizer consumption in 1970sand 1980s. Districts such as Kapurthala and Ludhiana begin to high fertilizer-use. Butin1990s many of the districts in central region became potentially unsustainable with index falling to 0.38 from 0.71 (Fig. 1). The trend remained similar in 2000.Post 2000s, use of chemical fertilizers became tremendously high which resulted in; central region been entirely shifted from potentially unsustainable to highly unsustainable categories, index value falling from 0.38 to 0–0.22 (Fig. 1). A similar trend was visible in 2015, with Jalandhar, Ludhiana, Fatehgarh Sahib, Patiala and Moga remained highly unsustainable.

Water resource and Air pollution indices: The water deficit index indicates the gap between agricultural water demand and supply. In 1970s, the entire Punjab region seemed sustainable and by 1980s few districts in central region such as Ludhiana, Fatehgarh Sahib, Patiala, Sangrur and Barnalaregistered a decline in sustainability category, with index value falling from 1 to 0.76 (Fig. 2). In 1990s, districts in central and south western region shifted towards unsustainable and potentially unsustainable category. Ludhiana, Patiala, Fatehgarh Sahib, Firozpur and Fazilika shifted to unsustainable category, with index declining to 0.54. Kapurthala, Jalandhar, NawanShehar and Mansa districts shifted to potentially unsustainable category with index declining to 0.67. A similar trend is visible in 2000s. While post 2000s, water deficit rose in entire Punjab, with

Table 1. Indicators and variables selected for measuring resource sustainability index

Natural resources	Indicators	Variables
Land	Land productivity	Combined yield of Rice-wheat (kg/ha)
	Fertilizer consumption	Fertilizer consumption per unit of land (kg/ha)
	Cropping intensity	Ratio of gross cropped area upon net sown area (%)
Water	Water demand and supply gap	Gap between agricultural water demand and supply (m^3/ha)
Air	Crop residue burning emissions	Emissions from crop residue burning(tons/ha)



Notes: 1.Districts Mansa and Fatehgarh Sahib were created in 1992, hence data of these districts is included in Bathinda and Patiala respectively.2. DistrictsMuktsar, Moga and Nawanshehar were created in 1996, Data of Muktsar and Moga included in Faridkot and that of Nawanshehar in district Jalandhar. 3. Districts Tarn Taran, Nawanshehar and Barnala were created in 2006 hence data of these districts is included in Amritsar, Rupnagar and Patiala, Sangrur district respectively

Fig. 1. Indices of land productivity, cropping intensity and fertilizer consumption

districts in central region been immensely affected. In 2015, the gap further aggravated the entire central, south-western and north-western region became unsustainable with index declining to 0.54 from 1(Fig. 2).

With rising productivity and amount of crop residue generated in the state has increased. Since crop residue burning is the most common farm practice to remove the residues and prepare the field well on time for the next crop. The emission index indicates emissions due to crop residue burning. In 1970s, low crop productivity led to less amount of residue generation. Due to on farm residue burning was very less, so were the air pollutant emissions. The index started rising in 1980s and by 1990s with high use of modern varieties and farm mechanization, amount of residue generated on the field increased specifically in the central region. The emission index value in Ludhiana, Patiala, Fatehgarh Sahib reached to 0.49 from 0.74. In 2000 and 2010, massive amount of air pollutants were emitted. Again, the central region became unsustainable in which Ludhiana, Moga, Sangrur Patiala and were highly unsustainable as the emission index value ranged from 0-0.496. By 2015, the number of districts in unsustainable category increased. Thus, the index for Kapurthala, Firozpur, Fazilka, Faridkot, Moga, Ludhiana, Jalandhar, Fatehgarh Sahib, Patiala, Sangrur, Barnala, has seen fall from 0.74 in 1970s to 0.49 in 2015.

Trends in overall resource sustainability: The overall sustainability index indicates the district-wise resource use of land, water and air. The highest index value declined from 1 in 1970s to 0.62 in 1990s and further to 0.49 in 2015 (Fig. 3). A similar trend was seen in the lowest index which decline from 0.69 in 1970s to0.49 in 2015s. All the districts during 1970s and 1980s were either sustainable or fairly sustainable. The index was very high ranging from 0.69 to 1 (Fig. 3). In 1990s, the index values considerably declined. This decade transformed the Punjab story, as it marked the beginning of unsustainable resource use. It includes different

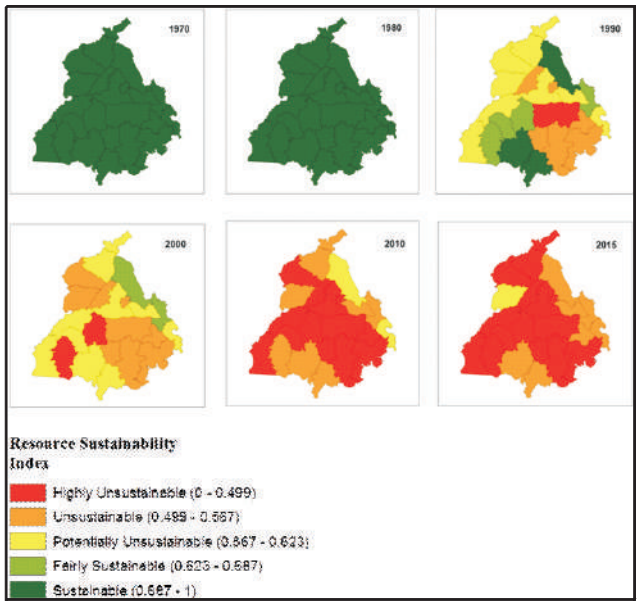


Fig. 3. Resource sustainability index

degrees of sustainability, which is represented in different clusters of districts in the state. At first, the potentially unsustainable districts include Firozpur, Fazilka, Amritsar, Gurdaspur and Pathankot, with index value ranging between 0.57-0.62. Secondly, Sangrur, Patiala, Kapurthala and Fatehgarh Sahib were unsustainable with index ranging from 0.49-0.57. Lastly, Ludhiana was the only highly unsustainable district with index value ranging from 0-0.49 (Figure 3).

The districts which were sustainable in the 1990s became unsustainable in 2000s as indicated by the fall in index values. Only Hoshiarpur and Rupnagar were fairly sustainable in 2000s as index value reduced from 0.69 to 0.62. In 2010s, districts in the central regions became critical with lowest index value ranging from 0 to 0.49. By 2015, districts in central, south-western and Mandi region became unsustainable with index falling from 0.68 in 1970 to 0.49 in

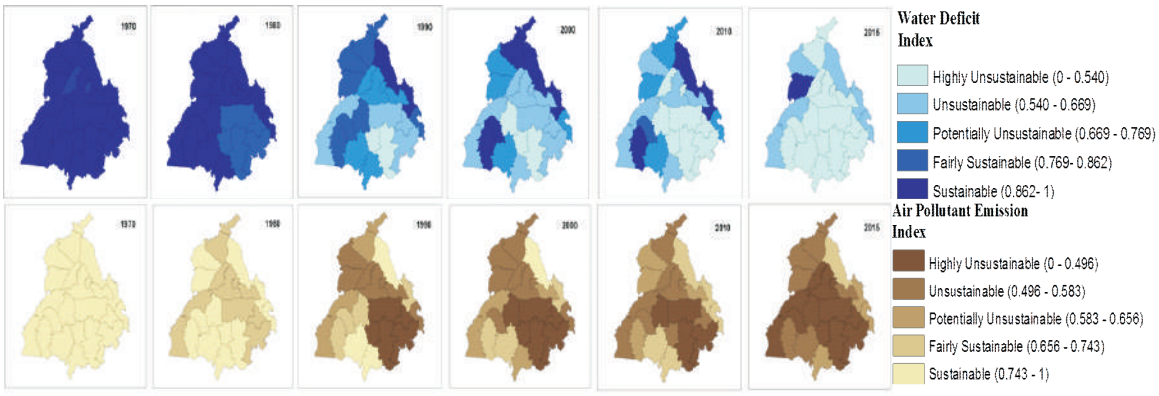


Fig. 2. Indices of water deficit and air pollution

2015 (Figure 3). Analysis of five decades depicts the march towards highly unsustainable resource use affecting the sustainability of agricultural systems. The index directly points the need for a greater focus on addressing the sustainability issues in the districtsof Ludhiana, Amritsar, Kapurthala, Jalandhar, Moga, Sangrur, Firozpur, Faridkot, Muktsar, Fazilka, Patiala, Gurdaspur and Pathankot.

CONCLUSION

Resource sustainability of Punjab state is critical for the agricultural economy of India. The assessment of resource sustainability reveals that green revolution led to gains in productivity but was practised without adhering to scientific principles, and hence proved to be detrimental to natural resources, which are essential for advancement in productivity. The index reveals the magnitude of damage to land, water and air resources during the last four decades. In 1970s and 1980s, the extent of resource sustainability was low. In 2000s and 2015, the sustainability of resources entered into "overexploitation phase", resulting in rising cost of cultivation, stagnation of productivity and farm income. Moreover, high variability in terms of resource sustainability was visible among the districts. Around 40% of the districts in Punjab were found to be highly unsustainable and therefore, demand greater attention. For improving resource sustainability, a system should be developed for productivity enhancement with improvement in soil, water, biodiversity, atmosphere etc. For this system sustainable agriculture technologies should be developed enhancing resource conservation. Along with technological development, regular monitoring and measurement of resource sustainability is required at micro level such as district and farm level. The resource sustainability is an appropriate tool which can be used for monitoring the sustainability of agriculture systems. It can be used by the policy makers to identify regions which require more stringent actions. For better planning for sustainability, more quantifiable accounting of resources should be done for achieving long term sustainable agriculture.

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Water Use Efficiency of Different Mustard Cultivars under Varying Thermal Conditions in Ludhiana, Punjab

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Abstract: A field study was conducted during two consecutive *rabi* seasons of 2012–13 and 2013–14 to observe the water use efficiency (WUE) of mustard varieties, viz, PBR 91, GSL 1 and Hyolla PAC 401 sown on three dates (D1-25th October, D2-5th November and D3-15thNovember). Three water application treatments were applied as per recommendations of package of practices of *rabi* crops published by PAU, Ludhiana. Water use efficiency of PBR 91was higher in all the three dates of sowing during both *rabi* seasons due higher seed and straw yield. Delayed sowing reduced the yield and yield contributing characters in all the cultivars under all the irrigation levels. Hence, delayed sowing increased the consumptive water use but decreased the water use efficiency of all the cultivars. The coefficient of determination for seed yield, straw yield and heat use efficiency was 78 , 84 and 64 per cent, respectively during rabi season 2013–14 and 92, 94 and 46 per cent, respectively during rabi season 2014–15 when water use efficiency was regressed against these. The relationship was observed to be fairly positive during both the *rabi* seasons.

Keywords: Water use efficiency, Mustard crop, Irrigation, Regression

Water is essential for crop production because plants require water for growth and tissue expansion. However, over 90 per cent of the water required by terrestrial plants is not 'used' in any biochemical way but lost through transpiration. (Morison et al 2008). Water use of a crop, with adequate available soil water supply, is primarily affected by its canopy and weather conditions (Suyker and Verma 2010). Water is becoming scarce in the semi-arid areas due to rapid urbanization and industrialization (Chakraborthy et al 2008). Water deficit is a major limiting factor for crop production in the world. Under such constraints, emphasis needs to be focused on increasing water use efficiency (WUE) of the crops. This can be possible through proper irrigation scheduling, i.e., by providing the water as per the crop evapo-transpiration requirements and at critical growth stages (Wang et al 2001, Norwood and Dumler 2002 and Kar et al 2005).The concept of crop water use efficiency (WUE), determined by the ratio between the marketable yield and the seasonal values of actual evapotranspiration, has become a suitable tool for analysing the strategies that allow attaining the best use of water in agriculture.

Rapeseed-mustard crop is sensitive to water shortage. A substantial rapeseed-mustard area in Rajasthan (82.3%), Gujarat (98%), Haryana (75.6%), and Punjab (92.4%) is covered under irrigation. A positive effect of irrigating rapeseed-mustard at critical stages is observed. Water use efficiency was highest when irrigation was applied at 0.8 IW:CPE ratio and increased with increasing N rate (Pandey et al 2004, Parihar 2001). Number of irrigations is important for working out the most efficient water use by mustard. Kar et al (2007) observed a significant increase in water use efficiency of mustard by increasing irrigations from two to three. Oilseed crops are next to cereals in the agricultural economy of India being less water requiring and important source of fats and proteins. The present study was undertaken to evaluate the water productivity of mustard varieties under different sowing dates.

MATERIAL AND METHODS

The field experiment was conducted at Punjab Agricultural University, Ludhiana during *Rabi* 2013-14 and 2014-15. Ludhiana is situated at 30˚54′N latitude, 75˚48′E longitude and at an elevation of 247m above m.s.l. and has semi-arid climate with hot summer and mild winter seasons. The soil of the experimental field was sandy loam in texture. Three varieties namely PBR 91, GSL 1 and Hyolla PAC 401 were sown under three dates of sowing (25th October, 5th November and 15th November) during 2013-14 and 2014-15. The irrigation and fertilizer dose was applied as per the recommendation of package of practices provided by PAU, Ludhiana. The crop received nutrients @40 kg N/ha and 12 kg P2O5/ha. Half of nitrogen and full amount of phosphorus was applied as a basal dose while the remaining half of nitrogen was applied 30 days after sowing.

To compute soil water use by the crop, the difference in soil water retention for the two successive samplings was taken as soil water use by the crop, assuming that no deep drainage (or percolation) occurred below the root zone. From the date of irrigation to the day of next soil moisture sampling, the daily rate of actual pan evaporation was considered. The crop consumptive use was calculated by adding the value of consumptive use of all the crop life cycle interval formula:

$$CU_j = 0.6 \text{ or } 0.8$$

$$\sum_{k=1}^{N} Ek + \sum_{i-1}^{n} \frac{M_i - M_{ii}}{100} \times ASi \times Di + E_{RF}$$

$$CU = \sum_{j=1}^{N} CU_j$$

CU = Consumptive use of water or seasonal Et_a (cm)

ΣCU_j = Summation of consumptive use of water (cm) of n number of crop growth intervals when j is equal to i^{th} growth interval

$\sum_{K=1}^{N} Ek$ = Summation of actual open pan evaporation for N number of irrigation days i.e. between the days of sampling before and after k^{th} irrigation

$\sum_{i-1}^{n} \frac{M_i - M_{ii}}{100}$ = Moisture percent on dry weight basis before and after irrigation application in i^{th} layer of soil profile

ASi = Apparent specific gravity of i^{th} layer of soil profile

Di = Depth of i^{th} layer of soil (cm)

E_{RF} = Effective rainfall (cm) in the j^{th} growth interval

0. 6 = Constant for the cooler months (Nov-Feb)

0.7 = Constant for months (March-April and Sept-Oct)

The water use efficiency for seed yield or straw yield was calculated as seed or straw yield (kg/ha) /total water use (mm) .

Biometric Parameters

Seed yield: The gross plot size was 8 × 6m^2, from which the net plot area of size 7.5 × 5m^2 was harvested or biomass to exclude the border row error. Total seed yield from each of the net plot was recorded after sun drying and threshing of produce and expressed in kg/ha and straw yield (kg/ha) was calculated by the formula:

Straw yield = Total weight of harvested material – Seed weight from each plot

Heat use efficiency: The heat use efficiency was calculated by using the following formula:

$$\text{Heat Use Efficiency (kg/ha/°C days)} = \frac{\text{Grain or dry matter yield (kg/ha)}}{\text{AGDD (°C days)}}$$

AGDD = Accumulated growing degree days

RESULTS AND DISCUSSION

During 1st date of sowing the variety Hyolla PAC 401 higher water use (336 mm) followed by PBR 91 (Table 1). But during 2nd and 3rd date of sowing (5th r and 15th November, respectively) the water use was higher for GSL 1 followed by PBR 91 and then Hyolla PAC 401 during *rabi* season 2013-14. Similar trend was during *rabi* season 2014-15. The average water use was higher under15th November sowing and variety GSL1 i.e. 350.4 mm and 368.9 mm during *rabi* season 2013-14 and 2014-15, respectively. The variety PBR 91 had higher water use efficiency for seed and straw (6.7 and 21.2 kg/ha/mm, respectively) as compared to the GSL 1 and Hyolla PAC 401 under 25th October sowing during *rabi* season 2013-14. During *rabi* season 2014-15, the water use efficiency was again higher for PBR 91 (seed: 4.2 kg/ha/mm and straw: 14.5 kg/ha/mm) (Table 2) but it was lower as compared to *rabi* season 2013-14 due to reduction in seed and straw yield because of aberrant weather conditions. During and 5th December 15th November sowing the straw water use efficiency was higher for variety Hyolla PAC 401 as compared to PBR91 and GSL1 during the *rabi* season 2013-14 and during *rabi* season 2014-15, it was higher for PBR 91 (Table 3, 4) whereas PBR91 had higher seed water use efficiency under all the three dates of sowing during *rabi* season 2013-14 and 2014-15. Tesfamariam et al (2010) observed that well watered control gave highest value of water use and seed yield. Similar results were observed by Kingra et al (2012). The water use efficiency was higher under the conditions where higher yield was produced indicating the best utilization of available moisture from the soil profile, while the minimum values of efficiency was found where less yield was produced.

Table 1. Total water use by mustard crop under three dates of sowing during *Rabi* season 2013-14 and 2014-15

Variety	Total Water Use			Mean
	D1	D2	D3	
Rabi season 2013-14				
PBR 91	309.0	397.3	341.8	349.4
GSL 1	308.0	402.3	340.8	350.4
Hyolla PAC 401	336.1	331.3	252.0	306.5
Mean	317.7	377.0	311.5	
Rabi season 2014-15				
PBR 91	312.3	387.0	376.3	358.5
GSL 1	326.2	408.0	372.6	368.9
Hyolla PAC 401	332.9	371.4	312.7	339.0
Mean	323.8	388.8	353.9	

Regression analyses: The water use efficiency (kg/ha/mm) was regressed against seed yield (kg/ha), straw yield (kg/ha) and heat use efficiency (kg/ha/˚C days) during *rabi* season 2013–14 and 2014–15 (Fig. 1-6). The coefficient of determination (R^2) explained 78 and 94 percent variability between water use efficiency and seed yield during *rabi* season 2013–14 and 2014–15, respectively. Similarly, the coefficient of determination explained variability between straw yield and water use efficiency as 84 per cent during 2013–14 and 92 per cent during 2014–15. When water use efficiency was regressed against heat use efficiency, the variability was 64% and 46% as explained by coefficient of determination during *rabi* season 2013–14 and 2014–15, respectively. There was strong positive relationship between water use efficiency and seed and straw yield during 2013–14 and 2014–15. The relationship was fair and positive between water use efficiency and heat use efficiency as observed during *rabi* season 2013–14 but during *rabi* season 2014–15, the relationship was observed to be positive but not enough strong.

Table 2. Water use efficiency of mustard crop under 1st date of sowing (25th October) during *Rabi* season 2013–14 and 2014–15

Crop variety	Total water use	Yield		Water Use efficiency (kg/ha/mm)	
		Seed (kg/ha)	Straw (kg/ha)	Seed	Straw
Rabi season 2013–14					
PBR 91	309.0	2061.3	6561.4	6.7	21.2
GSL 1	308.0	1810.0	4483.8	5.9	14.6
Hyolla PAC 401	336.1	1800.0	5562.7	5.4	16.6
Rabi season 2013–14					
PBR 91	312.3	1301.2	4541.3	4.2	14.5
GSL 1	326.2	1020.4	3114.1	3.1	9.5
Hyolla PAC 401	332.9	934.4	3583.9	2.8	10.8

Table 3. Water use efficiency of mustard crop under 2nd date of sowing (5th November) during *Rabi* season 2013–14 and 2014–15

Crop variety	Total water use	Yield		Water Use efficiency (kg/ha/mm)	
		Seed (kg/ha)	Straw (kg/ha)	Seed	Straw
Rabi season 2013–14					
PBR 91	397.3	1921.7	4863.2	4.8	12.2
GSL 1	402.3	1509.0	3058.4	3.8	7.6
Hyolla PAC 401	331.3	1497.9	4623.4	4.5	14.0
Rabi season 2013–14					
PBR 91	324.0	948.1	3884.5	2.9	12.0
GSL 1	379.1	787.7	2685.6	2.1	7.1
Hyolla PAC 401	311.9	717.5	2886.4	2.3	9.3

Table 4. Water use efficiency of mustard crop under 3rd date of sowing (15th November) during *Rabi* season 2013–14 and 2014–15

Crop variety	Total water use	Yield		Water Use efficiency (kg/ha/mm)	
		Seed (kg/ha)	Straw (kg/ha)	Seed	Straw
Rabi season 2013–14					
PBR 91	341.8	1296.2	3725.1	3.8	10.9
GSL 1	340.8	1021.5	3388.3	3.0	9.9
Hyolla PAC 401	252.0	918.3	2946.1	3.6	11.7
Rabi season 2013–14					
PBR 91	376.3	846.7	3675.8	2.2	9.8
GSL 1	390.2	686.7	2451.4	1.8	6.3
Hyolla PAC 401	322.7	650.0	2685.6	2.0	8.3

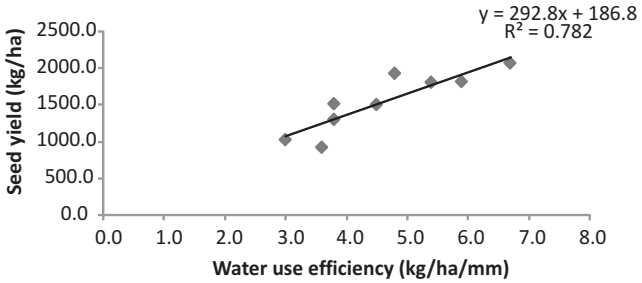

Fig. 1. Relationship between seed yield and water use efficiency of mustard crop during *rabi* season 2013–14

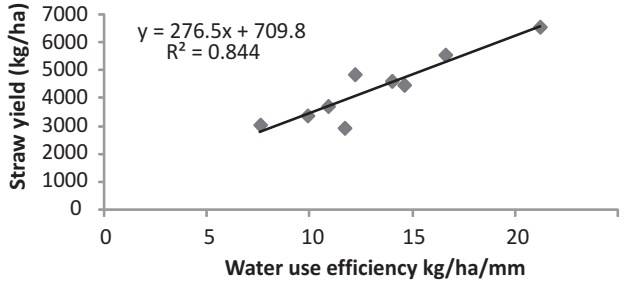

Fig. 2. Relationship between straw yield and water use efficiency of mustard crop during *rabi* season 2013–14

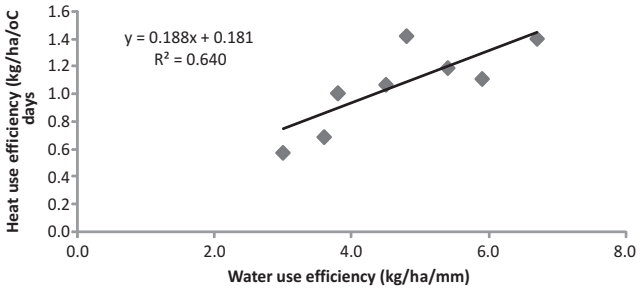

Fig. 3. Relationship between heat use efficiency and water use efficiency of mustard crop during *rabi* season 2013–14

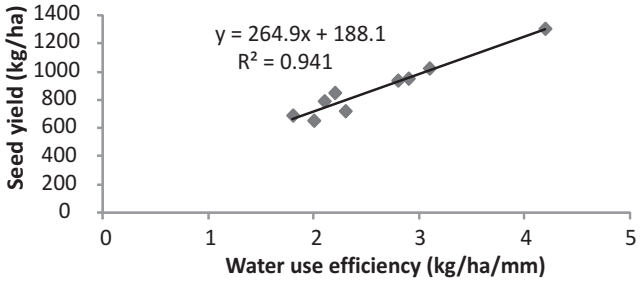

Fig. 4. Relationship between seed yield and water use efficiency of mustard crop during *rabi* season 2014–15

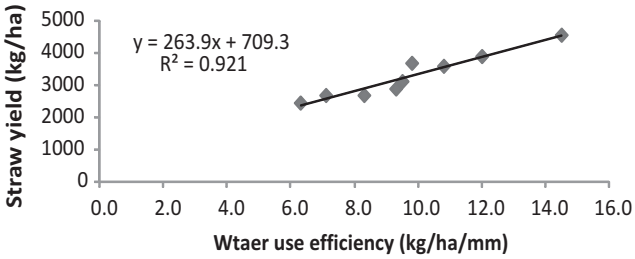

Fig. 5. Relationship between straw yield and water use efficiency of mustard crop during *rabi* season 2014–15

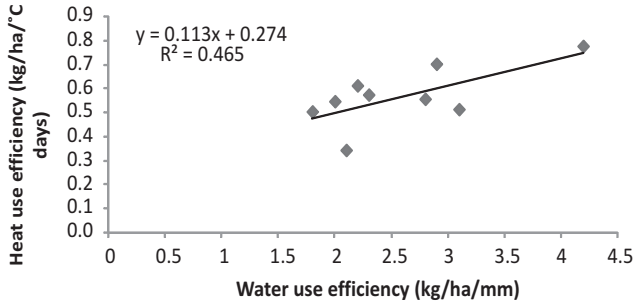

Fig. 6. Relationship between heat use efficiency and water use efficiency of mustard crop during *rabi* season 2014–15

Thus, it can be concluded that normal sown crop (25th October) exhibits higher water use efficiency under varieties PBR 91, GSL 1 and Hyolla PAC 401 as compared to the delayed sowing dates. Among varieties, PBR 91 had higher water use efficiency for seed under 25th October under both *rabi* season 2013–14 and 2014–15 followed by GSL 1 and Hyolla PAC 401. During 5th and 15th November sowing seed water use efficiency was somewhat more for GSL 1 than Hyolla PAC 401. Delayed sowing reduced the yield and yield contributing characters in all the varieties. Hence, delayed sowing increased the consumptive water use but decreased the water use efficiency of all the varieties. Water use efficiency during *rabi* season 2014–15 was lower as compared to *rabi* season 2013–14 because of aberrant weather at the time of maturity. Rainfall increased the total water use but reduced the water use efficiency due to decrease in seed and straw yield of mustard crop. The relationship between water use efficiency and seed and straw yield was also observed to be fairly positive during both *rabi* seasons (2013–14 and 2014–15).

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Isolation and Identification of Extremely Halophilic Bacteria Producing Extracellular Hydrolyses from Khur

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Abstract: The present study aims to isolate and identify extremely halophilic bacteria producing extracellular hydrolyses from Khur salt lake, Iran. Soil samples taken from different parts of the lake were cultivated in 20% (W/V) NaCl culture medium. In order to purify the strains, after colony growth and appearance, pure cultures were collected from single colonies. Bacterial screening led to the identification of 12 extremely halophilic bacteria. Four strains have the potential to produce a variety of extracellular hydrolytic enzymes. Most produced enzymes were related to gram-positive Amylase, Cellulase and DNase enzymes and the least amount of enzymes produced by Lipase and Protease, were grown at temperatures ranging from 34-37˚C and pH 7. Four selected strains were identified and sequenced in terms of phylogeny and molecular characteristics. The studied strains were among the gram-positive bacteria belonging to the *Firmicutes* phylum, *Bacilli* order, *Halobacillus* and *Thalassobacillus* genus and showed the highest enzyme diversity in this study. Consequently, these strains, with their various hydrolytic activities, have a high potential to be used for biotechnological purposes.

Keywords: Biodiversity, Extremely halophilic bacteria, Hydrolytic enzymes

Iran has different saline environments, such as hypersaline lakes, where microbial diversity and potential for producing various hydrolytic enzymes is unknown. These environments are divided into two parts of saline water and soil, including mines, deserts, seas, lakes, lagoons, and salt rivers. Salt lakes contain more than 3 percent salt of different bacteria that have been developed in order to maintain their structure and function in accordance with salinity condition in these environments. Such bacteria are of high importance and widely used in the production of compounds such as extracellular enzymes (Rodriguez-Valera 2003, Margesin and Schinner 2001). Halophilic microorganisms are found as bacteria, eukaryotes and arches in the environment. One of the important characteristics of halophilic bacteria is growth in salt-rich environments with the minimum contamination risk. Other features of these organisms are simple food need, the use of different compounds as a source of carbon and energy, conversion and biological purification of metal compounds in natural environments, etc., (Nichaus et al 1999, Ventosa et al 1998). Extremely halophilic bacteria can be grown in a 20 per cent salinity environment, isolated from very salty and highly alkaline seas, which can produce hydrolytic enzymes such as Amylase, Protease, Cellulase, DNase, Lipase, etc and they can also act at high salt concentration, high temperature and high pH (Gomez and Steiner 2004).

Enzymes isolated from extremely halophilic bacteria can be applied to food supplements, animal feeds, textile industries, detergents for dry cleaning, leather production, etc. (Mellado and Ventosa 2003, Birbir and Ilgaz 1996). Soil-rich environments have been widely distributed in salt lakes, salt lagoons, and so on, which are good sources of salt and potash and baking soda. The Great Lakes in Utah, Playa, and Saline Spring created from underground saline sedimentation are the examples of hypersaline environments in the world with a variety of microbial cells and a source of enzymes adaptable to various salt and pH concentrations (Noroozi et al 2017). Salt environments have high osmotic powers and microorganisms must be able to accept osmolality changes. Preserving the survival of halophilic microorganisms is the accumulation of low molecular-weight water soluble compounds to prevent the harmful effects of salinity on cellular physiology and the loss of water from these bacteria in salt environments. Amongst the investigations carried out on the hyprsaline environments of Iran can point out to study of biodiversity and the production of hydrolytic enzymes of halophilic microorganisms cultivated in the western coast of Lake Urmia, seasonal lake of Houz-Soltan, salt lake of Aran and Bidgol, Bakhtegan lake in western Neyriz and Inche Brun hypersaline lagoon. The principal objective of this research is to investigate a hypersaline ecosystem (Khur salt lake) in

terms of the diversity of halophilic microorganisms and identification of the ability of extremely halophilic microorganisms in the production of extracellular hydrolytic enzymes. Also, availability of species and new gender is studied to add to the country's reserves in order to have a rich microbial and bacterial bank and no need to buy strains from outside the country.

MATERIAL AND METHODS

Firstly, soil samples were taken from Khur salt lake, located in Khur City and Biabanak county of Isfahan Province, one of the largest salt lakes stretched between the central to the southern central desert of Iran. The geographical location of this lake is E5515 to E5615 and N3330 to N3430 in Isfahan Province, which is the largest seasonal salt lake. The height of the lake is 707 m from sea level and is considered to be the lowest point in the Iranian plateau. Unlike other salt lakes, the depth of salt in the central Iranian plateau is very thin and varies from 5 cm to 10 meters due to difference of the permanent movement of in groundwater saline aquifers and black sludge of the golden layers that prevents formation and concentration of salt platforms (Youssef et al 2012).

Isolation of microorganisms and growth conditions: At first step, after preparation of samples from the studied area, initial experiments were carried out after specimens were transferred to the laboratory and pH was measured. Samples were cultured in broth medium with a total concentration of 20% of all salt types including (g/L) NaCl 162, $MgSO_4.7H_2O$ 19.4, $MgCl_2.H_2O$ 14.0, $CaCl_2$ 7.2, KCl 4.0, NaHCO3 0.12, NaBr 0.052. The pH of the culture medium was adjusted to 7 before autoclaving and then the environments were incubated at 34˚C in an orbital shaker 150 rev min for 3 to 7 days or more, dependent to isolates isolation process. Then the solid medium was prepared by adding 12 to 15 grams of agar (Merck) (Amoozegar et al 2008). In order to purify the strains, after colony growth and appearance, even single−colonies were cultured pure in the agar nitrite medium, and was repeated sequentially. To confirm the pureness of the colonies, distinguish and investigate their morphology, gram staining was carried out. Hot spotting and observation with an optical lens of 100 light microscopes were performed. All isolates were studied in terms of the colonies′ shape and characteristics, warm reaction, microscopic shape of the cells, and the position of spores. The catalase activity was positive by bubble generation in a solution of 3% hydrogen peroxide and oxidizing activity was determined by oxidizing p-amino−1-dimethylalanine oxalate and the use of oxidase disks.

Strain screening for extracellular hydrolytic activity: At this stage, the detection of extracellular hydrolysis was performed by measuring on plates containing agar and various enzymes. pH of all environments was adjusted to 7 and 20% of the total salt was added to the extremely halophilic bacteria to detect hydrolytic activity.

Determining the activity of extracellular amylase: The presence of Amylase activity on the plates was investigated using a starch agar medium (Merck) containing 20% total salt. The specimens were incubated at 37−34˚C for one week. The plates were then coated with 0.3% I2-0.6% KI solution. A bright area around the colony represents starch hydrolysis (Amoozegar et al 2008).

Determining the activity of cellular protease: To investigate the proteolytic activity of skim milk agar, 10% skim milk and 2% agar plus 20% total salt were used to determine the hydrolytic activity of absolute halophilia. A clear halo around the colony after a week showed proteolytic activity (Amoozegar et al 2008).

Determining the activity of extracellular lipase: In order to observe the production of Lipase , the strains were cultured on aqueous nitrate plates containing 2.5% olive oil and victoria blue (0.4 mg/L), and the appropriate concentration of salt and initial pH 7; and the plates was incubated at 37 ˚C for 48 hours. Colonies with a blue halo of strains producing specific Lipase were considered (Samad et al 1989, Martin et al 2003).

Determining the activity of extracellular DNase: Active DNase strains were detected using 42 g/L DNase test agar medium (Merck) plus 20% total salt. After incubation at 37 ˚C for one week, the plates were covered with a 1 N HCl solution. The bright halo around the colony represents the activity of DNase (Onishi et al 1983).

Determining the activity of extracellular cellulase: Cellulase activity in a solid culture medium containing carboxy methyl cellulose (CMC), KCl 1 gl_i, gl_i15 agar 1 gl_i1, NaNO3 1 gL_i1, K2HPO4 2 gl_i1, MgSO4 0.5 gl_i1, yeast extract 0.5 gl_i 1, glucose 1 gl_i1 and 20% total salt was performed. After incubation at 37 ˚C for one week, the plates were coated with a 0.1% concave solution. The bright halo around the colony showed Cellulase activity (Zhou and Li 2004).

Identification of strains: The study of morphological and physiological characteristics of isolated strains was also performed on broth nitrite or agar nitrate with 20% sodium chloride salt by Smibert and Krieg method (Smibert and Krieg 1994). Many strains were selected randomly due to the production of extracellular hydrolytic enzymes. The DNA genes of these strains were extracted by Extraction Kit (Bioneer, South Korea), according to their manufacturers′ recommendations. The 16S rRNA gene using the universal primers 8 F (5-AGAGTTTGATCCTGGCTCAG-3) and 1492R

(5-CACGGAT CCTACGGGTACCTTGTTACGACTT- 3) strengthened. One PCR cycler (Biometra) was used for boosting. The replication reaction took place in a final volume of 25 liters (Rohban et al 2009).

Following the conditions used to amplify the 16S rRNA gene, 40 cycles of 94 degrees for 35 seconds, 50 degrees for 30 seconds, 72 degrees for 1.5 minutes, with the final 10 minutes at 72 degrees, were developed. PCR products were examined on agarose gel using Etidium bromide staining. Pure PCR products were performed using a purification kit (Bioneer, South Korea). The pure PCR product was sequenced in both directions using an automated sequencer by Seq Lab (Germany). The phylogenic association of isolates was determined by comparing sequencing data related to the 16S rRNA gene sequence in the National Center for Genetic Bank Database for bioinformatics data through BLAST search.

Phylogenic analysis using MEGA version 5 software was done by CLUSTAL_X after obtaining balanced levels of available information from public databases (Thompson et al 1997). The evolutionary two by two distances was calculated using the correction method and the clusters were carried out using the neighbor-joining method (Saitou and Nei 1987). The validity of the tree branches was evaluated using the Bootstrap analysis algorithm with 1000 times sampling (Felsenstein 1985).

RESULTS AND DISCUSSION

Isolation of bacterial strains from Khur Salt Lake: Twelve strains were separated from the studied lake, all of which were part of extremely halophilic bacteria.

Investigating the activities of hydrolytic enzymes: Purified strains were investigated for hydrolytic enzymes activity. Hydrolytic activity of positive tests of extracellular enzymes in isolated strains is shown in (Fig. 1).

A total of 7, 5, 4.8 and 6 isolates were able to produce DNase, Cellulase, Amylase, Lipase and Protease, respectively. 2 strains were also found in a mixture of 5 hydrolytic enzymes. A strain comparison based on the ability to produce various enzymes is shown in (Table 1).

PCR results: The PCR process was carried out at RENA's Biotechnology Company. Then, the extracted genome was evaluated by electrophoresis. The 16S rRNA gene was replicated. Primers with a length of 1500 were nucleotides.

Table 1. Hydrolytic activity of isolated strains

Strains	Protease	Lipase	Amylase	Cellulase	DNase
S_1	+	+	+	+	+
S_2	+	–	+	+	+
S_3	+	+	+	+	+
S_4	–	–	+	–	–
S_5	+	–	–	–	–
S_6	–	–	+	–	+
S_7	–	–	+	–	–
S_8	+	–	–	–	+
S_{10}	+	–	–	–	–
S_{12}	–	+	+	+	+

Phylogenetic studies of selected strains: Based on the sequencing of 16S rRNA, the examined isolates belonged to *Firmicutes* phylum, *Bacilli* order and include *Halobacillus* and *Thalassobacillus* genus, with 98-96% similarity between species and strains belonging to this genus. It demonstrates a significant difference in species level with that species known in these genus and may be considered in new species. The phylogenetic tree of the strains is plotted using the Neighbor joining algorithm and is shown in (Fig. 2).

Extremely halophilic bacteria have high potential to be used for biotechnology and nanotechnology purposes, producing industrial compounds such as enzymes, polymers, pigments, etc., with specific physiological characteristics (Kaye and Baross 2004). Of the environmental factors affecting the growth of halophilic bacteria we can refer to temperature of the culture medium, which has a significant effect on growth and classification of the bacteria to halophilic and salt-tolerant bacteria (Margesin and Schinner 2001, Ventosa et al 1998). Many extremely halophilic bacteria have extracellular hydrolytic enzymes such as Amylases, Proteases, Lipase, DNases, Pulpulanases, Xylanases, Chitinases, Inulinases, and Cellulases that are highly applicable in various processes and industries such as food industries, food additives,

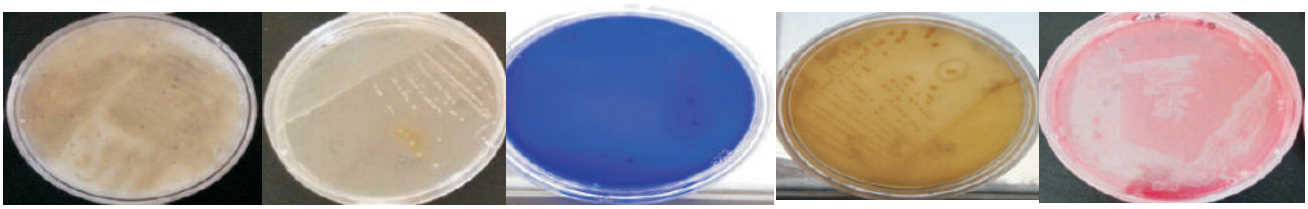

Fig. 1. Positive tests for hydrolytic enzymes in isolated strains

chemical industries, and medical sciences. Also, enzymes that show optimal activity in difficult industrial condition such as temperature and salts are very important and have high salt-saturated coatings that are likely required to maintain their catalytic activity in the environments with low active water. Also, halophilic microorganisms are considered a possible source of these enzymes.

Halophilic bacteria have physiological and genetic properties for success in hypersaline environments. These features include compatibility with indoor environments, efficient ion pumps, UV absorbing pigments and acid proteins that help resistance against osmotic stress and the effects of salt shrinkage combined with intense sunlight. Although, nowadays, halophilia applications limit the main constraint for solvents in cosmetics industries, beta-carotene and hydrolysis in nutrition and food industries, many new applications are in development. They include specialized programs for bacteriophodos in films of halophilia for a variety of optical nanoscale instruments, including high-capacity computer storage and for sustainable enzymes for use as industrial catalysts, some of the ability to work in organic solvents. The metabolic activities of halophilia are also used for various environmental programs, such as the protection of contaminated waste in saline sewage. Some sub-cellular components, such as polyhydroxyalkaloic granules and phasolipids, and bioactive compounds such as halocin, are designed for medical applications. Halophilic microorganisms′ uses are diverse and have significant commercial opportunities in the chemical, environmental, biofuel, medical and educational industries (Das sarma et al 2010).

Studies similar to the study conducted by (Sanchez Porro et al 2003) revealed the prevalence of 5 hydrolytic enzymes including Amylase, Protease, Lipase, DNase and Polulanase in moderately halophilic bacterial in saline ponds in Spain. Besides, (Zavaleta and Cardenas-Fernandez 2007) showed the genetic diversity of 18 moderately halophilic bacteria producing 3 hydrolytic Amylase, Protease and Lipase enzymes from Pilluana saline waters in Peru, and (Moreno et al 2007) demonstrated the biodiversity of mandatory halophilic bacteria producing 4 hydrolytic enzymes such as Amylase, Protease, Lipase and DNase in saline habitats, in Spain. The specificity of this study, compared to recent works, is that firstly it shows the prevalence of 5 extracellular hydrolytic enzymes (Amylase, Protease, Lipase, DNase, carboxymethyl Cellulase) in the extremely halophilic bacteria in Khur salt lake (the highest amount of produced enzymes were related to Amylase, Cellulase, and DNase in gram-positive *bacilli* and the lowest amount of produced enzymes were related to Lipase and Protease). Secondly, the ecological studies in saline water of Khur salt lake resulted in isolation and identification of some of the extremely halophilic bacteria with an ability to produce a mixture of these enzymes. The obtained strains are considered valuable and can be used for biotechnological purposes, since no study has been carried out on the

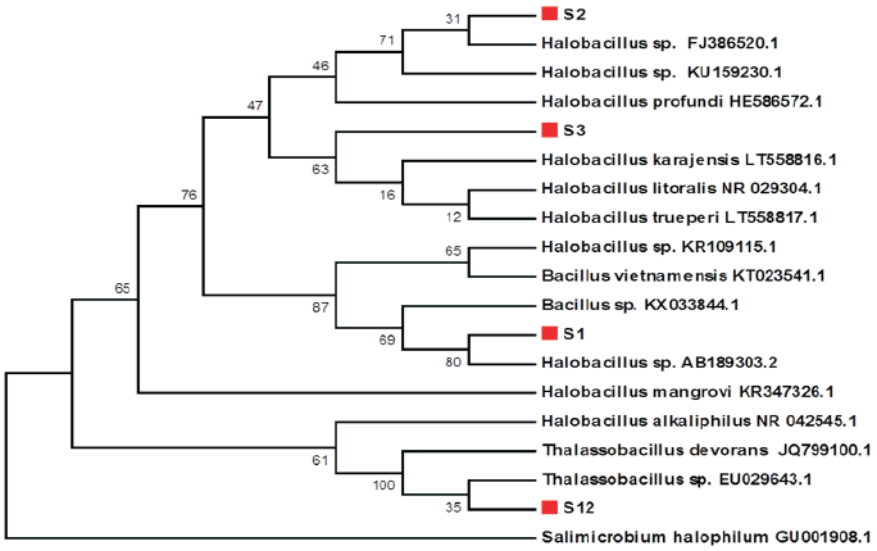

Fig. 2. Neighbor-joining tree for 16s rRNA sequences of Extremely Halophilic Bacteria Producing Extracellular Hydrolyses (hyper saline lake) in Iran and reference strains. The numbers at branching points are bootstrap values based on 1000 replicates. The out group in the tree is the sequence of *Salimicrobium haliphilum,* Bar, 0.05 substitutions per nucleotide position

extremely halophilic bacteria in the study area so far.

Four selected strains, in addition to phenotypic traits, were identified and sequenced in terms of phylogeny and molecular characteristics by the 16S rRNA technique, which included gram positive bacteria belonging to the *Halobacillus* and *Thalassobacillus* genus. In general, among the halophilic bacteria in terms of enzymes diversity and abundance of enzymes production is gram positive *bacillus*. Based on the results of the present study, most of the gram positive environmental isolates producing hydrolytic enzymes belong to the *Halobacillus* genus. In another study conducted by (Sanchez Porro 2003) on saline areas in southern Spain, no strain was isolated from the mentioned genus and some strains were isolated from *Salinivibrio* genus, while, in this study, no strain was isolated from this genus. This could be attributed to higher concentration of salts in the Khur salt lake. This bacterium has optimum growth in 2.5‒10% NaCl and the maximum concentration in which it can grow is up to 17% NaCl, whereas the salt concentration in the studied salt lake is much higher and reaches 20% salt. (Sanchez Porro 2003), isolated strains of *Chromohalobacter* genus in their screening, while no strain was isolated from this genus this study. Generally, among the gram‒positive bacteria, *Halobacillus* bacteria are predominant and are known to be producers of extracellular hydrolytic enzymes, and most industrial processes use the species belonging to this genus to produce industrial enzymes.

Of the features of halophilic microorganisms are reduced risk of environmental pollution, growth and proliferation in high salt concentrations, simple dietary requirements for evolution, and use of various compounds as a source of carbon and energy compared to other microorganisms. Other types of extreme conditions such as high pH, high or low temperatures, low oxygen availability, pressure and toxicity of metals due to their abilities, biodiversity and biotechnology use of halophilic microorganisms have been interesting for microbiologists. Most of the environmental isolates producing hydrolytic enzymes belonged to the gram‒positive genus were especially from the spore gram‒positive *bacilli*. Results were quite expected due to extreme conditions that predominate in the studied area because of high salt content as an extreme factor.

Comparing the results of the present study and other studies, the researchers found that, in general, the ability to produce a combination of extracellular hydrolytic enzymes in gram‒positive strains belonged to *Firmicutes* phylum, *Bacilli* order and *Halobacillus* and *Thalassobacillus* genus is more evident, so that identification of such strains in various industries is valuable.

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Effect of Silver and Zinc oxide Nanocompound Mixture on Growth and Some Physiological Properties of *Sclerotinia sclerotiorum*

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Abstract: Laboratory experiments were carried out in at Kerbala University, Iraq to study the effect of silver and zinc oxide nanocompound (Ag/ZnO) on the *sclerotinia sclerotiorum* (Lib.) De Bary. A series of experiments were carried out, which included the isolation and diagnosis of *Sclerotinia sclerotiorum*, phenotypic and laboratory, and then molecularly using the polymerase chain reaction technique, using ITS4 , ITS1 (Internal transcribed spacer), and the fungal isolates *S. sclerotiorum* (MMBIRAQ) were recorded for the first time in Iraq National Center for Biotechnology Information (NCBI) under Entry Numbers (MF167296) at GenBank. the highest percentage of genetic similarity was with the isolated from Italy, amounting to 99%, while the more distant isolated was from Canada, accounting to 96%.The mixture between Silver and Zinc oxide nanocompound (Ag/ZnO) was present in the laboratory in terms of 1 nanocompound volume / 50 the volume of the potato dextrose agar solution before solidation). The results showed that Ag/ZnO had a significant effect on the fungal colony diameter in Potato dextrose agar (PDA) after 5 and 12 days of inoculation at 50 µml and the highest volumes. The Ag/ZnO compound caused the disappearance of sclerotia ranging from 25µml to 2 ml. The sclerotia mass was 0.04 g. The effect of Ag/ZnO on biomass of Potato dextrose broth (PDB) was significant at 25µml and the highest volumes. The effect was significant on cell length at 25 µml and the highest volumes, while the thickness was at 50µml. The effects of Ag/ZnO on cell decomposition and destruction were caused by cell wall rupture. The significant difference in the production of oxalic acid was at the volume of 25 µml and the highest volumes. The average number of sclerotia in the subsequent generation was 8.88 sclerotia with a diameter of 0.16 cm.

Keywords: *Sclerotinia sclerotiorum*, Fungal nanotechnology

Sclerotinia sclerotiorum (Lib) De Bary is a plant pathogen that affects more than 400 plant species in different stages of growth (Bolland and Hall 1994) . It is considered that the fungus is difficult to eliminate because of its production of sclerotia that is resistant to inappropriate conditions (Mohammed 2012). The sclerotia can resist drought, heat, fungicides and can remain active. Species belonging to the *Sclerotinia* are closely related to the external appearance and can be distinguished by microscopic examination or by genetic material DNA (Malvarez et al 2007). Polymerase chain reaction (PCR), is characterized by rapid, high resolution and sensitivity (Qin et al 2011). Pesticides are one of the important methods of controlling and managing plant diseases, which are chemical methods used for the elimination of various plant pathogens, but this method has effects due to the continuous use of pesticides, large amounts of them or their products have deteriorated or accumulated in the ecosystem, and not all the applied chemical pesticides reach their targets, but the rest remain in the soil. All-Naser (2006) found that the benomyl pesticide with the recommended concentration or the double concentration had an effect on the fungal groups found in the rhizosphere area of the bean roots, the effect lasted for two weeks for the recommended concentration and three weeks for the multiplier concentration. Nanotechnology has been introduced as an advanced technology based on the study and understanding of nanoscience and basic science with the technological ability to synthesize nanomaterials and control their internal structure by restructuring and arranging atoms and molecules to ensure unique and unique products, so the nanotechnology is one of the most important and in the forefront fields and fields in chemistry, physics, engineering and biology (Fouda 2012). The transformation from micro-particles to nanoparticles occurs in a number of changes in physical properties, the one of this applications is controlling plant pathogens, and it has shown many forms of impact on or against microbes and microscopic organisms (Clement and Jarrett 1994). Silver ion showed a safe control of plant pathogens compared with the pesticides (Park et al 2006). Transgenic nanoparticles have also been used to control pathogens properly compared to fungicides, such as nanoparticles of Ag-SiO_2, which have the inhibitory activity of *Botrytis cinerea* (Yamamoto 2001). Zinc oxide powder showed an inhibitory effect on fungi and bacteria) (Sawai and

Yoshikawa 2004). The aim of this study was to reduce using a conventional chemical pesticide and to reduce pollution.

MATERIAL AND METHODS

Samples Collection: The stems of the infected eggplant plants were collected from farms GPS 32˚47′25.9"N 44˚23′57.5"E based on the phenotypic symptoms and initial diagnosis. The sclerotia were washed with normal water and then sterile by immersing them for 3 minutes with 6% commercial chlorax solution, washed several times with sterile distilled water and dried on sterile filter sheets (Mohammed 2001).

Diagnosis the fungus *S. sclerotiorum* according to method of earlier workers (Khon 19679, Tariq et al 1985, Saharan and Mehta 2008). The DNA was extracted using the Cat No: FAPGK100 extraction kit processed by Taiwan−China Favorgen. DNA purity was determined by applying the following formula described by William and others (1997): DNA purity= the amount of absorbance at wavelength of 260 nm. The amount of absorbance at wavelength of 280 nm. The polymerase chain reaction test (PCM PreMix, Cat. No. K−2012) was conducted by the Korean company Bioneer. The polymerase chain reaction was performed with a volume of 20 microliter and containing 1 microliter of all the frontal initiators (5′− TCCGTAGGTGAACCTGCGG−3′: ITS1) and posterior (5′−TCCTCCGCTTATTGATATGCI−3′: ITS4) . After completing the specimen transfer on gel layer, examine the gel containing the DNA packets under UV trans illumination and take photos. The PCR products were sent to the Korean company Microgen for the determination of the nucleotide sequence and in the front and rear directions of the multiply products of the fungal isolates. The nucleotide sequences are analyzed using the Basic Local Alignment Search Tool (BLAST) to compare the data available at the National Center for Biotechnology Information (NCBI), which belong to the same isolate and internationally recognized.

Cultivate the sclerotia *S. sclerotiorum*: One sclerotia was planted in the middle of a petri dish containing a medium of chloramphenicol 250 mg / L. After five days of incubation at 20 + 2 ˚ C, and before the new sclerotia formed, the dish was divided into cubed pieces for the propagation of fungus on the wheat grain media as described in Mohammed (2001) to produce as many sclerotia as possible.

Preparation of Ag/ZnO: The compound was prepared according to the modified Kunde et al (2016) method. The compound consists of the combination of silver nanoparticles with zinc nanoparticles, as the followings:−

Solution 1: Weight of 29.7 g of zinc nitrate, and add 167 ml of ethanol to zinc nitrate and 2 ml of ethylene chloral to the solution made of zinc and ethanol.

Solution 2: Weight of 4.2 g of silver nitrate and dissolved in 100 ml distilled water.

Solution 3: Add 0.6 ml of HNO3 to 26 mL distilled water Weight of 5 g of Polyvinylpyrrolidone (PVP).

The solution 1 was placed on the magnetic mixer and shaking well, then the solution 3 was added to it with the continues shaking. After that, solution No. 2 was distilled into the solution of 1 + 3, after which 5 g of PVP was added, At 120 ˚ C until obtained a third of the solution. The resulting solution is a stock of nanoparticle. The concentration of Nano-silver is 32.8 mg/ml and the concentration of Nano-zinc oxide is 323 mg/ml, from which the subsequent concentrations are obtained by adding different volumes of 1, 2, 0.7, 0.5, 0.3 and 0.1 ml, 50 µ ml, 25 µ ml to 50 ml from the medium (Table 1).

Attributes studied: *Sclerotinia sclerotiorum* diagnosis using traditional method and molecular properties as well as sequencing of fungi and its registration in the World Genomic Bank was done. The properties of nanoparticles prepared by FTIR Infrared Spectrometer, AFM Atomic Force Microscopy, SEM, Electron Microscope Scanner, U.V. visibale Spectroscopy of Visible and Ultraviolet Radiation Spectroscopy. Ag/Zn Nanocompound are evaluated for the growth of the *sclerotinia sclerotiorum* using different sizes using the following media:

Solid PDA: The following characteristics were studied

The vegetative growth of *Sclerotinia sclerotiorum* in term of diameter of the fungal colony (cm) after 5and 12 days from inoculation, the percentage of inhibition using the equation of Kim and his group (2012). [Inhibition Rate (%) = R-r/ R, R=the growth in the control dish, r= the growth in the treatment], the number and mass (g) of sclerotia grown on PDA after 12 days of inoculation, the Microscopic parameters

Table 1. Concentrations of nanocompound (Ag/Zn) mg / ml) based on the volume used in the medium Concentrations of nanocompound (Ag/Zn) mg / ml) based on the volume used in the medium

Concentration of Nano−compound Ag/Zn) mg / ml)	Volume used in media							
	25 mlµ	50 mlµ	0.1 ml	0.3 ml	0.5 ml	0.7 ml	1 ml	2 ml
Ag	0.820	1.640	3.280	9.800	16.400	22.960	32.800	65.600
ZnO	8.075	16.150	32.300	96.900	161.500	226.100	323.000	646.000

of mycelium treatment with Ag/ZnO after 12 days of inoculation and the vitality of the pathogen produce from Ag/ZnO treated fungus in terms of number and weight of resulting sclerotia .

Liquid PDB: The following characteristics were studied: The mean of fungal biomass (g) after 12 days of inoculation, using the modified Asha et al (2006) and Navale et al (2015), Estimation of oxalic acid produced by fungi in liquid media (mg/l) after 12 days of inoculation (Bateman and Beer (1965).

RESULTS AND DISCUSSION

The fungus is microscopically dependent on the nature and form of sterile mycelium as applied to the taxonomic keys contained in Saharan and Mehta (2008), Tariq and his group (1985) and Kohn (1979). As identified by Mohammed and Almothafer (2013) and ALmasody (2015). The results of DNA extraction of *S. sclerotiorum* isolation and the use of polymerase chain reaction, used internal transcribed spacer (ITS4) and ITS1, showed that it is similar to the same isolates identified by Mohammed and Almothafer (2013) and ALmasody (2015), although the sequence of the prefixes used in the two studies are different, but they are similar to the same isolates (Figure 1).

The fungal isolation was recorded in the name *S. sclerotiorum* MMBIRAQ fungi the first time in Iraq at the National Center for Biotechnology Information (NCBI) under the Accession number MF167296 in GenBank. The results revealed that the isolated *S. sclerotiorum* MMBIRAQ isolated in this study is a new isolation previously unknown in the world. The results of the Nucleotide Sequence Analysis of the amplification DNA bundle and using the BLAST program and comparing them with the data available at the National Center for Biotechnology Information (NCBI), showed that isolating the *S. sclerotiorum*. is the highest genetic resemble isolated from *S. sclerotiorum* isolated from Japan (Accession number: LC318723) of 99%, while the most genetically divergent isolated was from *S. sclerotiorum* isolated from Canada (KF859935: Accession number number) of 96%. Other isolates gave homozygous ratios ranging from 96-99% with isolated *S. sclerotiorum* isolates in this study from Babylon (Figure 2, Table 2).

Ag / ZnO characteristics of prepared compound

By FTIR: The Nano-silver at package 875 after the dissociation of glucose as a result of giving electrons of the material reduces the conversion of silver from ion to metal after taking the electrons and comes the role of the installer to be formed in the form of balls. Note that the package between 703-666 represents the vibration of nanoparticles To demonstrate the composition of nanoparticles on the difference of the reduced factor, silver nanoparticles appear

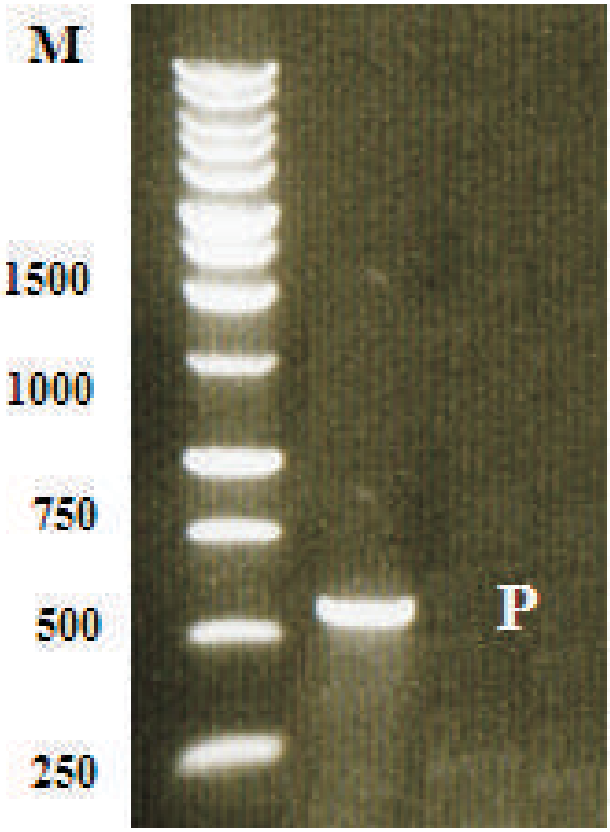

Fig. 1. Electrolysis of Cellulose Gel for DNA Complications by PCR of S. sclerotiorum isolated from Babylon province.
M = DNA ladder marker 1Kpb; P= product

in different sizes and diameters (Sun 2013, Rycenga et al 2011, Sakamoto et al 2009) (Figure 3).

By AFM: The results of the microscopic examination by the atomic force microscope in Fig. 4, show that the obtained compounds are nanoparticles and possess the characteristics of the nanoparticles through the rise of the nanoparticle and its fear. This is shown by the microscopic atomic force, where the heights and sizes of nanoparticles varied according to the reduced factor (Van Hyning and Zukoski1998).

By electron microscope SEM scanner: The electron microscopy shows forms of nanoparticles of different diameters according to the reduced factor (Fig 5). The nanoparticle mix with the zinc oxide is shown in the shape of its silver heart and its zinc form (Ferreira da Silva et al 2011, Rogers et al 2012, Alarcon et al 2012).

Optical and ultraviolet radiation spectroscopy: By examining the resulting nanoparticles with ultraviolet-visible light, Figure 6 appears package locations for nanotubes by the wavelength of maximum absorption. Thus, showing the wavelength of the wavelength of light falling on the surface of nanoparticles with their free electrons orbiting the surface of

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....|....| ....|....| ....|....| ....|....| ....|....|
10         20         30         40         50
CAGAGTTCAT GCCCGAAAGG GTAGACCTCC CACCCTTGTG TATTATTACT
....|....| ....|....| ....|....| ....|....| ....|....|
60         70         80         90         100
TTGTTGCTTT GGCGAGCTGC TCTCCGGGGC CTTGTATGCT CGCCAGAGAA
....|....| ....|....| ....|....| ....|....| ....|....|
110        120        130        140        150
TATCAAAACT CTTTTTATTA ATGTCGGTCT GAGTATTATA TAATAGTTAA
....|....| ....|....| ....|....| ....|....| ....|....|
160        170        180        190        200
AACTTTCAAC AACGGATCTC TTGGTTCTGG CATCGATGAA GAACGCAGCG
....|....| ....|....| ....|....| ....|....| ....|....|
210        220        230        240        250
AAATGCGATA AGTAATGTTG AATTGCAGAA TTCAGTGAAT CATCGAATCT
....|....| ....|....| ....|....| ....|....| ....|....|
260        270        280        290        300
TTGAACGCAC ATTGCGCCCC TTGGTATTCC GGGGGGCATG CCTGTTTGGA
....|....| ....|....| ....|....| ....|....| ....|....|
310        320        330        340        350
GCGTCATTTC AACCCTCAAG CTCAGCTTGG TATTGAGTCC ATGTCATGTA
....|....| ....|....| ....|....| ....|....| ....|....|
360        370        380        390        400
ATGGCAGGCT CTAAAATCAG TGGCGGCGCC GCTGGGTCCT GAACGTAGTA
....|....| ....|....| ....|....| ....|....|
410        420        430        440
ATATCTCTCG TTACAGGTTC TCGGTGTGCT TCTGCCAAAA
```

Fig. 2. The nucleotide sequence of the DNA (PCR-amplified product) from *S. sclerotiorum* isolated from some farms in Babylon province, which is characterized by PCR

the nanoscale to show Plasmon, which turns the metal surface electrons to give a bundle in the ultraviolet light (Kadir et al 2005).

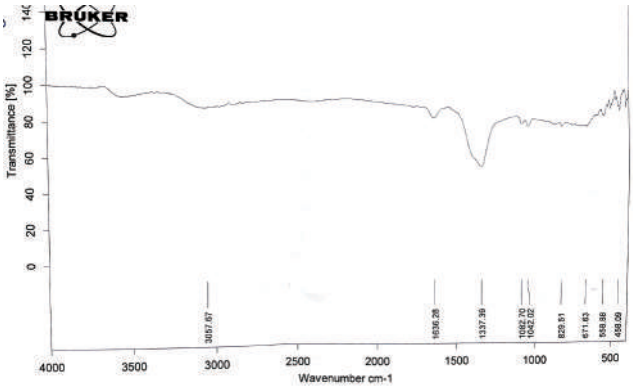


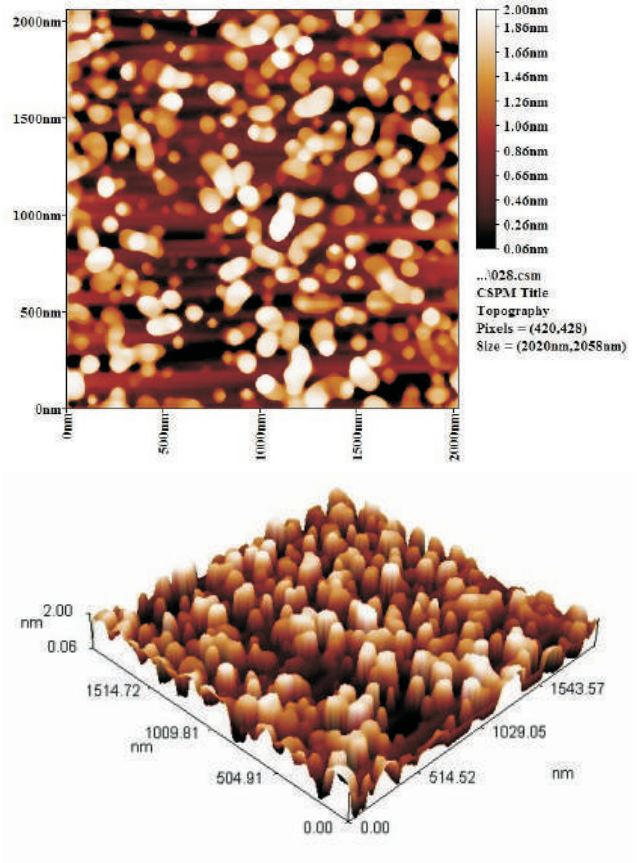
Fig. 3. Ag/ZnO characteristics compound by FTIR

Evaluation of the Ag / ZnO nanocompound on the PDA: The Ag / ZnO nanocompound affected the fungus in terms of growth and phenotypic shape of the fungal colony (Table 3). That the Ag / ZnO nanocompound had a significant effect on the fungal colony diameter. After 5 and 12 days of inoculation at 50 µml the highest volumes, leading to slow and distorted growth (Fig. 7). The shape of the colony in the media was characterized by its distorted shape and uneven growth, as well as irregular and curvilinear edges (Fig. 7). The growth distinguished by 25 µml being close to the control form, 50 µml was a distorted and irregular growth, so at 0.1 ml and 0.3 ml, the spinning form was spread out and far from the PDA. The Ag / ZnO nanocompound compound was not affected by the

Table 2. Comparison of the neoclutidosis ratios of *S.sclerotiorum* isolates from Babylon province and other isolates of the same fungus registered globally at the National Biotechnology Information Center (NCBI)

Fungus	Isolate or strain name	Origin	The most similar sequence in GenBank database	
			GenBank accession	Sequence similarly (%)
S. sclerotiorum	*MMBIRAQ	Iraq	MF167296	100
S. sclerotiorum	MuNi-339	Japan	LC318723	99
S. sclerotiorum	3Sd	Italy	EU627005	99
S. sclerotiorum	SSAG01	India	KT281863	99
S. sclerotiorum	1	Chile	KF148604	99
S. sclerotiorum	CAF-11011	Republic of Korea	KX951645	99
S. sclerotiorum	SS5	USA	KF545319	98
S. sclerotiorum	DB 090720091	Italy	GQ375746	98
S. sclerotiorum	CR 45	Iran	KY694474	98
S. sclerotiorum	SQC-000	China	KY750530	98
S. sclerotiorum	CXL 14041906	China	KX781301	98
S. sclerotiorum	SK-8	China	KJ576850	98
S. sclerotiorum	CBS-537.77	Japan	AB926090	97
S. sclerotiorum	Wb560	Austria	AF455413	97
S. sclerotiorum	F0675	Japan	AB693927	97
S. sclerotiorum	Wb560	Austria	AF455413	96
S. sclerotiorum	–	Canada	KF859934	96
S. sclerotiorum	–	Canada	KF859935	96

* Isolation of *S.sclerotiorum* isolated in this study from a farm in Babylon province



CSPM Imager Surface Roughness Analysis

Image size 2029.63nm x 2058.10nm

Amplitude parameters:
Sa(Roughness Average) 0.488[nm]
Sq(Root Mean Square) 0.565[nm]
Ssk(Surface Skewness) -0.0277
Sku(Surface Kurtosis) 1.83
Sy (Peak-Peak) 1.94[nm]
Sz(Ten Point Height) 1.71[nm]

Hybrid Parameters:
Ssc(mean Summit Curvature) – 0.00225[1/nm]
Sdq(Root Mean Square Slope) 0.0372[1/nm]
Sdr(Surface Area Ratio) 0.0688

Functional Parameters:
Sbi(Surface Bearing Index) 5.63
Sci(Core Fluid Retention Index) 1.48
Svi(Valley Fluid Retention Index) 0.0738
Spk(Reduced Summit Height) 0.167[nm]
Sk(Core Roughness Depth) 1.75 [nm]
Svk(Reduced Valley Depth) o.o532[nm]
Sdc 0-5(0-5% height intervals of Bearing Curve) 0.1[nm]
Sdc 5-10(5-10% height intervals of Bearing Curve) 0.0966[nm]
Sdc 10-50(10-50% height intervals of Bearing Curve) 0.775[nm]
Sdc 50-95(50-95% height intervals of Bearing Curve) 0.968 [nm]

Spatial Parameters :
Sds(Density of Summits) 5.8 [1/um2]

Fractal Dimension 2.58

Fig. 4. Ag / ZnO characteristics of prepared compound by AFM

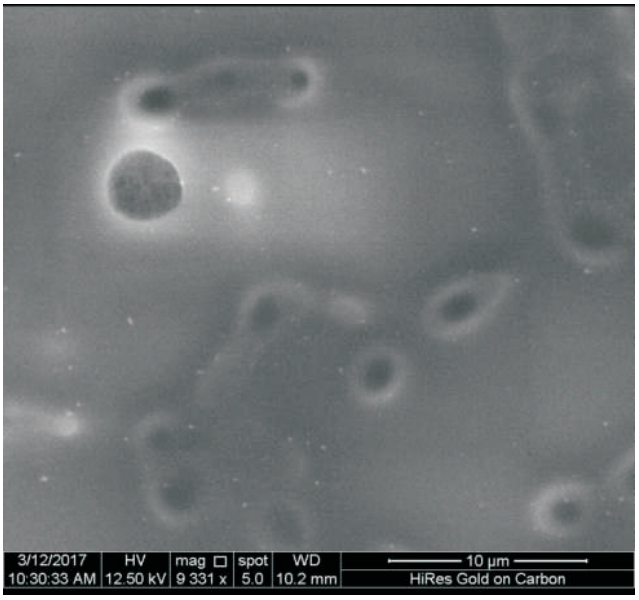


Fig. 5. Ag / ZnO characteristics of prepared compound by SEM scanner

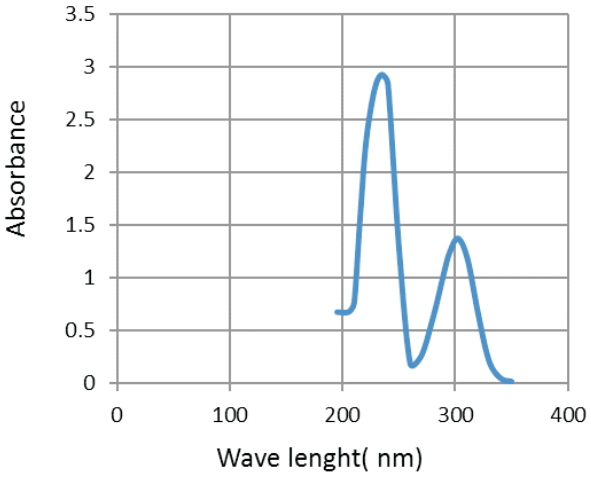


Fig. 6. Ag/ZnO characteristics of prepared compound by means of the optical and ultraviolet radiation spectroscopy U.V. visible

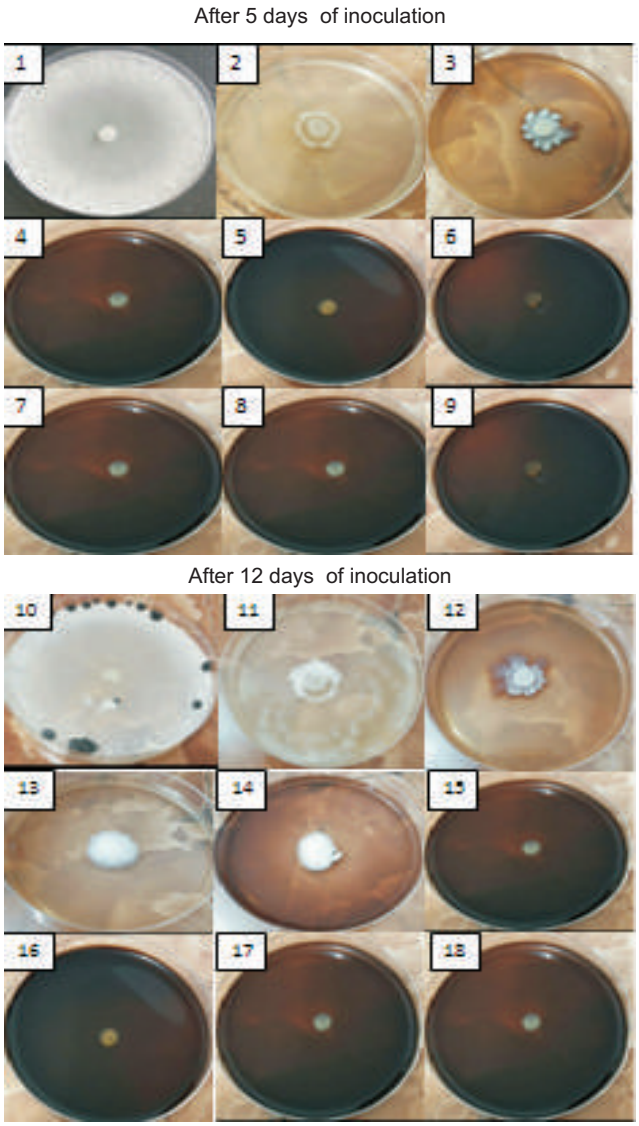


Fig. 7. Effect of different sizes of Ag / ZnO nanocompound on the diameter of fungal colonies(cm) the number and weight of sclerotia at the age of 5 and 12 days of inoculation on the PDA at 20 ± 2 ˚ C

3,12=50 µml 2.11= 25µml 1,10=control
6,15=0.5ml 5,14=0.3ml 4,13=0.1ml
9,18=2ml 8,17=1ml 7,16=0.7ml

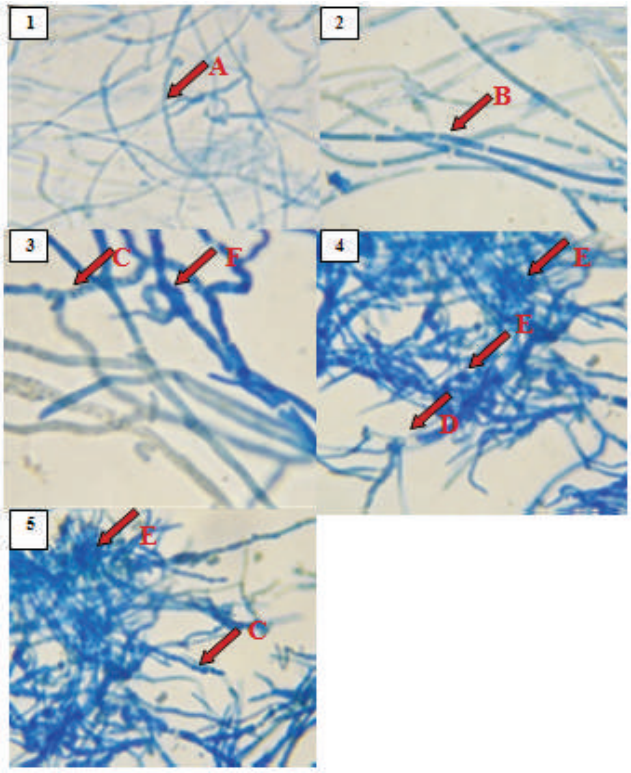


Fig. 8. Effect of different sizes of Ag / ZnO nanocompound on fungal cells after 12 days of Inoculation on the PDA at 20 ± 2 ˚ C (40X)

1= control , 2 = 25µml , 3=50 µml, 4= 0.1ml, 5= 0.3ml.
A= Normal growth, B= Separation of the cellular all and the aggregation of the protoplasm, C= The aggregation of the protoplasm and cell collapse, D = Disintegration in cells, E= The aggregation of the protoplasm and began initiation of sclerotia, F= Cell deformation and path deflection

time, 50 µml in the 5 days and 12 days was not different. The increase in the size of the Ag / ZnO nanocompound increases the inhibition rate (Table 4). This effect may be caused by an increase in the saturation and absorption of nanoparticles by fungal mycelium leading to a decrease in the activity of plant pathogenic fungi due to the effect of silver on microscopic, microorganisms DNA replication ability and inhibition of protein expression by ribosomes and enzymes necessary for energy

Table 3. Effect of different sizes of Ag / ZnO nanocompound on the diameter of fungal colonies (cm) the number and weight of sclerotia at the age of 5 and 12 days of inoculation on the PDA at 20 ± 2 ˚ C

Size of Ag/ZnO Age of the colony (Day)	Control	25µml	50µml	0.1ml	0.3ml	0.5ml	0.7ml	1.0ml	2.0ml	The average
5	9.000	9.000	2.500	1.000	0.000	0.000	0.000	0.000	0.000	2.389
12	9.000	9.000	3.000	2.500	2.000	0.000	0.000	0.000	0.000	2.833
	*(15) **(0.360)	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	
The average	9.000	9.000	2.750	1.750	1.000	0.000	0.000	0.000	0.000	
CD (p=0.05)	Interaction=0.862				Size= 0.609					Days=0.287

Each number represents three replicates
*= Average number of sclerotia
**= Average weight of sclerotia

Table 4. Effect of different sizes of Ag / ZnO nanocompound on the length and width of the mycelium (µm) at the age of 12 days of inoculation on the PDA at 20 ± 2 ˚ C

Volume of Ag/ZnO characteristic study	Control	25µml	50 µml	0.1 ml	0.3ml	0.5ml	0.7ml	1ml	2ml	Average	$LSD_{0.05}$
Average length of hypha (mµ)	80.000	32.500	27.000	10.000	10.000	0.000	0.000	0.000	0.000	17.720	9.34
Average width of hypha (mµ)	2.000	3.000	4.000	2.000	2.000	0.000	0.000	0.000	0.000	1.440	1.139
LSD (0.05)	Length=9.340		Width=1.139								

Each number represents three replicates

Table 5. Effect of different sizes of Ag / ZnO nanocompound on the Average number of Sclerotia and Average diameter of sclerotia (cm) in the subsequent generation at the age of 12 days of inoculation on the PDA at 20 ± 2˚C

Volume of Ag/ZnO characteristic study	Control	25µml	50µml	0.1ml	0.3ml	0.5ml	0.7ml	1.0ml	2.0ml	The average
number of clerotia	15.000	11.000	20.000	13.000	20.000	0.000	0.000	0.000	0.000	8.770
12	0.330	0.300	0.230	0.330	0.300	0.000	0.000	0.000	0.000	0.350
$LSD_{0.05}$	Average number of sclerotia=2.491			Average diameter of = 0.118 sclerotia (cm)						

Each number represents three replicates

Table 6. Effect of different sizes of Ag / ZnO nanocompound on the fungal biomass rate (gm), the number, diameter of the sclerotia (mm), and the rate of oxalic acid (ppm) production at 12 days of inoculation on PDB at 20 ± 2˚ C

Volumes of Ag/ZnO characteristic	Control	25µml	50 µml	0.1 ml	0.3ml	0.5ml	0.7ml	1ml	2ml	Average	$LSD_{0.05}$
Average of Biomass (gm)	0.460	0.240	0.180	0.160	0.150	0.000	0.000	0.000	0.000	0.132	0.127
Average number of sclerotia	15.000	11.000	20.000	13.000	20.000	0.000	0.000	0.000	0.000	8.770	2.491
Average diameter of sclerotia (mm)	0.330	0.300	0.230	0.330	0.300	0.000	0.000	0.000	0.000	0.350	0.118
Average product of oxalic acid (ppm)	5.580	3.180	2.790	2.280	1.265	0.000	0.000	0.000	0.000	1.677	1.127

Each number represents three replicates

production (Yamanaka et al 200, Feng et al 2000). These results were identical to Kim's et al (2012). The effect was significant on mycelium length at 25 µml and the highest sizes, while the width was at 50µml (Table 4).

Figure 8 and Table 4, showed that the effect of different sizes of Ag / ZnO nanocompound on fungal cells after 12 days of inoculation on a PDA, this effect is between separation of the cellular wall, aggregation of the protoplasm, cell collapse, disintegration in cells, cell deformation and path deflection and began initiation of sclerotia, is the important phenomenon to survival the fungus over inappropriate circumstances and this is the main cause to regrowth the fungus during the subsequent generation. The average number of sclerotia in the subsequent generation was 8.77 sclerotia with a diameter of 0.35 cm (Table 5). This experiment may open up horizons for the effect of other nancompounds that may have an effect on later generations of the second generation, or that repeated treatment with nanoparticles may conceal the sclerotia of the fungus without fear of a mutation, due to the effect of silver on several vital processes in the fungus making the role of mutation or nanoparticle resistance is completely excluded (Herrera et al 2001, Wright et al1999).

Evaluation of the Ag / ZnO nanocompound on the PDB: There was a significant at 25µml the highest volumes until 0.5ml Ag / ZnO nanocompound and the highest there were no growth (Table 6).

The Ag / ZnO nanocompound caused the significant decrease number of sclerotia, and disappear in the volumes ranging from 0.5 ml to 2 ml. The Ag / ZnO nanocompound effects in cell decomposition and destruction were caused by cell wall rupture. The production of oxalic acid also showed a significant decrease in the production of acid with increasing sizes of Ag / ZnO nanocompound. However, it is shown

increase in acid production with volume increase except in size 25, Which indicates some of the anomalous behavior of the fagainst some external influences (Cessna et al 2000).

CONCLUSION

The fungal isolates *S. sclerotiorum* (MMBIRAQ) were first recorded in Iraq at the National Center for Biotechnology Information (NCBI) under the entry number (MF167296) at the GenBank Genomic Bank. By comparison, the highest genetic similarity was isolated with isolates isolated from Italy, 99%, while the most isolated from isolated from Canada. Nanocompound influenced fungi on the growth, biomass and number of sclerotia, and showed their effect on the phenotype in the dish as well as on the microscopic level of mycelium. They varied according to the incubation period between 5 to 12 days, and in the solid and liquid media. The effect of nanomaterials on the first generation after treatment has not continued.

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Incidence of Blossom Midge, *Contarinia maculipennis* Felt on Jasmine (*Jasminum sambac* L.) and its Natural Enemies in Tamil Nadu

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***Abstract*:** Jasmine blossom midge (*Contarinia maculipennis* Felt Cecidomyiidae, Diptera) was found to be the serious pest posing severe threat to flower yield. Field surveys indicated the presence of the pest in the surveyed region in varying intensity with maximum incidence in Madurai (34.27 %), Ramanathapuram (33.62 %) and Tirunelveli (33.19 %) respectively. Coccinellid predators like *Cheilomenes sexmaculata, C. transversalis, Scymnus* sp.*, C. septumpunctata, Brumus suturalis, Illeis cincta* and *Chilocorus* sp. were present in the jasmine ecosystem with a mean population of 3.1 per plant. Neuropteran predators, *Chrysoperla zastrowi sillemi* and *Mallada boninensis* were found with a mean population of 2.2 per plant. A wide range of preying mantises and spiders with a mean population of 3.8 and 4.3 per cent, respectively was present. A dipteran predator, *Systasis dasyneurae* played a vital role in natural suppression of the pest. Native weeds and flowering plants like *Parthenium hysterophorus, Rosa* sp.*, Nerium oleander, Vernonia cinera, Datura metal, Lantana camara, Tagetus erecta, Ipomea carnea, Helianthus annus* and *Coriandrum sativum* provide nectar to the adult stages of the predators in jasmine ecosystem.

***Keywords*:** Jasmine, Blossom midge, Pink discolouration, *Systasis* sp., Coccinellid, Chrysopid, Spider, Preying mantises

Jasmine is cultivated in an area of more than 8,000 ha with an annual production of flowers worth Rs. 80–100 million in India. Tamil Nadu is the leading producer of jasmine in the country with an annual production of 77, 247 tonnes in an area of 9,360 ha (Prakash and Muniandi 2014, Thakur et al 2014). The production of jasmine is affected by various factors, among which, insect pests are the most devasting factor. The major pests affecting jasmine are jasmine bud worm (*Hendecasis duplifascialus* Hampson), blossom midge (*Contarinia maculipennis* Felt), leaf webworm (*Nausinea geometralis* Guenee), gallery worm (*Elasmopalpus jasminophagus* Hampson), leaf roller (*Glyphodes unionalis* Hubner.) and the two spotted mite (*Tetranychus urticae* Koch.). Of these, budworm and blossom midge gain major economic importance, as they cause excessive damage to the buds. Blossom midge has attained the status of a major pest causing severe economic loss by reducing the marketable quality of the flowers. In case of severe infestations, buds dry prematurely leading to bud drop or blossom drop, thereby the marketable quantity of the flowers are greatly reduced. The pteromalid, *Systasis dasyneurae* Mani (Pteromalidae, Hymenoptera) is a general midge predator found in different agro-ecosystems (Parnell 1983). It has the potential to prey on the larval stages of midges. The larvae of this wasp parasitizes the midge larvae in the buds, attaching to the midges and extracting body fluids from its host. Each wasp larva can destroy 3-4 midge larvae (Pruthi 1937). Level of predation of late instar midge larvae can exceed 50 per cent (Ahmad and Mani 1939).

Lady bird beetles and green lace wings were reported to feed on the egg and larval stages of the insect pests (Dixon 2000). Spiders as carnivorous arthropods, consume a large number of larvae present in jasmine ecosystem including midge maggots (Rajeshwaran et al 2005). Preying mantises play an important role in the environment as an efficient predator. Studying the identity, intensity of infestation of the pest and the natural enemies associated is a pre requisite to develop the management strategy. Classical biological control involving the utilization of host – specific parasitoids requires the information on the native natural enemies involved with them. The present study was aimed at studying the intensity of damage caused by blossom midge and documenting the various natural enemies associated with them in different jasmine growing region of Tamil Nadu.

MATERIAL AND METHODS

Roving survey: Roving surveys were conducted during June-August 2015 around ten major jasmine growing Southern districts of Tamil Nadu *viz.,* Kanyakumari, Tirunelveli, Tuticorin, Virudhunagar, Madurai, Ramanathapuram, Theni Dindigul, Erode and Coimbatore

districts to study the incidence of blossom midge and the natural enemies associated with them.

Blossom midge incidence: In each district, 10 jasmine gardens were randomly selected and the per cent incidence of blossom midge was recorded by counting the pink discoloured buds with shriveled budstalks and total number of buds per plant. The number of maggots present per plant was also recorded. The observations were recorded at fortnightly interval for six months from June− December, 2016.

Natural enemies associated with blossom midge: The population of natural enemies *viz.,* predators and parasitoids that were seen actively moving near the infested buds from ten randomly selected plants were observed and recorded. The pink infested buds were collected in small containers and brought to lab and maintained to check for any predator/parasitoid emergence. The collected predators/parasitoids from ten randomly selected plants were reared still adult stage to confirm the identity of the natural enemies. The flowering plants and weeds in and around the jasmine gardens were observed and recorded for the activity of parasitoids/predators.

Taxonomic identification of natural enemies of blossom midge: Field collected predators were killed using ethyl acetate, preserved as dry mounts and identified using standard taxonomic keys. The identity was confirmed by the repository collection of natural enemies maintained at Insect Systematic Laboratory, Department of Entomology, Tamil Nadu Agricultural University Coimbatore. The emerged parasitoids from parasitized larvae as well as pink infested buds were collected and preserved in 70 per cent ethanol and sent to Division of Systematics, National Bureau of Agricultural Insect Resources (NBAIR), Bengaluru.

RESULTS AND DISCUSSION

The incidence of blossom midge was noticed in all the ten districts of Tamil Nadu. The jasmine growing regions of Tamil Nadu showed slight to heavier infestation of blossom midge However, the incidence was maximum in Madurai district recording 34.27 per cent, followed by Ramanathapuram, Tirunelveli, Kanyakumari and Thootukudi. The lowest per cent incidence was recorded in Erode and Dindugal. Similar trend was noticed in the number of pink discoloured buds/ plant with Madurai recording the maximum number of 19.10 buds/plant followed by Tirunelveli with 14.80 buds/plant. The variations in blossom midge incidence in the study locations may be due to the interplay of various biotic and abiotic factors that influence the pest population.

A specific midge predator, *Systasis dasyneurae* was recorded in all the jasmine gardens surveyed (Fig. 1). The larva of *Systasis dasyneurae* is a carnivorous predator of dipteran maggots (Fig. 2). The adult predators oviposit a single egg, in tip of the jasmine flower bud (Fig. 3). The emerging larvae feed on the midge maggots present inside the bud, pupate inside the buds and the adults emerge from the buds after being dried and fall off. The *Systasis dasyneurae* adults prefer to oviposit in buds with midge eggs. This clearly depicts the specific predatory role of *Systasis dasyneurae* to midge maggots. The *Systasis* larvae was present abundantly in pink discoloured buds, which reveals that the predator sense the olfactory stimuli of either the bud volailes due to damage of its prey or the kairomomal odours from midge body. The herbivore induced volatiles might be the reason for the oviposition of predators in midge damaged buds.

The saturated hydrocarbons, linalool, naphthalene, azulene, methyl salicylate, methyl anthranilate, alpha farnescene, phenol and naphthalene are emitted from midge damaged buds (Merlin Kamala et al 2017). The potent natural enemy attractant, allyl isothiocyanate were also emitted from midge damaged buds in volatile form. The attraction of *Systasis dasyneurae* in olfactometer showed a positive response to midge damaged bud extracts (Merlin kamala 2017). Hence, the field collected pink discoloured shrivelled buds of jasmine were kept in plastic containers for predator emergence. More number of predators emerged from buds collected from Madurai, followed by Tirunelveli, Kanyakumari, Dindugal and Erode. *Systasis* sp., as a potent predator of jasmine blossom midge was reported by David et al 1991.

The coccinellids observed in jasmine ecosystem ranged from 1.66 to 6.00/plant (Table 3) with a mean number of 3.1 /plant (Table 4). Ramanathapuram recorded the highest population of ladybird beetles. The different coccinellids observed in jasmine ecosystem were *Cheilomenes sexmaculata* (Fabricius), *Scymnus coccivora* (Fabricius), *C. transversalis* (Fabricius), *C. septumpunctata* (Linnaeus), *C. repanda* (Fabricius),*Brumus suturalis* (Fabricius), *Illeis cincta* (Fabricius), *Chilocorus* sp. and *Propylea dissecta* (Mulsant).

Chrysopid predators identified during the survey were *Chrysoperla zastrowii sillemi* and *Mallada bonensis* with a mean number of 2.2/plant (Table 3). The number of chrysopids ranged from 1.00-4.33 / plant including both grubs and adults in the different regions surveyed with the highest number recorded in Dindugal (Table 2). The various lifestages of chrysopids were invariably observed in many jasmine gardens with the eggs oviposited in the undersurface

of leaves. The grubs were found sucking sap from the midge maggots in damaged opened buds and hence makes an efficient predator. Chrysopids as voracious feeders of sucking pests with inherent potential to tolerate pesticides were reported by Rimoldi et al (2012) and Silva et al (2012). The voracious feeding of *C. zastrowi sillemi* grubs on the midge maggots was witnessed under laboratory conditions (Merlin Kamala 2017). The widespread occurrence of

Table 1. Incidence of blossom midge in different districts of Tamil Nadu and the extent of predator emergence from infested buds

Districts	GPS co-ordinates of the location		No. of pink discoloured buds/plant	Per cent midge incidence	No. of *Systasis dasyneurae* emerged / 50 infested buds
	Latitude	Longitude			
Kanyakumari	8˚ 04′ 48.00" N	77˚ 34′ 12.00" E	8.60^{c}	27.18^{c}	4.80^{b}
Tirunelveli	8˚ 43′ 48.00" N	77˚ 42′ 0.00" E	14.80^{b}	33.19^{b}	5.20^{ab}
Thootukudi	8˚ 34′ 17.15" N	78˚ 07′ 11.71" E	12.30^{b}	27.15^{c}	4.20^{c}
Virdhunagar	9˚ 56′ 24.00" N	77˚ 34′ 12.00" E	7.10^{cd}	26.68^{d}	3.20^{d}
Madurai	9˚ 50′ 20.33" N	78˚ 08′ 5.17" E	19.10^{a}	34.27^{a}	5.80^{a}
Ramanathapuram	9˚ 22′ 48.00" N	78˚ 49′ 48.00" E	14.30^{b}	33.62^{b}	2.60^{e}
Theni	10˚ 03′ 60.00" N	77˚ 44′ 59.99" E	7.20^{cd}	23.54^{e}	2.80^{e}
Dindugal	10˚ 22′ 8.26" N	77˚ 58′ 49.30" E	8.90^{c}	21.30^{f}	3.90^{d}
Erode	1˚ 20′ 34.08" N	77˚ 43′ 38.68" E	5.30^{e}	19.42^{g}	3.10^{d}
Coimbatore	11˚ 14′ 60.00" N	77˚ 18′ 60.00" E	6.70^{de}	26.64^{d}	5.40^{ab}

In a column, means followed by common letter(s) are not significantly different by LSD (P= 0.05)

Table 2. Natural enemies associated with blossom midge in different districts of Tamil Nadu

Districts	Predators recorded				Flowering plants observed near the jasmine gardens
	Specific predator	Coccinellids	Chrysopids	Others	
Kanyakumari	*Systasis* sp.	*Coccinella septumpunctata* *Brumus suturalis*	*Chrysoperla. zastrowi sillemi*	Preying mantises, Spiders	*Parthenium hysterophorus* *Rosa sp.* *Nerium oleander*
Tirunelveli	*Systasis* sp.	*Cheilomenes sexmaculata* *Propylea dissecta*	*C. z. sillemi*	Preying mantises, Spiders	*Vernonia cinera*
Thootukudi	*Systasis* sp.	*Coccinella transversalis,* *C. septumpunctata*	*C. z. sillemi*	Preying mantises, Spiders	*Datura metal*
Virdhunagar	*Systasis* sp.	*B. Suturalis, Scymnus* sp.	*C. z. sillemi*	Preying mantises, Spiders	*Lantana camara*
Madurai	*Systasis* sp.	*C. sexmaculata* *B. suturalis* *Illeis cincta* ***C.** transversalis,*	*C. z. sillemi* *Mallada boninensis*	Preying mantises, Spiders	*Tagetus erceta* *Ipomea carnea*
Ramanathapuram	*Systasis* sp.	*Coccinella transversalis* *P. dissecta*	-	Preying mantises, Spiders	*Helianthus annus*
Theni	*Systasis* sp.	*C.transversalis,* *C. septumpunctata*	*C. z. sillemi*	Preying mantises, Spiders	*Lantana camara*
Dindugal	*Systasis* sp.	*Scymnus* sp. *C transversalis*	*C. z. sillemi*	Preying mantises, Spiders	*Coriander sativum*
Erode	*Systasis* sp.	*B. suturalis* *Scymnus* sp.	-	Preying mantises, Spiders	*Lantana camara*
Coimbatore	*Systasis* sp.	*C. sexmaculata,* *C. septumpunctata* *L. cincta,* *B. suturalis* *C. transversalis* *Chilocorus* sp.	*C. z. sillemi* *Mallada boninensis*	Preying mantises, Spiders	*Tagetus erceta* *Ipomea carnea*

Table 3. Incidence of generalist predators in jasmine ecosystem

District	Coccinellids	Chrysopids	Preying mantises	Spiders
Kanyakumari	3.66^{c}	1.23^{d}	4.33^{b}	4.33^{b}
Tirunelveli	3.33^{c}	1.00^{d}	3.33^{c}	5.33^{a}
Thootukudi	2.00^{d}	2.00^{c}	3.66^{c}	3.66^{c}
Virdhunagar	3.33^{c}	2.00^{c}	5.33^{a}	2.33^{d}
Madurai	2.33^{d}	2.33^{c}	3.66^{c}	4.33^{b}
Ramanathapuram	5.33^{a}	1.33^{d}	3.66^{c}	4.66^{b}
Theni	2.66^{d}	2.33^{c}	2.66^{d}	5.33^{a}
Dindugal	4.33^{b}	4.33^{a}	3.00^{c}	3.66^{c}
Erode	1.66^{e}	3.33^{b}	2.33^{d}	3.00^{cd}
Coimbatore	2.34^{d}	2.00^{c}	5.66^{a}	5.66^{a}

In a column, means followed by common letter(s) are not significantly different by LSD (P= 0.05)

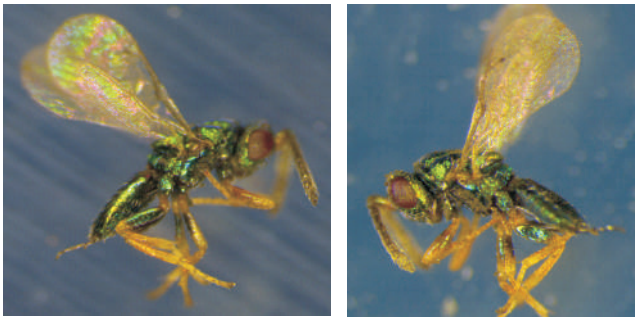

Fig. 1. *Systasis dasyneurae* adult

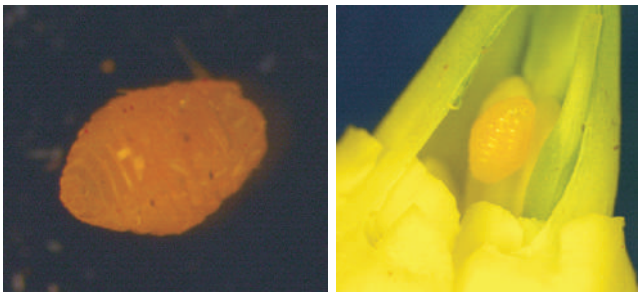

Fig. 2. *Systasis dasyneurae* larva

Fig. 3. Adult *Systasis dasyneurae* ovipositing on jasmine flowerbud

coccinellids and chrysopids in habiting diverse habits can be utilized for pest management in jasmine. Preying mantis predators recorded were *Mantis religiosa* (Linnaeus), *Creobroter urbana* (Fabricius), *Euantisa pulchra* (Fabricius), *Empusca pennata* (Thunberg), *Gongylus gongylodes* (Linnaeus), *Creobroter urbana* (Fabricius), *C. pictipennis* (Wood-Mason), *Odontomantis micans* (Saussure), *Hestiasula brunneriana* (Saussure), *Amorphoscelis* sp., and *Thesprotia* sp. with the mean of 3.8/ plant (Table 2, 4). The number of preying mantises ranged from 2.66 to 5.66 / plant with the highest number recorded in Coimbatore (Table 3). Their predatory role can be utilized in effective management of jasmine blossom midge.

A variety of spiders were found in jasmine plant leaves, twigs, trunk as well as flower and buds, preying jasmine pests. Spiders belonging to different families *viz.*, araenidae, clubionidae, theridiidae, linyphiidae, miturgidae, oxyopidae, salticidae, sparassidae, tetragnathidae, thomisidae, ulaboridae etc. were encountered in different region of Tamil Nadu. The predominant spiders observed being *Argiope anasuja* (Thorell), *Neoscona theisi* (Walkckenaeur), *Neoscona mukherjee* (Tikader), *Olios milleti* (Pocock), *Chikunia nigra* (O. Pickward-Cambridge), *Pisaura putiana* (Barion and Litsinger), *Peutica viridana* (Stoliczka), *Oxyopes javanus* (Thorell), *Oxyopes birmanicus* (Thorell), *Oxyopes shweta* (Tikader), *Phintella vitata* (C.L.Koch), *Myrmaplata*

Table 4. Incidence and species complex of predators during the study

Predators observed	Species of predators in decreasing trend	Mean number of predator/plant
Pteromalid	*Systasis dasyneurae*	4.1
Coccinellids	*Cheilomenes sexmaculata* > *Coccinella transversalis*> *Scymnus* sp. > *Coccinella septumpunctata* > *Brumus suturali* > *Illeis cincta* > *Chilocorus sp.*	3.1
Chrysopids	*Chrysoperla zastrowi sillemi* > *Mallada boninensis*	2.2
Preying mantises	*Mantis religiosa* > *Odontomantis micans*> *Creobroter pictipennis* > *Creobroter urbana* > *Euantisa pulchra* > *Hestiasula* sp.	3.8
Spiders	*Oxyopes javanus* > *Plexippus paykulli* >*Thyene imperialis* >*Telamonia dimidiata* > *Hyllus semicupreus* > *Thomisus projectus* >*Neoscona mukherjee* > *Olios milleti* > *Peucetia viridana*	4.3

plataleoides (O. Pickard-Cambridge), *Plexippus paykulli* (Audouin), *Telamonia dimidiata* (Simon), *Telamonia dimidiata* (Simon), *Rhene danieli (*Tikader*), Carrhotus viduus (C.L.Koch), Thyene imperialis* (Rossi), *Hyllus semicupreus* (Simon), *Thomisus projectus* (Tikader), *Araneus* sp., *Heteropoda* sp*., Theridion* sp., *Uthina* sp., *Clubiona* sp., *Cheiracanthium* sp., *Bavia* sp., and *Misumena* sp. The mean number of spiders observed was 4.3/plant (Table 4). Different species of spiders belonging to different families were seen actively preying pests of jasmine including blossom midge maggots. Prey searching ability, wide host range, ease in multiplication and polyphagous in nature make them as a potential predator in biological pest suppression (Rajeshwaran et al 2005). The positive response of spiders in naturally managing pests can be utilized in biological control and care should be taken to use safer and compatible insecticides that may not harm them. Flower spiders that fondly live on flowers were noticed to feed on midge maggots. A pteromalid parasitoid, *Pteromalus* sp., was emerging from the pink discoloured buds. *Pteromalus* sp. is a potential parasitoid of dipteran maggots especially fruit fly maggots (Cavaloro 1982). But its parasitic role on blossom midge of Jasmine was not defined. *Pteromalus* sp., as a parasitoid was reported in rice ecosystem (Catling and Islam 2013).

The flowering plants like *Parthenium hysterophorus, Rosa* sp*., Nerium oleander, Tagetus erecta* and *Helianthus annus* as well as native weeds like *Vernonia cinera, Datura metal, Lantana camara, Ipomea carnea,* and *Coriandrum sativum* were noticed in and around jasmine gardens, which provide nectar to the adult stages of the predators in jasmine ecosystem. The highest activity of the natural enemies may be due to the ample supply of nectar to the adult stages of the predators by the adjacent necariferous crops. The adult natural enemes in jasmine ecosystem were survived by the pollen and nectar from flowering plants as feed and the foliage for shelter and overwintering. The positive influence in increasing the population of beneficials in the jasmine gardens by growing nectariferous crops was reported Altieri and Nicholls (2004).

CONCLUSION

The present survey projected blossom midge of jasmine, *C. maculipennis* as the major pest infesting jasmine in all the major jasmine growing tracks of Tamil Nadu. The pest was associated with a rich pool of natural enemies that provide natural suppression of blossom midge of jasmine. These natural enemies need to be conserved by raising flowering plants in and around jasmine gardens to support adult predators and parasitoids as a source of nectar during the period of scarce availability of target hosts. The strategic planning with safer insecticides for management of blossom midge to preserve the native natural enemies in jasmine gardens needs priority.

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Multivariate Analysis of Water Quality Parameters in the Seasonal Wetland Ecosystem

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Abstract: Diversity and distribution of aquatic plants, water birds and their relationship of water parameters were investigated from seasonal wetlands of Ramanathapuram district, Tamilnadu, India. Three sampling stations such as Thamaraikulam, Manankudi and Pudhumadam were selected to present study. Fifteen aquatic macro floras representing 12 families, 7 classes and 9 orders were recorded. Out of these, 7 were submerged, 6 rooted floating weeds, and only one species of floating weed and rooted macrophytes. Twenty nine species of water birds with representing 13 families and 7 orders were recorded from two different habitats such as aquatic habitat and shrubby habits. *Anhinga melanogaster, Threskiornis melanocephalus* and *Mycteria leucocephala* are near threatened species. *Myriophyllum spicatum* L, *Hydrilla verticillata*, *Nymphaea nouchali Burm*.f, *Ceratophyllum demersum* L, *Lemna minor* L, *Marsilea quadrifolia* L, *Patamogeton nodosus* poix, and *Najas minor* are under IUCN categories especially least concern and IUCN population trend also recorded and a variety of plants and aquatic birds are also reported from this ecosystem.

Keywords: Seasonal wetland, Water quality, Aquatic flora, Water birds, IUCN Threatened species

Wetlands are important element to biological diversity and ecosystem functions. This utility performance was determined by hydrological factors (Banner and MacKenzie 2000). In natural environment, wetlands provides essential habitat for many wildlife such as fishes, animals, birds, amphibians, plants (both macro and micro floras) and addition to this, it provides feed and breeding wildlife animals particularly to avifauna (Hernandez and Mitsch 2007). Aquatic plants can also influences the abiotic factors and biota at across multiple tropic levels as providing habitat and food (Norlin et al 2005). The abiotic factors are the most common factors for growth of micro and macro flora that form the base of the biological food chain. The wetlands with higher tropic states generally supports more aquatic birds, since these environments usually have an abundance of plants and animals that can be used for food and shelter by aquatic birds. Present day, importance of wetlands has been considerably focused due to rich potential production, untapped resources and fruitful nourishment resources for many other organisms. In many countries, wetland biodiversity is serious threat from anthropogenic activities, including unsustainable harvesting of wetland resources, industrial pollution, poisoning, agricultural runoff, siltation and the introduction of exotic and invasive species into wetland ecosystems (HMGN/MFSC 2002, Baral and Inskipp 2005). In present study, the macrophyte flora and water birds distribution of a wetland ecosystem which consists of two entirely different habitats (fresh water habitats and shrubby habitats), are investigated to identify the different plant and avifaunal communities are present in the aquatic ecosystems and environmental factors that influence their abundance and distribution of flora and avifauna in seasonal wetlands of Tamilnadu, India

MATERIAL AND METHODS

Study area: Tharavai wetland is one of the important and largest seasonal wetland ecosystems in Ramanathapuram district of Tamil Nadu, India. It originating from Regunathapuram village near in Ramanathapuram town and it has a length of 35 – 40 km and breath of 100 to 200 m up to Pirappanvalasai village. Then it flows in small channel (30−40m breath) and finally ends in Palk Bay coast. The total area of wetland ecosystem is 2425.6 hectares (245.5 sq. km). A total stretch of 15 km distances of Tharavai wetland located along the coastal villages like Thamarikkulam, Ammapattinam, Pudumadam, Nariyurani, Katukkavalasai, Notchiyurani and Manankudi. Among this, three sampling sites such as Manankudi, Pudumadam and Thamarikkulam were selected to study the status of physicochemical parameters and its influences on diversity of aquatic macrophytes. Station1 is the Thamaraikulam (10˚23.484N; 077˚.57.134E) located 2.5 km away from Pudhumadam

village. Station 2 is Manankudi (09˚36.976N; 078˚83.083E) present in the eastern side of Pudumadam village and. station 3 located in Pudhumadam (09˚27.711N; 078˚99.089E)

Physicochemical parameters analysis: Water samples were collected at interval of 15 days for a total period of 12 months. In every station the samples were collected on south and north sides. The physicochemical parameters were estimated at the three sites during the period of February 2010 to January 2011. Temperature, *p*H and salinity were observed *in situ* by using mercury-in-glass thermometer, portable pH meter (Eutech, Japan) and Refractometer (Atago, Japan) respectively. The dissolved oxygen was determined by using Winkler's method (APHA, 1998). Turbidity (NTU) and conductivity was measured using a TN−100 turbidimeter by Eutech Instruments, Singapore and conductivity meter, Model 1601 respectively. A total dissolved solid was determined (Trivedy and Goel 1987).

Collection and identification of aquatic flora: All the aquatic hydrophytes were identified using regional floras (Gamble 1921, Gamble and Fischer 1935, Nair and Henry 1983, Henry et al 1987, 1989, Matthew 1991). Further, the specimens were authenticated for identification by relevant literature and a list quadrate was prepared with their botanical names, common name, family, habit type and habit, were presented.

Observation and identification of water birds: The peak activity in most birds lasts for 1 or 2 hours after sunrise or before sunset, so monitoring of transects was done either in early morning or late evening hours (Thankur 2006). Population estimation was undertaken for a variety of least concern, near threatened and vulnerable species. The important species are *Anhinga melanogaster, Threskiornis melanocephalus, Ciconia episcopus, Coracias benghalensis, Merops orientalis, Anas poecilorhyncha* and *Anas crecca.* Survey area was divided into two different habitats, aquatic fresh water habitat (FWH) and shrubby habitat (SH) depending on the various types of vegetation present over there. The birds were identified by some standard books and field guides (Ali 1969, King et al 1978, Sonobe and Usui, 1993, Grimmett et al 2001). A photographic digital camera with 14 mega pixel and Binocular (super Zenith prismatic field) with aid of 10×50 used as tools for observation and identification of birds.

Statistical analysis: The correlation and WQI of physico−chemical parameters were analyzed to measure significant differences between sampling stations. Pearson correlation (r) test was performed to identify the association between pairs of variables for sampling stations.

In this study, seven parameters were chosen to calculate the water quality index, using the standards of drinking water quality recommended by (ICMR 1975, BIS1993).

Water Quality index :

$$WQI = \sum_{n=1}^{n} q_n w_n / \sum_{n=1}^{n} w_n$$

Where, $q_n = 100\ [V_n - Vio]/(S_n - V10)]$,q_n = Quality rating for the nth water quality parameter;, Vn =estimated value of the nth parameter at a given sampling station , Sn= standard permissible value of nth parameter, Vio = ideal value of nth parameter in pure water (pH = 7, DO = 14 mg/l and for other parameter = 0), Wn = unit weight for nth parameter, Sn = standard value for nth parameter, K = constant for proportionality

RESULTS AND DISCUSSION

Physico-chemical characterization of water: The temperatures did not show variations in wetland, 30.78°C in station 2 and 31.57°C in station 1. The pH ranged from 7.0−7.7 slightly alkaline. The concentration of salinity varied from 0.70−1.60 ppt with average of 0.94 ppt. The dissolved oxygen ranged from 7.40 to 8.40 with average 7.97mg/l and was with in optimum range of 7 to 8.5 (BIS 2003). The electrical conductivity varied between 348−586 average of 384.28 ms/cm. Total dissolved solids ranged from 214 to 320 ms/cm and turbidity from 3.7−6.6 NTU. However, the complication rate was lower of (0.11%) for pH and this influenced the rage

Table 1. Physicochemical parameters (Mean ± S.E) in three wetland stations

Parameters	Station 1	Station 2	Station 3
Temperature (˚C)	31.00 ±0.34	31.57 ± 0.32	30.78 ±0.45
pH	7.33 ± 0.09	7.32 −0.11	7.43 −0.07
Salinity (ppt)	0.88 ± 0.03	1.13 −0.15	0.82 −0.02
Conductivity (ms/cm)	361.75 ±4.15	435.33 −43.88	355.75 −4.4
TDS (ms/cm)	238.17 ±	275.42 −12.77	230 −7.56
D.O (mg/l)	7.88±0.1	8.05 −0.1	7.97 −0.1
Turbidity (NTU)	4.63 −0.37	5.38 −0.53	4.57 −0.4

Table 2. ANOVA results of water quality parameters in the study area

Water quality parameters	Effect	f value	P value
Temperature (˚C)	0.31	1.106	0.407
pH	0.07	0.180	0.965
Salinity (ppt)	0.33	1.181	0.374
Dissolved oxygen (mg/l)	0.32	1.129	0.396
Conductivity (ms/cm)	0.29	1.004	0.456
TDS (ms/cm)	0.51	2.478	0.092
Turbidity (NTU)	0.13	0.370	0.860

of individual parameters. The level of dissolved oxygen standardizes the distribution pattern of flora and fauna (Kotadiya Nikesh and Acharya 2014). The BIS/ ICMR reported that, the dissolved oxygen of 5mg/l is optimum. Water quality index has been used to evaluate status of wetland water quality through water quality index (Chatterji and Raziuddin 2002, Rameshkumar and Rajaram 2016). In the present study, water quality was very poor in all three stations (WQI >76)**.** This finding was confirmed by some previous study (Thakor et al 2011, Jena et al 2013, Korgaonkar et al 2014). More human activities were altering and deteriorate water qualities on these wetlands than other kinds. The status of water quality in these study sites are given in (Table 3). The salinity was positively correlated with electrical conductivity, total dissolved solids and turbidity. Similarly the conductivity correlated positively with TDS and turbidity (Table 4). The number of species was correlated significantly negative with all physic-chemical parameters except pH, but the electrical conductivity, total dissolved solids and turbidity. This indicated that, the total number of species decreased with increased electrical conductivity, turbidity and total dissolved solids in wetland ecosystem. The pH was correlated negatively with all physico-chemical parameters but was statistically not significant.

Distribution and abundance of aquatic macrophytes : The *Ceratophyllum demersum* L. *Egeria densa* planch, *Lemna minor* L. *Marsilea quadrifolia* L., *Patamogeton nodosus* poix, *Nymphaea nouchali* Burm.f, *Nymphaea odorata* Aiton, *Nelumbo nucifera* Gaertn, *Myriophyllum spicatum* L, *Hydrilla verticillata, Chara globularis, Sagittaria guyanensis, Isoetus ribaria, Eichornia crassipes* kunth, and *Najas minor were recorded (Table 5).* The highest number of 12 plant species was observed in Station 1 whereas the minimum of 7 species were recorded at station 2. The variations of species distribution were based on the physico chemical and environmental parameters. Present study revealed that, most of the wetland covered by submerged macrophytes (7 species) and rooted floating weeds (6 species) than those of floating weed (1 species.) and rooted macrophytes (1 species). Adhishwar and Choudhary (2013) observed 137 macrophytes belong to 50 families. With respect to water quality changes in water chemistry has been considered to exert influence in the distribution of many aquatic plant species (Engelhardt and Ritchie 2001, Lentz–Cipollini and Dunson 2006).

In wetland, macro vegetation have imperative role in determining the limno-biological environment (Das et al 2009) that can reflected in taxonomic composition of plants

Table 3. Water quality index (WQI) of the seasonal wetland ecosystem

Parameters	Standard value (s_n)	Unit weight (w_n)	Station-1			Station-2			Station-3		
			Observed value	Quality rating (q_n)	W_nq_n	Observed value	Quality rating (q_n)	W_nq_n	Observed value	Quality rating (q_n)	W_nq_n
Ph	6.5 – 8.5	0.2190	7.32	21.33	4.67	7.43	28.89	6.33	7.33	22.22	4.87
D.O (mg/l)	5	0.3723	8.05	66.11	24.61	7.97	67.04	24.96	7.88	67.96	25.30
Conductivity (ms/cm)	300	0.3710	435.33	145.11	53.84	355.75	118.58	43.99	361.75	120.58	44.74
TDS (ms/cm)	500	0.0037	275.42	55.08	0.20	230.00	46.00	0.17	238.17	47.63	0.18
Range of water quality		0.9660			83.32			75.45			75.08

Table 4. Pearson correlation coefficients matrix between the physic-chemical parameters of and species distribution

Parameters	Temperature (˚C)	pH	Salinity (ppt)	D.O (mg/l)	Conductivity (ms/cm)	TDS (ms/cm)	Turbidity (NTU)	Species nos.
Temperature (˚C)	1							
pH	-0.325	1						
Salinity (ppt)	0.628	-0.64	1					
D.O (mg/l)	-0.04	-0.139	0.433	1				
Conductivity (ms/cm)	0.58	-0.575	.987**	0.526	1			
TDS (ms/cm)	0.638	-0.654	.987**	0.513	.989**	1		
Turbidity (NTU)	0.475	-0.574	.975**	0.474	.984**	.956**	1	
Species nos.	-0.482	0.211	-0.803	-0.515	-.877*	-.824*	-.858*	1

* Correlation is significant at the 0.05 and ** at 0.01 level (2-tailed).

(Croft and Chow-Fraser 2007). Macro vegetation can be used to maintain the ecological balance obtaining through nutrient from water in benthic zone. Aquatic macrophytes are used to remove the aquaculture effluents and maintain the water quality for fish culture in natural water bodies (FAO 2000). The submerged *Egeria densa* used to remove the concentration of nitrogen. Submerged vegetation provide structure for spawning, sheltering for larvae and juveniles and habitat for the benthic and planktonic prey for psicivores and forage species (Casselman and Lewis 1996). This may be due to presence of emergent vegetation which provides shade to duck weeds and also compete for nutrients (Hermandez and Mitsch 2004). The light penetration in the column promotes the growth of submerged and floating macrophytes have spatial variation throughout the year (Hermandez and Mitsch 2004). The roots of aquatic plants (*Pistia*) have used to escape the fry and other fishes from the predation (ICAAE 1992). Free floating macrophyte of *Eichornia crassiepes* Kunth was dominating in Station.1. It has positive and negative impact on ecosystem and water quality. This also reduces the biological diversity, eliminating the native submerged species by obstructive sunlight, and eliminating the underwater species like fishes. Whereas, it provides shadow a cooler place for fish and macro-invertebrates by provide shadowing the water column. The submerged and free-floating hydrophytes have a higher capacity to remove large concentrations of nutrients (Sooknah and Wilkie 2004).

Distribution and Abundance of Aquatic Birds: In the present investigation 29 species of water birds belonging to 13 families were identified from freshwater and shrubby habitats. The dominant species were *Anhinga melanogaster, Threskiornis melanocephalus, Mycteria leucocephala, Ardea purpurea, Sarkidiornis melanotos, Anas Penelope, Anas poecilorhyncha, Spatula querquedula*, *Ciconia episcopus* (Table 6), among these 3 species are near threatened, one species of vulnerable and in 11 species the population is decreasing as per IUCN list. Most of the observed birds are aquatic freshwater habitats residents mainly due to occurrence of various types of microhabitat within the lakes, streams, pools, sanctuary, nearby ocean and a large pond.

Table 5. Aquatic plants species diversity in the seasonal wetland

Binamial name	Family	Common name	IUCN Red list	Type	St-1	St-2	St-3
Ceratophyllum demersum L.	Ceratophyllaceae	Rigid Hornwort	Least concern (stable)	Submerged			
Egeria densa planch	Hydrocharitaceae	Egeria	–	Submerged			
Lemna minor L.	Araceae	Common duck weed	Least concern (un known)	Submerged	×	×	
Marsilea quadrifolia L.	Marsileaceae	Water Shamrock	Least concern (unknown)	Submerged	×	×	
Potamogeton nodosus poix	Potamogetonaceae	Loddon Pondweed	Least concern (un known)	Rooted & Floating	×	×	
Nymphaea nouchali Burm.f	Nymphaeaceae	Red or Blue water lily	Least concern (un known)	Submerged		×	×
Nymphaea odorata Aiton	Nymphaeaceae	Indian lotus	–	Rooted & Floating		×	×
Nelumbo nucifera Gaertn	Nelumbonaceae	White water lily	–	Rooted & Floating		×	×
Myriophyllum spicatum L	Haloragidaceae	Spiked Water-milfoil	Least concern (un known)	Rooted & Floating			
Hydrilla verticillata	Hydrocharitaceae	Indian Stargrass	Least concern (unknown)	Rooted & Floating			
Chara globularis	Characeae	Musk grass or Skunweed	–	Rooted & Floating			
Sagittaria guyanensis	Alismataceae	Arrow head	–	Submerged		×	
Isoetus ribaria	Isoetaceae	Quillwort	–	Submerged			×
Eichornia crassipes kunth	Ponteteriaceae	Water hyacinth	–	Floating		×	×
Najas minor	Hydrocharitaceae	Slender Naiad	Least concern (un known)	Rooted			
Total number of species in each stations					12	7	10

Table 6. Diversity of aquatic birds in the seasonal wetland ecosystem

Binomial name	Family	Common name	IUCN Red list	Habitat	St-1	St-2	St-3
Anhinga melanogaster	Anhingidae	Oriental Darter	Near threatened (decreasing)	AqH		×	
Phalacrocorax niger	Phalacrocoracidae	Little Cormorant	Least concern (Unknown)	AqH			
Phalacrocorax carbo	Phalacrocoracidae	Great Cormorant	Least concern (increasing)	AqH		×	×
Tachybaptus ruficollis	Podicipedidae	Little grebe	Least concern (decreasing)	AqH	×		
Ardea cinerea	Ardeidae	Grey Heron	Least concern (Unknown)	AqH/SH		×	×
Ardea purpurea	Ardeidae	Purple Heron	Least concern (decreasing)	AqH/SH		×	
Ardea alba	Ardeidae	(Great White Egret	Least concern (Unknown)	AqH/SH	×		×
Sarkidiornis melanotos	Anatidae	African Comb Duck	Least concern (decreasing)	AqH/SH	×		×
Nettapus coromandelianus	Anatidae	Cotton Pygmy-goose	Least concern (stable)	AqH/SH	×		×
Anas penelope	Anatidae	Eurasian Wigeon	Least concern (decreasing)	AqH/SH		×	
Anas poecilorhyncha	Anatidae	Indian Spot-Billed Duck	Least concern (decreasing)	AqH/SH		×	×
Spatula querquedula	Anatidae	Garganey	Least concern (decreasing)	AqH/SH	×		×
Anas crecca	Anatidae	Common Teal	Least concern (Unknown)	AqH/SH		×	×
Ciconia episcopus	Ciconiidae	Asian Woollyneck	Vulnerable (decreasing)	AqH/SH		×	×
Merops phillippinus	Meropidae	Blue-tailed Bee-eater	–	AqH/SH			
Halcyon smyrnensis	Alcedinidae	White-breasted Kingfisher	Least concern (Increasing)	AqH/SH			×
Egretta garzetta	Ardeidae	Little Egret	Least concern (Increasing)	AqH			
Mesophoyx intermedia	Ardeidae	Median Egret	–	AqH/SH			
Bubulcus ibis	Ardeidae	Cattle Egret	Least concern (Increasing)	AqH/SH			×
Ardeola grayii	Ardeidae	Indian pond-heron	Least concern (Unknown)	AqH/SH	×		
Tringa ochropus	Charadriidae	Green Sandpiper	Least concern (Stable)	SH/AqH	×		×
Tringa glareola	Charadriidae	Wood Sandpiper	Least concern (Stable)	SH/AqH			
Himantopus himantopus	Recurvirostridae	Black-winged Stilt	Least concern (Increasing)	SH/AqH			
Rostratula benghalensis	Rostratulidae	Greater painted-Snipe	Least concern (decreasing)	SH/AqH		×	
Threskiornis melanocephalus	Threskiornithidae	Black-headed Ibis)	Near threatened (decreasing)	AqH	×		×
Mycteria leucocephala	Ciconiidae	Painted Stork	Near threatened (decreasing)	AqH/SH			
Merops orientalis	Meropidae	Asian Green Bee-eater	Least concern (Increasing)	AqH/SH		×	×
Coracias benghalensis	Coraciidae	Indian Roller	Least concern (Increasing)	AqH/SH			
Alcedo atthis	Alcedinidae	Common Kingfisher	Least concern (unknown)	AqH/SH			×
Total number of species in each stations					21	19	14

AqH: Aquatic habitat, SH: Shrubby habitat

Due to the abundance of variety of plant and avifaunal communities are occurring in environment which is very favourable for bird conservation in this part of the wetlands. Water birds tend to be highly mobile in winter, moving to other areas in response to factors such as cold weather and changes in water levels and in food resources (Kershaw and Cranswick 2003). The present study concludes that wetlands are serious threat to biodiversity due to waste from agricultural waste, domestic, sewage effluents, fishing waste etc. During monsoon (October-December) and post monsoon (January-March) seasons many water birds are migrating from various parts. Hence, the conservation and management strategy is important to protect wetland ecosystem.

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Evaluation of Groundwater Quality by Using Water Quality Index Near Magnesite Mines, Salem District, Tamilnadu, India

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***Abstract*:** The present investigation meant to assess the water quality for the groundwater of around Magnesite Mines in Salem District. For ascertaining the WQI, the parameter considered were pH, total hardness, calcium, magnesium, chloride, sulfate, total dissolved solids, sodium, total alkalinity. All the physic-chemical parameters of groundwater samples were within the highest desirable limit as per WHO. The WQI varied from 55.45 to 81.29.In Sengaradu, Gollapatti, Vinayakampatti the WQI was higher due to convergence of magnesium, sulphate and chloride in the groundwater. A significant negative correlation was observed between calcium and sulphate, sodium and total alkalinity.

***Keywords*:** Groundwater, Magnesite mines, Chemical characteristics, Water quality index, Correlation

Groundwater assumes a critical part in Indian horticulture. The appropriateness of water system water relies on many elements counting the nature of water, soil sort and salt resilience qualities of the plants, atmosphere and waste qualities of the dirt (Michael 1990). Groundwater dependably contains little measure of solvent salts broke down in it. The sorts and qualities of these salts rely on the hotspots for revive of the groundwater and the strata through which it streams. The abundance amount of solvent salts might be unsafe for some products. Subsequently, for a superior comprehension of science of groundwater it is extremely fundamental to legitimately assess groundwater quality for water system reason. Paddy crops, vegetables, foods grown from the ground crops are the normal rural deliver of the general population in the contemplate zone (Abdoliman Amouei et al 2012). The waterway and tank waters are not accessible at many places in the investigation zone or in the event that if accessible, they are not ready to supply sufficient water for flooding crops even at basic phases of harvest development (Adelekan et al 2011). Under these conditions, the groundwater turns into the primary wellspring of irrigation. Geochemical forms in groundwater include the association of nation rocks with water, prompting the improvement of auxiliary mineral stages. The standards administering the synthetic attributes of groundwater are very much archived in many parts of the world (HadiHajizadesh et al 2011, Hariharan et al 2010, Mahadev et al 2010). This paper examines the conceivable concoction forms of groundwater shake collaboration in hard shake landscape. Geographic Information System (GIS) has risen as a capable innovation of guideline, for look into, and for building the stature of projects have directed GIS-based examination and understanding of groundwater quality information.

MATERIAL AND METHODS

Study Area: Salem in Tamil Nadu, South India, is the center of essential hard-headed industry in the nation. Magnesite, the main crude material for fundamental refractory and additionally calcined Magnesia, is being mined from three huge and a few little mines situated in Salem. The ultramarine complex of Salem spreads over a region of 30 km^2 and is known as the Chalk Hills area. It is the archive of both obstinate and non-recalcitrant evaluations of magnesite. Salem area is limited by Villupuram locale in the east; Erode region in the west and Dharmapuri region in the north and Namakkal region in the south. The area lies between 11°21′30"N to 11°59′00"N Latitude, 77°38′00" E to 78°50′00"E Longitude and has a flying degree of 5245 km^2. The normal temperatures run from 37°C to 43°C. The normal precipitation for the area is 972.3mm. Normal annual rainfall over the district varies from 800 to 1600mm.(Arulmozhi et al 2017). The WQI has been computed by using standards of drinking water quality recommended by the world health organization (WHO), Bureau of Indian Standards (BIS) and Indian Council for Medical Research (ICMR). The major three steps are followed to compute the water quality index for the water samples.

To Calculate Quality Rating for the n^{th} Water Quality Parameter:

$q_n = 100 [Vn-Vio] / [Sn-Vio]$…… (1)

$Wn = [K / Sn]$…… (2)

$WQI = [\Sigma q_n Wn] / [\Sigma Wn]$…….. (3)

q_n=Quality rating for the nth water quality parameter, Vn= Estimated value of nth parameter at a given sampling station, Sn= Standard permissible value of the nth parameter, Vio=Ideal value of the nth parameter in pure water, Wn= Unit weight of the nth parameter and K=Constant of proportionality.

Table 1. Standard weight (wi) and calculated relative weight (Wi) for each parameters

Parameter	Indian standard	Weight (wi)	Relative weight (Wi)
pH	6.5-8.5	4	0.1429
TDS	500-2000	4	0.1429
TH	300-600	2	0.0714
TA	200-600	3	0.1071
Ca	75-200	2	0.0714
Mg	30-100	2	0.0714
Cl	250	3	0.1071
So4-	200-400	4	0.1429
DO	>5	4	0.1429
		$\sum$wi=28	$\sum$Wi =1.0000

RESULTS AND DISCUSSION

pH: In the study area the range of pH varies from 6.79-8.67. The standard range of pH is 6.5 –8.5 as per WHO and IS 10500:2012. The nature of water is more alkalinity in the Sengaradu location and minimum value of the pH (6.79) at Bodhinayakanpatti location. The reason for high range of pH is nature of rock and high value of calcium and sodium concentration in the Sengaradu study area.

Total Alkalinity: As per WHO and IS 10500:2012, the permissible limit for alkalinity is 200mg/L. In study area, the alkalinity ranged from 113 to 318mg/L. Sengaradu and Annamalai Nagar have high alkalinity value and Bodhinayakanpatti low as compared to the other location in the study area. The main source for natural alkalinity is rocks which contains carbonate, bicarbonate compounds. The presence of calcium carbonate or other compounds such as magnesium carbonate contribute the major part in the alkalinity of water. Sengaradu location comes under the Omalurtaluk in Salem district. In that location, the nature of soil is loamy skeletal to fine loamy; moderately slow to rapid permeability and its pH is 8.67 and medium in water holding capacity.

Chloride: As per World Health Organization, the maximum permissible limit for chloride is 250mg/L. In study area, the range chloride ion concentration varies from 159 454mg/L. Gollapatti has a high value of chloride concentration because of mines ores waste are disposed in that specified locations. An effect of high chloride in water is toxic to aquatic life, impacts vegetation and it is hazardous to human consumption and makes health problems.

Sodium: In a study area, the range of sodium ion varies from 104-214mg/L. Gollapatti has a high concentration of sodium ions because of disposal from the industries and nature of the earth crust.

Total dissolved solids: The concentration of TDS range from 206 – 972 mg/L. As per world health organization, the maximum permissible limit for total dissolved solids is 500mg/L. Vinayakampatti has a high concentration of total dissolved solids due to natural sources, sewage, industrial waste water, urban run-off and agriculture runoff during rainy season.

Total hardness: Thehardness ranged from 236-401mg/L. As per IS 10500-2012, the maximum permissible range of hardness is 300mg/L. Sengaradu location has a high level of concentration of hardness due to disposal waste from the urban area and industries. Ca and Mg are the critical basic earth metals causing hardness of water .

Calcium hardness: In a study area, the range of calcium is 98-180mg/L. As per IS 10500-2012, the maximum permissible level of calcium is 200mg/L.

Magnesium hardness: The maximum permissible level of magnesium as per IS 0500-2012 is 100 mg/L and ranged between 138-221 mg/L. Sengaradu location has a very high level concentration of magnesium. More number of Magnesite mines and industries are located nearby Sengarudu location in Salem district.

Sulphate: The concentration of sulphate in nature varies due to presence of terrain like sedimentary rocks. Which oxides to sulphates in humid climates, later it may be leach into groundwater and increase the concentration of sulphate in groundwater Thesulphatein study area, ranged between 106 and 482 mg/L. As per IS 10500-2012, the maximum permissible level of Sulphate in drinking water is 250mg/L. Sengaradu location has a higher concentration of sulphate. Sulfates are released into water from mines, material factories and tanneries..

Water quality index (WQI): The WQI esteems ranged from 55.45 to 81.29 (Table 2) and the WQI can be sorted into fantastic water, great water, poor water, extremely poor water and unfit for drinking reason. As indicated by WQI, 20% of water tests fall under great quality and staying 80% of water falls under low quality.

Table 2. Physic-Chemical parameter of groundwater samples

Sample station	Latitude	Longitude	pH	TA	Cl	TDS	T H	Ca	Mg	SO4−	Na	WQI
Adivaram	11.706058	78.179088	6.5	100	180	150	150	100	70	200	168	46.57
Ayyamperumalpatti	11.67771	78.082812	7.8	184	337	621	244	184	102	375	143	73.29
Chettichavadi	11.724912	78.15621	8.14	304	376	489	359	304	160	189	151	75.21
Karuppur	11.716306	78.087567	7.23	121	209	647	302	121	131	248	176	63.59
Gollapatti (pudur)	11.319183	77.79568	7.09	148	454	509	354	148	157	307	214	78.05
Kundur	11.747975	78.199441	8.16	278	273.9	451	378	278	169	170	158	70.16
Sengaradu	11.747699	78.138529	8.67	318	211	372	401	318	180	293	176	74.15
Vinayakampatti	11.724362	78.166434	8.14	278	377	972	332	278	146	301	164	81.29
Muniyappankovil	11.6269541	78.118495	7.1	187	329.8	343	298	187	129	407	152	72.88
Vellakkalpatti	11.468867	78.264831	6.9	159	240	472	382	159	171	379	104	72.5
Mettupatti	11.667368	78.311561	6.5	150	159.8	150	200	150	110	159	105	45.81
Daivanagar	11.738116	78.155626	6.9	100	150	140	136	100	76	198	134	43.64
Suramangalam	11.675316	78.120673	7	152	178	146	148	152	94	180	125	46.49
ATCnagar	11.693233	78.161246	7.31	140	159	262	381	140	171	221	183	62.16
Annamalainagar	11.681879	78.172118	8.2	318	284.9	148.8	348	318	154	189.6	135	68.55
Bodhinayakanpatti	11.424797	78.242788	6.79	113	248	482	438	113	199	106	183	65.43
Pasuvakkal	11.693206	78.086436	8.1	286	246	321	282	286	122	482	163	75.05
Mungilpadi	11.639105	78.852362	8.02	298	176	464	301	298	131	361	148	69.77
Karuppur East	11.706254	78.152422	7.23	121	209	647	302	121	131	248	176	63.74
Ayyamperumalpatti North	11.69124	78.212354	7.8	184	337	621	244	184	102	375	143	73.29

Table 3. Status of groundwater sample for study area

WQI values	Percentage of study area (%)	Quality
0-25	0	Excellent water
25-50	20	Good water
50-75	80	Poor water
75-100	−	Very poor water
>100	−	Unfit for drinking

Factual analysis: Statistical Package for Social Science (SPSS Ver.13) was utilized to establish out the statistical examination for groundwater in an examination zone. In measurable test were essential measurements like mean, middle and standard deviation is ascertained to know the synthetic parameters which are digressing from the Bureau of Indian Standard for drinking reason. In an examination territory, mean, middle, standard deviation for all parameters were observed and 90% of the areas are inside the points of confinement of BIS for drinking reason (Table 5). Connection investigation measures the cozy connection between the concoction parameters of the water tests. In this investigation, the esteem go between +1 to − 1 and it demonstrates the ideal connection between the two parameters (Table 6).

CONCLUSION

According to, IS 10500-2012, Sengaradu, Gollapatti, Vinayakampatti areas has a high grouping of concoction parameters. As per WQI, 20 percent of water sample fall under good quality water and 80 percent under low quality. The high

Table 4. Statistics analysis for Ground water samples

	pH	TDS	TH	TA	CA	MG	CL	SO4	NA
Mean	7.48	420.39	299	196.95	135.25	163.75	256.77	269.43	155.05
Median	7.27	457.5	302	171.5	131	171	243	248	155
Std.Dev	0.64	220.8	88.08	79.85	35.46	54.05	86.74	100.6	27.04
Max	8.67	972	438	318	199	239	454	482	214
Min	6.5	140	136	100	70	54	150	106	104
Indian.Std	8.5	500	300	200	75	30	250	250	200

Table 5. Correlation coefficient matrix of groundwater quality

Parameter	pH	TDS	TH	TA	Ca	Mg	Cl	SO_4−	NA
pH	1								
TDS	0.34	1							
TH	0.42	0.4	1						
TA	0.9	0.14	0.4	1					
Ca	0.34	0.28	0.65	0.36	1				
Mg	0.46	0.46	0.58	0.41	0.32	1			
Cl^-	0.34	0.56	0.35	0.31	0.26	0.4	1		
SO^{4-}	0.31	0.32	0.01	0.26	-0.1	0.93	0.31	1	
Na	0.14	0.33	0.42	-0.06	0.35	0.45	0.3	-0.02	1

estimation of WQI at this ar eais due to higher magnesium, chloride and sulfate and calcium in the groundwater. Sengaradu, Gollapatti, Vinayakampatti area needs essential treatment like sedimentation, coagulation, flocculation before .The industrial effluents and agricultural disposals must be treated before pumping into the river system.

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Water Quality Index Assessment of Domestic Water Supplies in System Tank

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Abstract: The study was confined toa system tank zone of River Noyyal in Coimbatore. The ground water and surface water of the monsoon and post–monsoon seasons were analyzed for various physico-chemical parameters. The Parametric Water Quality values in the respective units of measurement were found to be in the IS permissible ranges prescribed for EC (3to15dS/m), pH(6.2to 6.8), Total dissolved salts (500 t0 2000) and sulphates (200 to 400). The overall quality indices for both surface and ground water were arrived at in a gradation system of weightage limits from 1 to 5, as less hazardous to severely hazardous status. The indices established the values in the moderate range of 2.3 to 3.8, suggesting the feasibility of quality sustained domestic water supplies.

Keywords: System Tank, Water Quality Index, Parametric Index, pH, EC, Turbidity, Hardness, Alkalinity, domestic water supplies

Surface water reserves such as the tanks and subterranean aquifers embedded with dug wells and bore wells store the rainwater for the diversified usage in their vicinity viz., irrigation, domestic and industrial water supplies in an ingenious way of roaster based rotational distribution through open channels and pipeline networks (Debels et al 2005,Giridharan et al 2010). By and large, the system tanks constructed at various zones of Coimbatore were primarily envisaged to cater to the irrigation needs of agricultural crops in their downstream command areas. However, over the past twenty years this scenario has undergone dramatic changes partly due to extensive urbanization and intensive industrialisation as well. Eventually the agricultural land area has diminished drastically and got converted into real estate pockets. In response to this impulse the agricultural needs also got decreased but the domestic and industrial water requirements got exponentially shotup. Hence the paradigm shift of transforming agricultural requirements of the water towards domestic water supplies has become inevitable. Mostly we resort to a conjunctive use of surface and groundwater storage that is also responsible for spatial and temporal water quality changes in accordance with the contaminant solute transport (Kannel et al 2007, WHO 2008, Sener et al 2017). However, a qualitative scrutiny of the water in storage and that reaching the groundwater aquifers is indispensible. Hence it could be impeccable if the existing water distribution schedule can be modified to suit the dominating domestic water needs compared to the barest minimum agricultural water requirements. By way of incorporating suitable mechanical filtration systems and disinfection schedules assured domestic water supplies at desirable quality level can be accomplished.

Besides, the sustainability of extracting and using both surface and groundwater from the system tank storage and dispersion zone needs extensive investigation. System tanks or non-system tanks do contribute to the aquifer recharge covering a certain radius of influence both on the downstream side and upstream side of storage indicated the well water level fluctuations (Subramani et al 2005) . The present investigation was contemplated to include nodal point water samplings related to the surface storage of water in the tank and well water in the vicinity. Based on these quality indices focused for domestic water supplies, the appropriate filtration and disinfection units can be designed and installed (Horton 1965).

MATERIAL AND METHODS

Study area: The Noyyal river stretch proliferating and meandering through Coimbatore region encompasses 21 Anaikuts and 31 Tanks, of which 8 system tanks are located within Coimbatore city urban viz.,Narasampathi tank, Krisnampathi tank, Selvampathi tank, Kumarasamy tank, Selvasindhamani tank, UkkadamPeriyakulam tank, Valankulam tank and Singanallur tank. The study was however limited only to UkkadamPeriyakulam tank that is knitted to the downstream reach of the Noyyal River feeding where the concentrated dumping of pollutants and contaminants along the stream flows gushing into the tank

water spread pose a severe threat on the surface and groundwater water qualities. The latitude of Coimbatore, Tamil Nadu (a State of India) is 11.017363, and the longitude is 76.958885. (GPS coordinates of 11° 1′ 2.5068″ N and 76° 57′ 31.9860″ E.). The experimental observations were made during the monsoon season (June-Nov, 2016) and during the non-monsoon (December-May, 2016) following the Indian Standards procedures in sample collection and analysis.

Sample sites and status of pollution: The primary data collected includes the laboratory analysis results for the water samples collected along the stretch of the UkkadamPeriyakulam tank. Secondary data such as rainfall, water quality, groundwater level, lithology, and aquifer parameters were obtained from state surface water and groundwater board. Four sampling sites were selected randomly by considering the domestic, agricultural and industrial factions. The ground water and surface water of the pre− monsoon/summer (March-June), monsoon (July−November) and post–monsoon (December-February) seasons were analyzed for various physico-chemical parameters in line with parametric considerations for 5 samples per parameter. The results were compared with the drinking water standards / guidelines by Indian Standards (IS 10500:2012) and World Health Organization (WHO 2008). The water quality indexing was done based on the weights affixed to these parameters and the overall index was taken as a weighted mean value of all the independent parametric water quality indices (Brown et al 1970).

The relative severity grading has been done on 1 to 5 grade scale in which <1 is hazard free or low, (>1to 2) is medium, (>2 to 3) is high, (>3 to 4) is severe and (>4) is critical. These gradations followed by the parametric Water Quality Indices obtained are discussed as follows. In case of Total Alkalinity (TA) the following gradation grouping was done:

TA, mg/l	<200	200 – 400	400 – 600	600 – 800	> 800
Hazard rating	Low	Medium	High	Severe	Critical
Weight	1	2	3	4	5

The grouping was done for total hardness (TH) as mentioned below:

TH, mg/l	<200	200 – 400	400 – 600	600 − 800	> 800
Hazard rating	Low	Medium	High	Severe	Critical
Weight	1	2	3	4	5

In case of electrical conductivity status assessment the following criteria was used:

EC, dS/m	< 3	3 – 6	6 −9	9 −12	12 −15
Hazard rating	Low	Medium	high	severe	critical
Weight	1	2	3	4	5

The classified as mentioned below

Cl, mg/l	<200	200 – 400	400 – 600	600 − 800	> 800
Hazard rating	Low	Mediu m	High	Severe	Critical
Weight	1	2	3	4	5

For the status of dissolved oxygen levels indicating the relative contaminant levels, the following IS gradation was reckoned:

DO, mg/l	<2	2 – 4	4 – 6	6 -8	> 8
Hazard rating	Critical	Severe	High	Medium	Low
Weight	5	4	3	2	1

RESULTS AND DISCUSSION

The distinctive effects on physio-chemical characteristic variations between the monsoon season contaminant dumps and the post-monsoon season residuals were not so distinct (Table1). However, marked differences was observed during the pre-monsoon water table depletion phase. As regards the colour and odour both surface and groundwater samples exhibited satisfactory appearance from clear to slight grey waters and not much of odour diffusion in the vicinity during the monsoon season and the variations were within the quality criteria as agreeable by the IS or WHO guidelines. Hence the weights for these two parameters were reckoned as unity without much error.

Water Quality Indices (WQI): Parametric Water Quality Indices within the stipulated ranges on a 5 grade system suggested and the overall Water Quality indices for the monsoon and non-monsoon seasons. The weighted mean values of the parametric pre-monsoon $(WQI)_t$ for the surface water was 4.6 and for groundwater 3.6. The same for monsoon quality rating were registered at 3.8 and 3.2, respectively. The corresponding values for the post-monsoon sampling were 3.2 for surface water and 2.5 for groundwater.

Turbidity: The respective parametric indices of turbidity for monsoon season were 81.4and 77.48 NTU. During post−monsoon season were declined to 76.33 and 74.30 NTU respectively.

Total Dissolved Solids (TDS): The weighted mean values of the parametric pre-monsoon $(WQI)_t$ for the surface water was 1.9 and for the groundwater1.4. The same for monsoon and post-monsoon quality rating were registered respectively at 1.

Electrical Conductivity (EC): By and large the level of contaminant concentration in domestic or irrigation or industrial waters are limited in the EC range of 3 to 15 dS/m. However, the tested values of EC fluctuated from 2 to 6 dS/m close range. Hence, the weight ranges were stipulated as indicated in the methodology.

On this gradation criterion, the WQI during pre-monsoon period was reckoned as 2.8 for surface water and 1.8 for groundwater. During monsoon season the WQI were obtained as 1.2 for surface water and 1.1 for groundwater. However, during the post-monsoon season the WQI values were obtained as 1.3 for surface water and 1.8 for groundwater.

pH: A perusal of the pH values from the tables suggests that the pH is well within the prescribed range of 6.5 to 8.5 as per IS or WHO guidelines in relation to the relative salinity/alkalinity/neutral levels. Hence, the parametric $(WQI)_{pH}$ is taken as 1 irrespective of the monsoon or post monsoon or pre-monsoon seasons for the surface and groundwater sampling.

Total alkalinity (TA): The level of contaminant concentration in surface and groundwater sampling irrespective of the monsoon are contained well within the IS prescribed TA range of 200 − 600 mg/l. The parametric indices of total alkalinity for monsoon season stood at 378.46 mg/l for surface water and 430.00 mg/l for the groundwater. In the same line, the parametric indices of TA for the post-monsoon season were reckoned to be 359.15 mg/l and 308.13 mg/l respectively.

On this gradation criterion, the WQI during pre-monsoon period was reckoned as 4.5 for surface water and 3.9 for groundwater. During monsoon season the values of WQI were obtained as 3.4 for surface water and 3.1 for groundwater. However, during the post-monsoon season the WQI values were obtained as 4.5 for surface water and 3.1 for groundwater.

Total Hardness (TH): The parametric indices of total hardness for monsoon season were 628.21 mg/l for surface water and that for the groundwater at 596.67 mg/l. The same indices of TH for the post-monsoon season were reckoned to be 563.33 mg/l and 571.00 mg/l respectively. Even as during the monsoon rains and catchment inflows the surface and ground waters are getting softened, the receding water table during the post monsoon dry spells may again impart hardness to the fluctuating waters. The TH indexing is slightly deviating from TA, with the same permissible range of 200-600 mg/l. The observed test values of the samples are also showing a trend of variations similar to that of TA, but some sample values exceeding upto 900mg/l.By this gradation criterion, the WQI during pre-monsoon period was reckoned as 3.6 for surface water and 3.4 for groundwater. During monsoon season the values of WQI were obtained as 3.7 for surface water and 3.4 for groundwater. However, during the post-monsoon season the WQI values were obtained as 3.9 for surface water and 3.6 for groundwater.

Chlorides (Cl): Based on the gradation criterion, the WQI during pre-monsoon period was reckoned as 2.6 for surface water and 2.4 for groundwater. During monsoon season the values of WQI were obtained as 1.5 for surface water and 1.5 for groundwater. However, during the post-monsoon season the WQI values were obtained as 1.6 for surface water and 1.8 for groundwater.

Sulphate (SO_4): WHO suggests a limiting value of 500, IS 10500:2012 prescribes the range from 200 to 400 mg/l. The values for pre-monsoon, monsoon and post monsoon

Table 1. Parametric water quality indices

Parameter	Pre −Monsoon		Monsoon		Post Monsoon	
	Surface water	Ground water	Surface water	Ground water	Surface water	ground water
Turbidity	4.6	3.6	3.8	3.2	3.2	2.5
Total dissolved salts	1.9	1.4	1	1	1	1
EC	2.8	1.8	1.2	1.1	1.3	1.8
pH	1.5	1.3	1	1	1	1
Total alkalinity	4.5	3.9	3.4	3.1	4.5	3.1
Total hardness	3.6	3.4	3.7	3.4	3.9	3.6
Chlorides	2.6	2.4	1.5	1.5	1.6	1.8
Sulphates	1	1	1	1	1	1
Dissolved oxygen	5.2	5.2	4.3	4.2	5.4	5.1
Overall index	3.15	2.75	2.35	2.32	2.42	2.31
Overall hazard rating	High to severe	Medium to high	Medium to high	Medium to high	Medium to high	Medium to high

situations indicated less than 200mg/l only. Hence, the parametric water quality $(WQI)_{sui}$ in the study area confined is taken as 1 irrespective of surface or groundwater sampling

Dissolved Oxygen: By the traditional quality standards prescribed by Thomann and Miller (1987) the saturated solubility of Oxygen in water at 1 atm. pressure and an ambient temperature of 20°C is 9.09mg/l with zero chloride concentration. However, it is a bit red-signalling to observe that the contamination levels have impaired both surface and groundwater qualities with DO alarmingly less than 3 mg/l only irrespective of whether monsoon and post monsoon seasons. They have also prescribed optimum levels in the range of 5 mg/l to 8 mg/l for the survival base to fish and other water borne entities. Hence, the following weight factor distribution in the reverse grade order was made. On the gradation criterion indicated in the methodology for DO status, the WQI during pre-monsoon period was 5.2 for both surface water and groundwater. During monsoon season. the values of WQI were obtained as 4.3 for surface water and 4.2 for groundwater. However, during the post-monsoon season the WQI values were obtained as 5.4 for surface water and 5.1 for groundwater.

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CONCLUSIONS

The dissolved oxygen status was low for both surface and groundwater irrespective of the monsoon and non-monsoon phases falling below the safe recoverable range 6.5 to 9 mg/L. The Electrical Conductivity criterion for irrigation and drinking water suitability was in the safe range of 2 to 6 dS/m as against the permissible range of 3 to 15dS/m irrespective of the seasons. The pH was also within safe neutral range of 6.8 to 7.2 indicating the suitability for crop production and domestic water usage. Chloride concentration for drinking water usage was out of safe range indicating the need for dilution. Sulphate content was well within the safe water quality range of 5.1 to 5.4 only against the prescribed limit of 500.

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Removal of Chromium (VI) from Aqueous Solution using *Azolla Caroliniana* as Adsorbent

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Abstract: In this study, the batch removal of Cr (VI) ion from aqueous solution using *Azolla caroliniana* is investigated. The biosorption capacity of *Azolla caroliniana* strongly depends on the pH and the maximum Cr (VI) sorption capacities of Azolla species was obtained at pH 2. Equilibrium uptake of Cr (VI) increased with increase of Cr (VI) concentration of biomass up to 10mg -5omg/l at pH 2. The maximum Cr (VI) uptake is acquired using 0.3mm size of particles of Azolla. The maximum monolayer adsorption capacity from the Langmuir isotherm model is obtained as 110 mg/g. The maximum efficiency of chromium removal using *Azolla caroliniana* was 73.6 percent.

Key words: *Azolla caroliniana*, Biosorption, Cr (VI), pH, Contact time, Concentration

Anthropogenic activities have contaminated the water bodies throughout the world (Babu et al 2008). The major source of pollutants is industrial effluent and the discharge of industrial effluents in to the ecosystem poses a serious threat to human health, plants and animals. Inorganic waste present in industrial effluent like heavy metals has led to disastrous consequences to the ecosystem as they cannot be degraded, highly toxic and have carcinogenic effect (Vetriselvi et al 2015). Due to these harmful effects and its persistence in nature, the removal of these heavy metals from the waste becomes essential. If these heavy metals are not removed prior to its discharge to the environment it will enter the food chain and will finally accumulate in large quantity in human body. The chemical – intensive industries discharge large amount of heavy metal contaminated waste such as Cu, Cr, Cd, Ni, As and Zn. These heavy metals can be removed from the inorganic effluent by using conventional treatment processes such as chemical precipitation, electro dialysis, coagulation reverse osmosis, ion exchange and electrochemical removal (Nimmala et al 2014). But these methods have significant drawbacks like incomplete removal and production of toxic sludge. Recently, alternative methods have evolved for removal and recovery of the heavy metals. These methods are based on biological methods of removal of metals. The biosorption process is transfer of ions from solution phase (dissolved species to be sorbent) to solid phase (biosorbent). The major advantages of biosorption technology are their effectiveness in reducing the concentration of heavy metal ions and the use of inexpensive biosorbent materials. Cr(VI) or chromate is a toxic form of chromium metal and rarely occurs naturally (Samson et al 2016). The hexavalent chromium is highly toxic and most commonly produced by industrial processes (Heena Gupta et al 2016). Cr(VI) species are more mobile and is considered acutely toxic and human carcinogen. Therefore, there is currently a need for new, innovative and cost effective methods for the removal of toxic substances from the waste water. The use of natural product as biosorbent has been widely investigated as a replacement for current costly methods of removing heavy metals from industrial effluent (Tabrez et al 2017). In this study, the batch removal of Cr (VI) ion from aqueous solution is carried out using *Azolla caroliniana*. The effect of dosage, pH, contact time, adsorbent concentration and metal ion/adsorbent ratio are also studied.

MATERIAL AND METHODS

Biomass: The raw biomass of *Azolla caroliniana* was collected from contaminated water bodies in Mallippattinam at Thanjore district, Tamilnadu. The biomass was washed with tap water to remove the impurities. The cleaned biomass was then sun dried for 3 days. Dry biomass was milled and sieved. An average of 0.3mm particles size of biomass was used for biosorption experiments.

Preparation of Cr (VI) solutions: All the chemicals used were of analytical grade. A stock solution of 1000mgL-1 of Cr (VI) was prepared by dissolving 2.8287 g (99.9%) potassium dichromate in 1000mL of solution. This solution was then diluted as required to obtain the standard solutions10-50 mg L-1 of Cr (VI). pH adjustment was carried out by 0.1N HCl and 0.1 N NaOH.

Measurement of Cr (VI) concentration in aqueous solutions: In the present study, di-pheynl carbazide method was used for the analysis of Cr (VI) in the solution which only

measures the amount of Cr (VI). This method has been reportedly used in many studies for analysis of Cr (VI) at low pH. The concentration of Cr (VI) ions in the effluent was determined spectrophotometrically by developing a purple−violet color with 1,5-diphenyl carbazide in acidic solution as a complexing agent. The absorbance of the purple-violet colored solution was read at 540 nm after 20 min.

Batch experiments: The sorption of Cr(VI) on *Azolla caroliniana* was studied by batch technique. The general method used for this study is described as follows: The experiment was conducted in 250 ml borosil conical flasks containing 100ml of Cr (VI) aqueous solution at desired level of each component at the beginning of the adsorption. The flasks were agitated on a shaker at a150 rpm constant shaking rate for 60 min to ensure equilibrium is reached. In batch experiments pH, contact time and adsorption capacity studies of Azolla biomass were conducted. About 0.4g of Azolla caroliniana biomass was allowed to contact with Cr(VI) solution in the pH range of 2− 6 under the shaking condition and room temperature to study the effect of ph on Cr(VI) sorption. Next, Azolla biomass was allowed to contact with Cr(VI) solution for a certain period of time 15, 30, 45, 60 and 75 minutes condition to find the optimum time for effective sorption. The favorable pH condition and optimum time for Azolla biomass to adsorb Cr(VI) were then applied to study the adsorption capacity by varying the concentration of Cr(VI) from 10 to 50 mgL-1.

The amount of Cr (VI) adsorbed by the *Azolla Caroliniana* dry biomass at equilibrium q_e and the percentage removal of Cr (VI) (sorption efficiency in %) are calculated using the following

$$qe\,(mg\ /\ g) = \frac{(Co\ -Ce\ )V}{m}$$

$$\%\ of\ adsorbiton = \frac{(Co\ -Ce\ )}{Co} \times 100$$

where, q_e is the adsorption capacity at equilibrium in mg g^{-1}, C_0 and C_e are the initial and equilibrium concentration of Cr (VI) in mg L^{-1}, *V* is the volume of Cr (VI) solution in ml and *m* is the total amount of *Azolla caroliniana* biomass in gm.

Isotherm study: The adsorption isotherm study is a fundamental study which yields certain values of co-efficient. These values are used to quantitatively describe the interaction between the adsorbate and adsorbent in a solid – liquid adsorption system. The applicability of newer adsorbents is established only by studying the distribution of adsorbate molecules between adsorbent and solution. In this context, Langmuir and Freundlich Adsorption models were used to study the distribution of Cr (VI) ions between the absorbent and solution. The equilibrium adsorption data were fitted in to respective isotherm equation (Namasivayam et al 1995). Freundlich adsorption model assumes that adsorption takes place on a heterogeneous surface and it is not restricted to the formation of the monolayer. The linear form of the Freundlich relationship in given as,

$$Log(q_e) = Log\ K_F + 1/n\ (Log\ C_e)$$

The constants, K_F and 1/n, indicates the adsorption capacity and intensity of adsorption respectively. q_e the amount of Cr (VI) adsorbed per weight of Azolla biomass and Ce is the concentration of the adsorbate in equilibrium in the liquid phase.

Langmuir adsorption isotherm assumes that the adsorption occurs at a definite localized homogenous site and holds a single adsorbent molecule (monolayer). The linearized Langmuir adsorption isotherm is given by,

$$1/(\ q_e) = 1/q_m + 1/K_A.q_mC_e$$

Where

q_e = the amount of Cr (VI) adsorbed per weight of Azolla biomass, C_e=Equilibrium concentration of adsorbate, K_A and q_m are constants , K_A = Rate of adsorption, q_m= Maximum adsorption capacity to form a monolayer.

The Langmuir isotherm can be expressed in terms of a dimensionless separation factor R_L, is defined as

$$R_L = 1/(1+ K_A.C_o) = 0.917$$

Where C_o = Initial concentration, R_L = Separation factor

Value of R_L predict whether the adsorption process is favorable or unfavorable. If the R_L value is between 0 and 1 ($0<R_L<1$) then the adsorption process is favorable and if $R_L>1$ then the adsorption process is unfavorable.

RESULTS AND DISCUSSION

Effect of pH on Cr(VI) ion removal: Biosorption capacity decreased with an increase in the pH, maximum adsorption being observed at a pH of 2 (Fig 1). It is well known that the dominant form of Cr(VI) at this pH is HCrO4−. Increasing the pH will shift the concentration of HCrO4−to other forms such as CrO4−and Cr2O7−(Popuri et al 2007). This clearly shows that the active form of Cr (VI) that can be preferentially adsorbed by *A. caroliniana* biomass is HCrO4-2.

Effect of biomass on Cr(VI) ion removal: The removal percentage of Cr(VI) as a function of adsorbent is shown in Figure 1. The percentage of adsorption increases rapidly up to 0.8 g/ 100 mL metal solution and after that reaches saturation level. It is apparent that the removal percentage of Cr(VI) increased rapidly with increasing algal biomass due to the greater availability of more adsorption sites on surface. The decrease in the adsorption rate at higher concentration is mainly to the decrease in the active sites due to partial

aggregation of adsorbent.

Effect of contact time on Cr(VI) ion removal : The biosorption was rapid during the first 15 mins and after 15 min increase in the adsorption rate was not well pronounced. The adsorption process attained saturation in 60 mins, which was selected as optimum contact time. The rapid removal of Cr(VI) from the solution during the first 15 min is attributed to the presence of more active sites on the surface of the adsorbent (Fig. 1).

Effect of initial Cr(VI) concentration on Cr(VI) ion

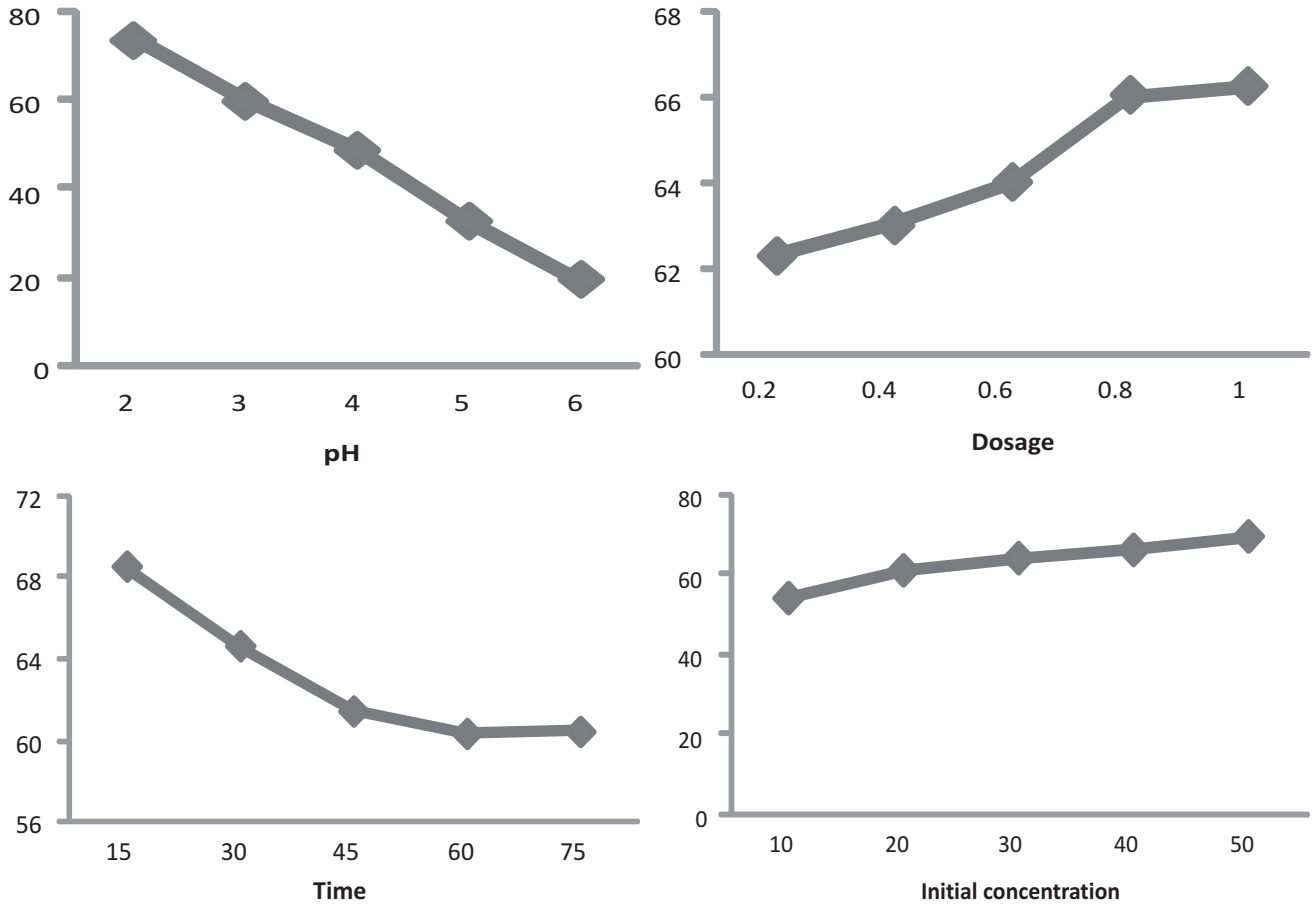

Fig. 1. Effect of different parameters on percent Cr(VI) ion absorbed

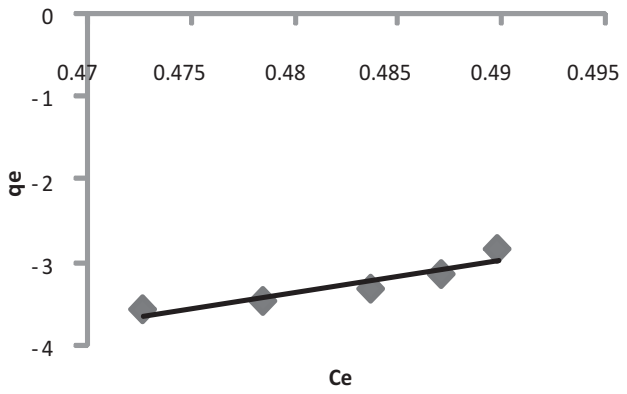

Fig. 2. Freundlich isotherm

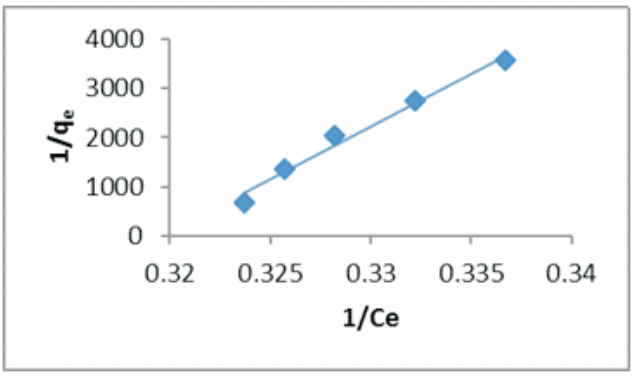

Fig. 3. Langmuir isotherm

Table 1. Comparison of adsorption capacities of *Azolla caroliniana* with other adsorbents for Cr (VI)

Adsorbent	Q_{max} (mg/g)	pH	References
Wool	41.1	2	Dakiky et al 2002
Olive cake	33.44	2	Dakiky et al 2002
Saw dust	15.82	2	Dakiky et al 2002
Almond	10.61	2	Dakiky et al 2002
Pine needles	7.08	2	Dakiky et al 2002
Coal	6.78	2	Dakiky et al 2002
Azadirachta indica leaf powder	7.43	2	Venkateswarlu et al 2007
Annona Squamosa Peel Powder	7.87	2	Krishnaa et al 2013
Citrus Limetta peel	250	2	Saha et al 2013
Unmodified groundnut shell	90	2	Samson et al 2016
Modified groundnut shell	131	2	Samson et al 2016
Azolla caroliniana	110	2	Present study

removal: When the Cr (VI) concentration is lower, the initial number of moles of metal ions is less compared to the available surface area and subsequently the adsorption process becomes independent of the initial Cr(VI) ions concentrations. However, when the Cr (VI) concentration is higher, the site available for adsorption is less therefore the removal of metal ion depends on the initial concentration. The rate of adsorption increases as the concentration of Cr(VI) ions increases from 10 to 50 mg/L. This is attributed to the fact that the site available for adsorption at the initial stage is more and if the Cr(VI) ions concentration is suf¯ciently large at this stage, the adsorbent surface is rapidly filled by the metal ions. The removal percentage of Cr(VI) as a function of initial Cr(VI) concentration (Fig. 1).

Isotherm Study: To evaluate the Freundlich constants, a logarithmic plot of Ce Vs q_e was made and a linear relationship was found to exists with a R^2 value of 0.963 (Fig. 2). The R^2 value is greater than 0.95 which indicates the applicability of this model for this study (Shadreck et al 2013).

The value of K_F and 1/n are 0.0025 and 0.241, respectively. The value of 1/n is closer to zero which shows that the surface has becomes more heterogeneous. It is also a positive value which indicates a favorable adsorption process. A graph of $1/C_e$ Vs $1/(q_e)$ was plotted for Langmuir adsorption isotherm and it follows a linear path as shown in the figure 3. The correlation coefficient R^2 value is found to be 0.978 which is very much closer to 1 indicating that Cr (VI) adsorbtion follows the Langmuir adsorption isotherm.

The maximum monolayer adsorption capacity of Azolla biomass is 110. This show that Cr (VI) has affinity towards Azolla biomass. The values of Langmuir isotherm constants K_A and q_m were 5.818×10^{-5} and 110. In this study, R_L value is 0.997 which is between 0 and 1 and indicates that the adsorption process is favorable.

Comparison of Cr (VI) adsorption of different adsorbents: The adsorption capacity of previously reported adsorbents was compared with the present research. The maximum adsorption capacity of Azolla caroliniana at pH 2 is comparatively higher than most of the reported adsorbent (Table 1). The results of this study clearly indicate that Azolla caroliniana can be used as an effective adsorbent to remove the Cr (VI) from aqueous solution. However Citrus Limetta peel and Modified groundnut shell showed higher maximum adsorption capacities of 250 and 131 respectively at a pH of 2.

CONCLUSION

The present research presents *Azolla caroliniana* dry biomass as adsorbent for effective removal of Cr (VI) ion from the aqueous solution. The removal efficiency was dependent on contact time, initial concentration and pH. Biosorption capacity decreased with an increase in the pH, maximum adsorption being observed at a pH of 2. The percent removal of Cr (VI) rapidly increased for the first 15min while increasing the contact time, the percentage removal became constant after lapse of 60minutes. Therefore, the optimum contact time for Azolla biomass was 60 minutes. The percentage removal was constant after 0.8 grams of concentration of *Azolla caroliniana*. The optimum dosage for Azolla biomass was concluded as 0.8grams/100ml at a pH of 2. The maximum efficiency of chromium removal using *Azolla caroliniana* was 73.6%. This elucidates that dry biomass of *Azolla caroliniana* can be effectively used as an adsorbent from the removal chromium ions from the aqueous solution.

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Feathers of Feral Pigeons (*Columbia livia*) as Bioindicator for Heavy Metals Pollution in Jaipur, India

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Abstract: Biological indicators are used to ascertain and monitor the health and functioning of ecosystem. This study investigates whether feral pigeons (*Columbia livia*) can be used as bioindicators for heavy metal pollution in an urban environment. The concentrations of copper (Cu), cadmium (Cd), lead (Pb) and zinc (Zn) were analysed in the contour feathers of pigeons. The average range concentration of Cu was 7.05 to 9.07 ppm, Cd was below the range of 0.02 to 2.02 ppm, Pb was 2.37 to 3.0 ppm and Zn was in range of 27.14 to 35.13 ppm. There was no significant difference between the concentrations of metals between various sites. Feathers reflect the body burden of metals and also can be used as a non-invasive tool for indicating the metals concentration of pigeons which indirectly indicates the metal pollution of an environment.

Keywords: Feathers, Heavy metals, Urban environment, Feral pigeon, Non-invasive

Heavy metal pollution has been an increasing problem in the last decade. Although the threat that heavy metals pose to the environment and its ecosystems have been know because of previous research only a few measures were undertaken to reduce the release of heavy metals into the environment. All metals with a density higher than 5 g/cm3 are called heavy metals. For example iron, copper, lead, cadmium, mercury, zinc, nickel and manganese (Vashishat and Kler 2014). Some of these metals like Copper and Zinc are essential micronutrients and therefore a limited amount of them is required within the body. In general heavy metals are persistent, highly accumulative and in certain concentrations toxic. To assess the pollution of the environment bioindicators have become an essential method. Many species have been proposed as suitable bioindicators but especially birds have become a general favourite since they are at a high trophic in the food web and tend to be more sensitive to environmental pollution than other vertebrates (Vashishat and Kler 2014). The diet of birds is very diverse the content of heavy metals in their bodies, therefore, reflects the contamination of their entire territory (Adout et al 2007). When deciding on a species of bird for a bioindicator it is necessary to use common species with a wide distribution in order to prevent further stress to an already endangered species. Another advantage of using species that is adapted to different habitats is the possibility of a comparison between different environments.

The feral pigeon (*Columbia livia*) is one of the most abundant species in the urban environment and it is known for its exceeding good adaptation to an anthropogenic environment. Therefore, it is self-evident to think of the feral pigeon as a possible species for a bioindicator. Previous studies have also shown that pigeons tend to stay in a fixed territory which offers the possibility of studying local effects (Frantz et al 2012). If birds are used as a bioindicator two general types of tools can be used for the analysis. Invasive tools, which include the analysis of internal organs such as liver and kidney or non-invasive tools where only fecal matter, egg shells or feathers are used. In this study a non-invasive tool was used in order to preserve the life of the pigeon. Feathers are metabolically inert after formation, so for those avian species with well known moult schedules, the analyses of specific individual feathers provide unique chemical information. There are several advantages for feather as monitoring units, first, they are easy to obtain and can be observed for a long period, so feather is useful for long when large number of samples are needed. The aim of the study is to investigate feathers of feral pigeon are suitable bioindicator of metal pollution in urban environment.

MATERIAL AND METHODS

Collection of samples: Feral pigeon feathers were collected from several sights within and outside of Jaipur. The 5 sites within Jaipur were Malviya Nagar, Albert Hall, on the roadside close to Albert Hall, near Hawa Mahal and behind Hawa Mahal. On all sites except the one at Albert Hall the pigeons received food from the people. The site outside of Jaipur was located at the campus of JECRC University in the industrial

area of Sitapura. No food was provided for the pigeons there. All types of contour feathers were collected.

Treatment of samples: Samples had been collected in paper bags from 6 different sites for each site 15-20 samples were used. After the collection the feathers were washed first with normal water and afterwards again with distilled water. They were air-dried overnight between two sheets of filter paper. To reduce the remaining amount of water they were also dried in an oven for 30 min at 50˚C. Afterwards the feathers were cut into small pieces with a scissor. Then for each site samples each weighing 0.1 g were put into test-tubes. For the digestion of the feathers 1 ml of 70% concentrated nitric acid was added to each tube and the tubes were placed in a hot water bath with 100˚C for 90 minutes. Then 0.5 ml of 30 % hydrogen peroxide was added to neutralize the solution and the tubes were heated in the water bath for another 30 minutes. The solution was then transferred to plastic tubes and diluted with deionized water to a total volume of 10 ml.

Heavy metal analysis: The samples were analysed with an AA500 atomic absorption spectrometer (AAS). The concentration of cadmium, copper, lead and zinc were analysed at 228.8 nm, 324.7 nm, 217.0 nm and 213.9 nm respective wavelengths. The mean concentration of the metal was calculated in parts per million (ppm) by the following formula:

$$\text{Concentration [ppm]} = \frac{\text{Mean of AAS readings x Dilution factor[ml]}}{\text{Weight of Sample [g]}}$$

Dilution factor = 25 ml, dry weight of sample = 0.1 g

RESULTS AND DISCUSSION

Lead*:* The lead concentrations in the feathers were similar for all sites. The lowest concentration of 2.5 ppm was found at Albert Hall, the highest concentration of 3.0 ppm was found in the sample from JECRC University (Table 1).

Zinc: The concentrations of Zinc in the feathers were higher than the lead concentrations. The highest concentration of Zinc was in the feathers at Malviya Nagar, 35.130 ppm and the lowest behind Hawa Mahal 27.140 ppm (Table 1). There are no differences between the concentrations from different sites.

Copper: The concentrations of copper were even lower than the concentrations zinc but still higher than the levels of lead. The highest concentration of copper, 9.070 ppm was in the sample at Malviya Nagar. The lowest concentration of 7.050 ppm was at JECRC University Campus (Table 1). The concentrations of copper are very similar at all six sites.

Cadmium: The analysis with the AAS could not detect absorption of cadmium. The working range of the AA500 atomic absorption was 0.02-2.20 ppm.

The metal with the highest concentration in the feathers was zinc, followed by copper and lead. Cadmium was not detectable at any of the six sites investigated. There were only minor differences between the concentrations of the three metals at the six sites. The levels of heavy metals are in accordance with results from previous research. In Israel lead levels of 0.29 µg/g were in the control group and of 10.3 µg/g were in industrial areas (Adout et al 2007). The levels measured in Jaipur are in the middle of that range and fit the results for an urban environment. The same applies for the concentration of copper and zinc (Table 1).

Other studies support the results for cadmium obtained here. In Paris, 0.08 µg/g concentrations of cadmium were in urban areas (Frantz et al 2012). In the city of Santa Cruz on Tenerife the cadmium levels were at 0.0231 µg/g wet weight

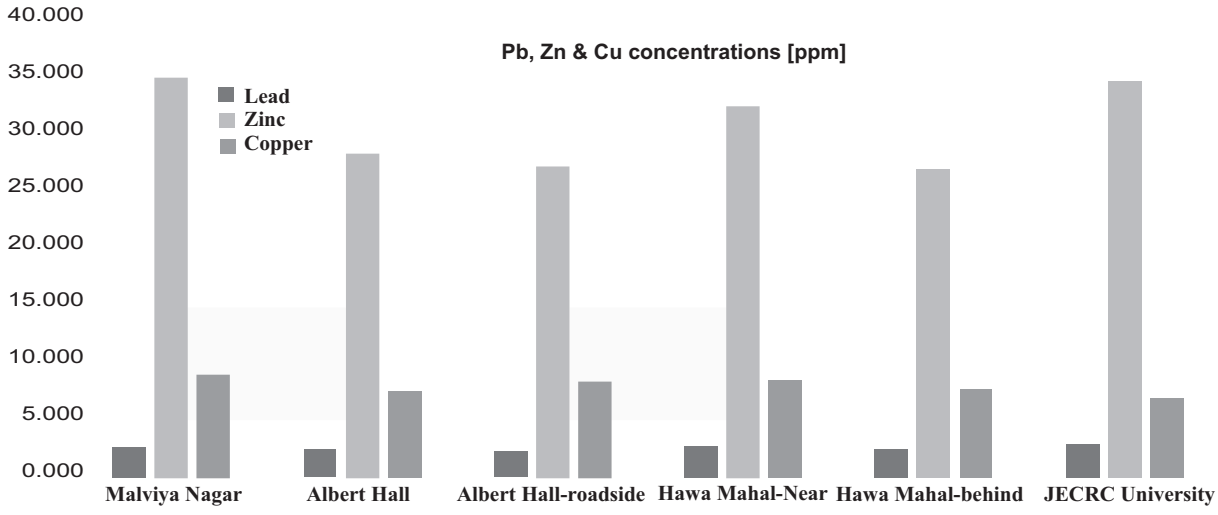

Fig. 1. Comparision of lead, zinc and copper concentrations in ppm at six sites of Jaipur

Table 1. Concentration of copper, cadmium, lead and zinc in feathers of feral pigeon (*Columba livia*) for different sites of Jaipur

Site (number of samples)	Concentration (ppm± S.D)			
	Copper (Cu)	Cadmium (Cd)	Lead (Pb)	Zinc (Zn)
Malviya Nagar (11)	9.070 ± 4.609	ND	2.750 ± 0.031	35.130 ± 16.619
Albert Hal l(15)	7.640 ± 4.732	ND	2.500 ± 0.023	28.510 ± 14.976
Albert Hall – Road (10)	8.435 ± 2.479	ND	2.375 ± 0.117	27.370 ± 12.171
Hawa Mahal – Near (13)	8.515 ± 3.867	ND	2.875 ± 0.131	32.695 ± 14.699
Hawa Mahal – Behind (16)	7.760 ± 3.740	ND	2.625 ± 0.119	27.140 ± 14.039
JECRC University Campus (18)	7.050 ± 4.792	ND	3.000 ± 0.084	34.775 ± 14.696

*ND−Not detectable below 0.02-2.02 ppm

(Torres et al 2010). This is very close to the lower end of the working range of 0.02 ppm in this study. Therefore, it might be realistic to find values below 0.02 ppm in an urban environment. In addition, the concentration for copper 9.607 µg/g wet weight and 2.696 µg/g wet weight for lead measured at Santa Cruz (Torres et al 2010) are again very similar to results obtain for the sites in Jaipur (Table 1).

Only the concentrations of zinc obtained in Jaipur are considerably lower than those reported in most of the previous research like 204.80 µg/g in Paris (Frantz et al 2012) and 144.9 µg/g wet weight in Santa Cruz de Tenerife (Torres et al 2010). Similar levels of heavy metals were also found in other bird species. In the feathers of sparrow hawks (*Accipiter nisus*), little owls (*Athene nocta*) and barn owls (*Tyto alba*) from Belgium concentrations of 0.05-0.33 ppm for cadmium, 0.606-9.13 ppm for copper, 2.51-9.9 ppm for lead and 23.8-74 ppm for zinc were found (Dauwe et al 2003). Another study from Egypt found concentrations of 7.070 ppm copper in the moorhen and 10.29 ppm in little grebe (Salah-Eldein et al 2012) which are very similar to the concentrations measured in the feathers of the feral pigeons (compare Table 1). The results are also in line with a recent study analysing the concentration of heavy metals in vegetables around Jaipur. Although the ranges are very wide, the levels ranging from 1.40-71.06 ppm for lead, 0.61-34.48 ppm for cadmium, 0.39-187.26 ppm for zinc (Kumar and Verma 2014) fit the results. An analysis of the soil and air pollution at the sites of the feathers would be necessary for an in-depth comparison. In addition, the food provided for the pigeons at the five sites needs to be analysed. In order to determine the uptake of heavy metals by the pigeon the concentration of heavy metals that is potentially available to pigeons needs to be investigated. That means the concentration of the metals in the habitat of the pigeons would have to be analysed for a more detailed comparison. Another fact that should be taken into account, concerning the concentration of lead, is the mandatory introduction of unleaded gasoline in India in 2000. There might have been a strong decrease in the contamination with lead due to this measure. Although a study from South Korea opposes that theory and found that levels of lead have been remaining at the same levels as in 1991 although in South Korea unleaded gasoline was introduced in 1993 (Nam and Lee 2006).

On the other hand, there are also previous results using feathers of feral pigeons, which could not identify differences in the concentrations among the locations (Begum & Sehrin 2013). This alludes to the assumption that studying local effects might depend entirely on the sites that are examined. Therefore, the difference in the environmental concentration of heavy metals in the six sites investigated in the present study might have been too small and therefore no significant differences appeared in the concentrations in the feathers of the pigeons. This theory is likely since four of the six sites were rather close to each other and in the same area of Jaipur. The old city of Jaipur is an urban area with lots of traffic. The site on the outskirts of Jaipur, Malviya Nagar is close to a very big highway. Because of that, it might face the same amount of pollution as the sites in the city centre. Finally, the site at JECRC University is far outside of Jaipur and there is not much traffic in the area but it is located in the Sitapura Industrial area. The pollution originating from the industry might account for the concentrations of heavy metals. Additionally the Pigeons were not fed at the University and the diet must therefore, vary greatly in comparison to the other sites of Jaipur

CONCLUSION

The analysing metal content of feral pigeon feathers provides an authentic, non-invasive tool for indicating environmental changes like pollution which increases the metal burden of the environment. Feather is a representing structure of pigeon body in which metals deposition occurs through inhalation and ingestion than after absorption into blood. So feather can be used as internal body organ in this case. Therefore, they can be used as non-invasive bioindicators of metal pollution

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Zoning and Trends of LGP Sowing Period in North-west India under Changing Climate using GIS

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Abstract: A study was conducted to quantify trends, variability and spatial distribution of length of growing period (LGP) in north-west India. For this purpose more than 30 years daily data on rainfall, maximum and minimum temperatures was collected from twenty two different agrometeorological stations situated in NW India. The map of north-west India was digitized and four LGP zones (<120 days, 120–180 days, 180-240 days and >240 days) were delineated using GIS. Growing period increased toward centre both from south and north end of the study area. Trends in LGP for different meteorological stations, hills, plains and north-west India were evaluated using trend analysis. Among stations the normal length of growing period was maximum for Manali and Ranichauri (365 days) and lowest for Ganganagar (59 days). The normal LGP for annual was 299.5, 151.9 and 191.9 days with coefficient variation of 17.5, 38.3 and 45.4 per cent for effective growing season normal LGP was 184, 73 and 103 days with coefficient variation of 45.5, 60.2 and 25.4 per cent and for dormant season it was 116, 78 and 89 days with coefficient variation of 25.4, 42.3 and 40.4per cent for hills, plains and north-west India, respectively. The highest LGP was observed in hills followed by plains and north-west India. A non-significant increasing trend was observed in rainfall, PET and LGP over north-west India.

Keywords: GIS, Length of Growing period, North-west India, Trend analysis, Zoning

The concept of the growing period is essential to crop ecological zoning and provides a way of including seasonality in land resource appraisal. Crops grow best in locations where the optimum climatic conditions and sufficient growing period is available. It was assumed that during the length growing period (LGP) the monthly rainfall had to be at least 50 per cent of potential evapotranspiration (PET) and that the mean daily temperature had to exceed 5˚C.LGP is an important variable determining carbon assimilation and evapotranspiration from vegetation and soils (Euskirchen et al 2006) at same time it is also an important constraint on agricultural productivity, particularly in colder climate (Olesen et al 2002). Probably the first serious attempt to use computers help to integrate climate, soil and plant information in order to determine agro–ecological zones throughout the world was that reported by Ghaffari et al (2000).

Under the global warming scenarios the changes in temperatures have shifted phenological phases, life spans and affected crop yields (Chmielewski et al 2011, Jangra and Singh 2011). Changes in the length of the growing season can have both positive and negative effects on the yield and prices of particular crops. Overall, warming is expected to have negative effects on yields of major crops, but at some individual locations may have beneficial effects (IPCC 2014). The season tends to end by about 10–12 days earlier per decade leaving long term impacts on agriculture and horticulture production (Baul and McDonald 2015). Length of growing period has been shown to increase by 4-6 days for every degree increase in annual average air temperature (White et al 1999). Kunkel (2014) reported that the average length of the growing season in USA has increased by nearly two weeks since the beginning of the 20th century and it has increased more rapidly in the West than in the East. Length of the growing period (LGP) is a very important concept to assess the crop production potential of a particular locality. Keeping the importance of the length of growing period for growing of different crops, the present study was undertaken with the objectives to delineate different LGP zones and its trend in north-west India which may be very useful for the growers in the selection of crops and varieties to enhance cro pproduction.

MATERIAL AND METHODS

Study sites: Twenty two meteorological stations, Srinagar, Jammu (Jammu and Kashmir), Manali, Shimla, Palampur, Solan (Himachal Pradesh), Ranichauri (Utrakhand), Ludhiana, Bathinda, Patiala (Punjab) Chandigarh, Ambala, Karnal, Rohtak, Sirsa, Hisar, Bawal, Narnaul (Haryana) Delhi, Sriganganagar, Jaipur (Rajasthan) Saharanpur and in

Uttar Pradesh located in north-west India were selected for the study. The experimental site was the north-west India, which approximately is located between 26^{0}40′ to 37^{0}10′ N latitude and between 72^0 50′ and 81^0 00′ E longitudes. The altitude of area varies between 200 to 8600 meters above mean sea level. Total area of the site is approximately 5 lakh square km out of this 1000 thousand hectare is covered under the fruit crops. It has geographic features like the cold desert, the coldest place on the earth (Akbar et al 2013), the Higher Himalaya, the Middle Himalaya, the Lower Himalaya, the Shiwalik hills, semi desert sandy plain and the Aravali range and the hot Thar Desert.

The geographical information (latitude, longitude and altitude) of all the stations is given in Table 1. Based on the altitude, the study area was divided >1000 meters as hills (Srinagar, Manali, Shimla, Palampur, Solan and Ranichauri) and < 1000 m as Plains (Jammu, Chandigarh, Ambala, Saharanpur, Delhi, Karnal, Patiala, Ludhiana, Rohtak, Bathinda, Hisar, Sirsa, Bawal, Narnaul, Ganganagar and Jaipur).

Data collected: Daily rainfall and maximum and minimum temperature data of twenty two locationsfor the year 1980 to 2014 and at Srinagar, Palampur, Ranichauri, Ranichauri, Sirsa, Bawal from 1985 to 2014, respectively were used for the study. These data were collected from India Meteorological Department, Central Research Institutes for Dry Land Agriculture (CRIDA), revenue department and state agricultural universities.

Calculation of PET: The Thornthwaite method (1948) was used for estimation of PET

$$PET = 1.6\,(10T/I)^a\,(D/12)\,(N/30)$$

For a month consisting 30 days and 12 hours a day, the above equation can be written as:

$$E = 1.6(10T/I)^a$$

Where, E = Unadjusted PET, cm/month, T = Mean air temp ˚C, I = Annual heat index. It is the summation of 12 values of monthly heat indices $i.i = (T/5)^{1.514}$,

a = an empirical exponent computed by an expression given as,

$$a = 6.75x10^{-7}\,I^3 - 7.71x10^{-5}\,I^2 + 1.79x10^{-2}I + 0.49239$$

For daily computation the equation is modified as:PET = (KxEx10)/30 (mm/day)

Where, K = Adjustment factor

Length of growing period: Long-term weekly data on rainfall and potential evapotranspiration (PET) were analyzed for calculation of length of growing period (LGP). The LGP is the period in days during a year when rainfall (P) exceeds half the potential evapotranspiration plus a period required to evapotranspiration assured estimated stored moisture (S) (Higgins and Kassam 1981). Lengths of growing period in individual years were calculated using Excel spreadsheet for the period of time that P + S exceeds 0.5 PET. The yields of many common crops decline markedly if the soil moisture falls below this level (Doorenbos an Kassam 1979). The soil moisture storage capacity was assumed to be uniform throughout the state, because a particular soil type was scattered irrespective of rainfall and PET zones. The LGP excludes any period in which the temperature is below 5°C unfavorable for crop growth. The LGP is the period in days during a year when rainfall exceeds half the potential evapotranspiration plus a period during which half of PET is met by assured estimated stored moisture (Higgins and Kassam 1981). Following formula was used:

$$LGP = d(P \geq PET/2) + 2ASM/PET$$

Where, d = day and ASM= Assured stored soil moisture

Calculation of statistical measures: Statistical measures like normal (long period average) standard deviation, coefficient of variation, slope and regression coefficient were computed using 'OP Stat" software from daily rainfall and potential evapotranspiration data of more than 30 years at each station. Monthly annual and seasonal statistical measures were computed for each station, hills, plains and north-west India, respectively

Table 1. Geographical information of different meteorological stations

Station	Latitude	Longitude	Altitude (m)
Srinagar	34.09	74.79	1600
Manali	32.27	77.17	2050
Shimla	31.11	77.17	2397
Palampur	32.12	76.53	1219
Solan	30.92	77.12	1600
Ranichauri	30.06	78.99	1950
Jammu	32.73	74.87	327
Chandigarh	30.75	76.78	321
Ambala	30.38	76.78	264
Saharanpur	29.96	77.54	268
Delhi	28.62	77.21	216
Karnal	29.69	76.98	245
Patiala	30.34	76.38	350
Ludhiana	30.91	75.85	244
Rohtak	28.89	76.57	220
Bathinda	30.23	74.95	201
Hisar	29.15	75.71	215
Sirsa	29.53	75.01	205
Bawal	28.08	76.58	266
Narnaul	28.01	76.01	308
Ganganagar	29.92	73.88	178
Jaipur	26.91	75.81	431

1-6 represents hill and rest plains division

Preparation of LGP maps: LGP map was prepared in the GIS environment using Arc GIS 10.1with following steps:

1. The hard copy of the map of the study area was digitized and shape file was created.
2. NW India polygon shape file was selected.
3. The latitude-longitude values of each of 22 points were find out and converted to degree-decimal format to enter in GIS.
4. The coverage file (point) was then generated from the location data in Arc info GIS.
5. The thermal and LGP data entered as attribute table and attached/joined to the point file already generated.
6. Then the point file was interpolated by GIS tools and converted to raster format by krigging/radial basis interpolation function.

RESULTS AND DISCUSSION

Length of growing period (LGP): The rainfall and PET was showing anon-significant increasing trend in north-west India (Fig. 1) with a rate 5.5 and 1.6 mm per year, respectively. The annual normal length of growing period was 299.5 days for hills, 151.9 days for plains and 191.9 days for north-west India with coefficient of variation of 17.5, 38.3 and 45.4 per cent, respectively. The normal length of growing period for effective growing season was 184 days for hills, 73 days for plains and 103 days for north-west India with coefficient variation of 45.5, 60.2 and 25.4 per cent and for dormant season, it was116,78 and 89 days with coefficient variation of 25.4, 42.3 and 40.4 per cent for hills, plains and north-west India, respectively. The coefficient of variation was more during effective growing season as compared to the dormant season (Table 1). A growing period of more than 300 days was available at Manali, Palampur, Solan and Ranichauri, between 300-200 days at Srinagar, Shimla, Jammu, Chandigarh, Patiala, Saharanpur, between 200–100 days at Ambala, Delhi, Karnal, Ludhiana, Rohtak, Bathinda, Bawal, Narnaul and less than 100 days at Sirsa, Ganganagar and Jaipur, respectively (Fig. 2). The longest growing period of 365 days was observed at Manali and shortest of 59 days at Ganganagar.

Spatial distribution of LGP: Length of the growing period (LGP), a concept introduced by the UN Food and Agriculture Organization, to assess the crop production potential of a particular locality. It is very useful as it describes an area within which rainfall and temperature conditions are suitable for crop growth for a given number of days in the year. Growing periods were computed based on availability of water for raising crops in different parts of the study area excluding areas having temperature less than 5°C and are depicted in Fig. 3. Based on water availability to meet the half of the crop water demand, the study area was divided into four growing zones. Growing period of 3 month was observed in both south-west to north-east and increased up to 8 months toward central part of study area. Cold desert, Kargil and upper Himalayan part of Jammu and Kashmir in north–east and arid hot desert in south-west comprised of less than 120 days LGP (Map 4.5.5). A part of south-west Uttar Pradesh, central Haryana, central Punjab and south-west Jammu and Kashmir comprised 120–180 days. South–western Uttar Pradesh, northern Haryana and Punjab and south-western Jammu and Kashmir comprised 180-240 days. A growing period of more than 240 days was available in some parts of Uttar Pradesh touching Utrakhand, whole of the Utrakhand, Himachal Pradesh and Jammu areas of Jammu and Kashmir except Lahau land Spiti of Himachal Pradesh.

Length of the growing period (LGP) is a very important concept to assess the crop production potential of a particular locality. Kunkel et al (2014) provided a complete description of the analytical procedures used to determine length of growing period (LGP) and trends. Based on water availability to meet the half of the crop water demand, the study area was divided into four growing zones(<120 days, 120–180 days, 180-240 days and >240 days) depicted in Map 2. Growing period of 3 months was observed in both south-west to north–east ends and increased up to 8 months toward central part of study area. Cold desert, Kargil and upper Himalayan part of Jammu and Kashmir in north-east and arid hot desert in south-west comprised of less than 120 days LGP having limited crop production as Fischer et al (2009) reported that a length of growing period shorter than 120 days at any area or locality was considered to pose a sever constraints in agricultural production system. A part of south-west Uttar Pradesh, central Haryana, central Punjab and south-west Jammu and Kashmir comprised 120–180 days and having moderate constraints to crop production (Fischer et al 2009, Singh and Bhatia 2011). South-western Uttar Pradesh, northern Haryana and Punjab and south-western Jammu and Kashmir comprised 180-240 days. A growing period of more than 240 days was available in some parts of Uttar Pradesh touching Utrakhand, whole of the Utrakhand, Himachal Pradesh and Jammu areas of Jammu and Kashmir except Lahaul and Spiti of Himachal Pradesh having the prospects of good crop production.

Bal et al (2009) computed the length of growing period for agro-ecological zones of entire state of Punjab depicting the constraints and prospects of crop production in the state in changing climate. Similar study was carried out by Sehgal et al (1992) for India. Climate changes between now and the

Table 2. Statistical measures for LGP (days) in north-west India

Parameters	Annual			Effective growing season (Mar-Oct)			Dormant season (Nov-Feb)		
	Hill	Plain	NW	Hill	Plain	NW	Hill	Plain	NW
Normal	299.5	151.6	191.9	183.5	73.0	103.0	116.0	78.0	89.0
SD	52.3	58.0	87.2	47.3	33.2	62.1	29.5	33.2	35.9
CD (p=0.05)	17.5	38.3	45.4	25.8	45.5	60.2	25.4	42.3	40.4

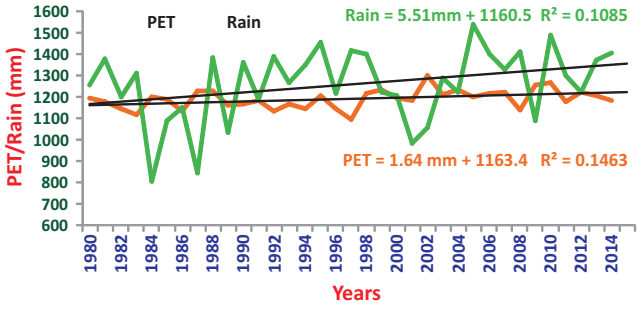

Fig. 1. Trend in rainfall and PET in NW India

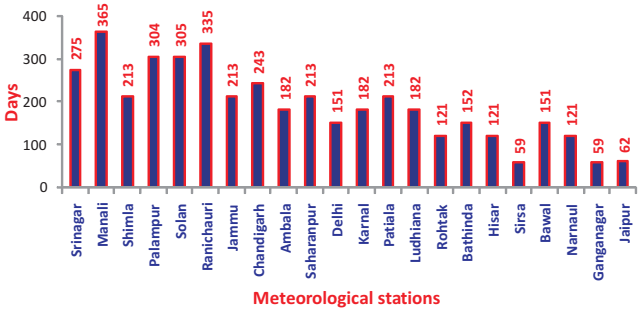

Fig. 2. Annual normal LGP available at different stations in north-west India

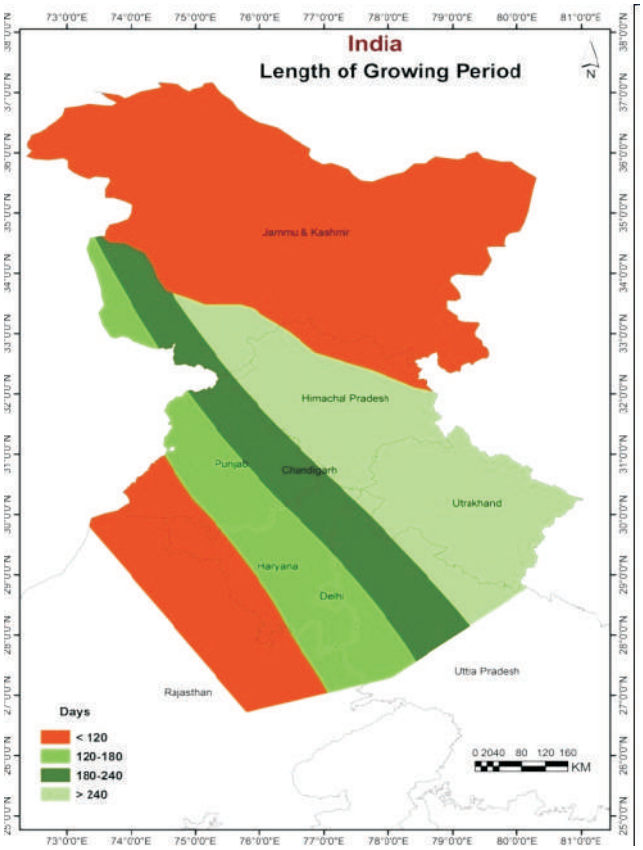

Fig. 3. Different LGP zone of NW India

2050s may significantly affect the length of growing periods in different crop growing regions of the world hence, some individual locations might be benefited with the increase in length of growing period (IPCC 2014, Philip 2014). In the present study higher and increasing trend in LGP in hills as compared to plains was probably due to more rainfall and low temperatures in comparison with the plains. A non-significant increasing rate was observed in the length of growing period, rainfall and PET over the study area. Similar results were observed by Jangra and Singh (2011) in rainfall and temperatures over Kullu valley of Himachal Pradesh.

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Effect of Different Drying Techniques on Quality of Red Chilli Powder

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Abstract: The experiments were carried out to analyze the effect of sun drying, improved sun drying and mechanical drying at 50, 60 and 70ºC on different quality parameters of red chilli powder namely ascorbic acid, capsaicin content, colouring matter and oleoresin content. Whole and slit chillies were used for the experiments. Mechanical drying at 50ºC showed the best quality in terms of all the quality parameters after every drying technique. Quality of the product reduced significantly during sun drying and mechanical drying at 70ºC. Improved sun drying technique was much better than sun drying technique in terms of different quality parameters.

Keywords: Ascorbic Acid, Capsaicin Content, Colouring Matter, Drying Techniques, Oleoresin Content, Physical Treatment, Red Chillies

Pepper is an important agricultural crop of India due its economic importance and for the nutritional value of its fruits that are an excellent source of natural colours and antioxidant compounds (Nevarro et al 2006). Different fruit characteristics like pungency, colour, shape, flavor, size, and their uses are used to classify the peppers In Asian cuisines dried chilli (*Capsicum annuum* L.) is one of the most widely used spice product as condiments for flavoring and colouring (Jitbunjerdku and Kijroongrojana 2007, Toontom et al 2010). A number of different parameters such as colour, hotness, ascorbic acid content and volatile flavor compounds are used to assess the quality of dried chilli (Wang et al 2009, Yaldiz et al 2010). Traditionally, sun drying was used to obtain the dried chilli and to reduce the moisture content of chilli to 10–15% approximately 7–20 days are needed depending on the weather conditions (Oberoi et al 2005). Currently for drying chilli, hot air drying is popular method due to a relatively short drying time, uniform heating and more hygienic characteristics. The temperature for this method ranges from 45 to 70^{0}C (approximately 10% of moisture content), and takes about 20 hours (Díaz-Maroto et al 2003, Berke and Shieh 2001).

Sun drying technique is not a time effective technique, is extremely weather dependent and has the problem of contamination with dust, soil and insects. While the mechanical drying technique is not a cost effective technique and leads to serious injuries such as the worsening of the taste, colour and nutritional content of the product, decline in the density and water absorbance capacity and shifting of the solutes from the internal part of the drying material to the surface, due to high drying temperature. Keeping the above problems, present work was focused on modifying the sun drying technique in order to minimize the problems associated with the sun drying technique and then comparing it with the other drying techniques in terms of their effect on the quality of red chilli powder.

MATERIAL AND METHODS

Raw material and sample preparation: The fresh red chillies of variety Punjab Sandhoori were procured from the Vegetable Farm of Department of Vegetable Science, PAU Ludhiana and were thoroughly sorted and graded. Green and partially red chillies were separated and discarded. The cleaned product was then weighed and was given physical treatment of slitting to half of the lot and making two lots as whole and slit chillies. Initial moisture content of the chillies was determined by standard oven drying method (AOAC, 1975) and chillies were dried using following techniques.

Sun drying: The drying was carried out under sun and samples were placed on perforated trays placed on the floors.

Improved sun drying: The drying was carried out under sun and samples were placed on a perforated wire mess table raised from the ground by about 2.5 ft (Fig. 1). The improved sun drying method was used to provide a better flow of air through the sample as compared to traditional sun drying method where the chillies were placed on the floor. This could result in relatively faster drying.

Fig. 1. Improved sun drying of whole and slit chillies

Mechanical drying: Drying experiments were carried out in a laboratory scale cross-flow tray dryer at a temperature of 50ºC, 60ºC, 70ºC and a fixed air flow rate of 0.8–1 m/s. The tray dryer consisted of a cabinet containing a series of perforated trays that carry the sample to be dried stacked one upon the other. Hot dry air was blown from the base of the dryer, passes through the perforation and sample. The moist air escaped the cabinet from the top through an opening.

In all the three methods samples of known quantity were placed on the trays and samples in the trays was continuously measured at regular time intervals. Drying was carried out until change in weight of sample became zero.

Quality characterstics of chillies

Ascorbic acid: The ascorbic acid content was measured by using the standard method as given by AOAC (1975). 5 gram powder of dried chillies was taken and extracted with 50 ml of 3% metaphosphoric acid solution. This solution was then filtered. 2 ml of this filtered solution was titrated against 2,6–dichlorophenol iodophenol dye. Ascorbic acid content was calculated by using the following formula as below:

$$Ascorbic\ \ ac\,id\left(\frac{mg}{100\ g}of\ dried\ \ powder\right)=\frac{1\times 25\times 100\times V}{D\times 5\times 2}$$

Where, D = Standard dye (Volume of dye used for 1 mg of ascorbic acid); V = Volume of dye used for sample (ml)

Capsaicin content: The capsaicin content was measured by using the method as given by Bajaj and Kaur (1979). 0.5 gram powder of dried chillies was taken and extracted with 25 ml of ethyl acetate. The mixture was shaken and allowed to stand overnight. 2 ml of the extract was passed through the basic alumina column (10 cm x 1 cm) and pure capsaicin was obtained. This column was made by putting the glass wool at the bottom, a layer of basic alumina (about 1.5 gm) in the middle and 1 cm layer of sodium sulphate on the top in the column of about 1 cm diameter and 20 cm height. After passing the extract, the column was washed with 5 ml acetone thrice. Pure capsaicin was eluted with methanol: acetone: water solvent system (75:25:1) collecting 50 ml. 10 ml of this solution was taken in a beaker and was kept for 24 hours so that the complete evaporation takes place. Then 0.5 ml of folin′s reagent and 6.5 ml of distilled water was added in the beaker. It was allowed to stand for 3 minutes. Then 1 ml of saturated sodium carbonate was added and the volume was made to 10 ml by adding distilled water. The optical density of this solution was read in the spectrophotometer (Spectronic 20) at 760 nm wavelength. Capsaicin content was calculated from the calibration curve which was prepared by using the pure capsaicin.

Coloring matter: The colouring matter was measured by using the method as given by Rosebrook et al (1968). 25 mg powder of the dried chillies was taken in a volumetric flask. The volume was made 100 ml by taking acetone. The sample was kept in dark for about 4 hours. The optical density of this sample was read from the spectrophotometer (Spectronic 20) at 460 nm wavelength. Colouring matter was evaluated using the following formula:

Where, ASTA units = American Spice Trade Association units and O.D. = Optical density

$$Colouring\ matter\ (ASTA\ units)=\frac{\text{O.D.}\times 16.4}{Sample\ weight\ (g)}$$

Oleoresin content: The oleoresin was extracted in a Soxhlet apparatus using acetone as a solvent by Wesołowska et al (2011). Approximately, 20gm powder of the dried chillies was taken into a thimble and placed in a Soxhlet apparatus. The apparatus was set up with acetone solvent and extraction was carried out for 6 hours. After completion of extraction the dark red extract was obtained and then it was cooled, filtered, and concentrated. The volume of dark red concentrated extract was recorded and 5 ml of the extract was poured into a Petri dish. The excess methanol was allowed to evaporate from the Petri dish at room temperature to obtain a thick sticky dark brown mass. This crude dried mass was weighed and the oleoresin content was estimated using the formula:

$$C=\frac{D\times V}{5\times 20}\times 100$$

Where, C = Oleoresin content (%), D = Weight of oleoresin obtained from 5ml of extract and V = Total volume of extract obtained (ml).

RESULTS AND DISCUSSION

Effect on ascorbic acid content: Ascorbic acid was not detected at all in chilli powders prepared from whole and slit chillies under all the drying techniques. According to Chand (2005) also ascorbic acid was not found in dried chilli. Vega–Gálvez et al (2008) reported that temperature in the hot air drying method had a detrimental effect on the retention of ascorbic acid. This was because heated air inherently exposed the products to oxidation, thus reducing their ascorbic acid content.

Effect of on capsaicin content : The capsaicin content

Table 1. Effect of different drying techniques on different quality parameters

Drying technique	Capsaicin content (%)		Colouring matter (ASTA units)		Oleoresin content (%)	
	Whole	Slit	Whole	Slit	Whole	Slit
Sun drying	0.69 ± 0.14	0.65 ± 0.04	50.02 ± 3.47	41.82 ± 1.15	13.26 ± 0.62	11.35 ± 1.62
Improved sun drying	0.86 ± 0.02	0.75 ± 0.04	77.08 ± 2.31	67.24 ± 2.31	13.70 ± 0.28	12.36 ± 0.14
Mechanical drying						
At 50ºC	0.95 ± 0.04	0.89 ± 0.04	95.94 ± 1.15	84.46 ± 3.47	15.63 ± 0.11	13.44 ± 0.07
At 60ºC	0.91 ± 0.04	0.86 ± 0.02	91.02 ± 1.15	90.2 ± 2.31	14.60 ± 0.21	12.52 ± 0.45
At 70ºC	0.73 ± 0.04	0.72 ± 0.02	63.14 ± 1.15	58.22 ± 1.15	12.68 ± 0.21	11.74 ± 0.33

varied between 0.65 to 0.95% on chilli powder basis (Table 1). Higher capsaicin content was observed for whole chillies than slit chillies. This variation on the basis of physical treatment given was found to be statistically significant ($p \leq 0.05$). Themaximum capsaicin content was found in red chilli dried by mechanical drying at 50^{0}C followed by mechanical drying at 60^{0}C and improved sun drying. Red chilli dried by mechanical drying at 70^{0}C had lesser capsaicin content than that dried by improved sun drying but more than that dried by sun drying. This variation on the basis of drying technique used was found to be statistically significant ($p \leq 0.05$).

If the interaction between these two factors is found out statistically, i.e. the effect of both the factors (physical treatment and the drying technique) together is considered on the capsaicin content, the interaction between these two factors was found to be statistically non significant ($p \leq 0.05$).

Kaleemullah and Kailappan (2005) observed that as the drying air temperature increased from 50 to 65˚C the average capsaicin content of dried chillies decreased. According to Chand (2005) quality of the product reduced significantly when the temperature was 70ºC.

Effect on colouring matter: The colouring matter varied between 41.82 to 95.94 ASTA (American Spice Trade Association units) on chilli powder basis, (Table 1). In case of whole chillies, the maximum colouring matter was found in red chilli dried by mechanical drying at 60^{0}C followed by mechanical drying at 50^{0}C and improved sun drying. Red chilli dried by mechanical drying at 70^{0}C had lesser colouring matter than that dried by improved sun drying but more than that dried by sun drying. In case of slit chillies, the maximum colouring matter was found in red chilli dried by mechanical drying at 50^{0}C followed by mechanical drying at 60^{0}C and improved sun drying. Red chilli dried by mechanical drying at 70^{0}C had lesser colouring matter than that dried by improved sun drying but more than that dried by sun drying. This variation was found to be statistically significant ($p \leq 0.05$) of the physical treatment given. This variation was found to be statistically significant ($p \leq 0.05$) of the drying technique used as well.

If the interaction between these two factors is found out statistically, i.e. the effect of both the factors (physical treatment and the drying technique) together is considered on the colouring matter, the interaction between these two factors was found to be statistically significant ($p \leq 0.05$).

Mangaraj et al (2001) also observed that punched chillies lost some colour over unpunched chillies. Sigge et al (2003) also revealed that colour was adversely affected by temperature during dehydration and loss was more prominent at higher temperature (70˚C and 75˚C). Chand (2005) also observed that the quality of the product reduced significantly when the chillies were dried mechanically with 70ºC air temperature.

Effect on oleoresin content: The oleoresin content varied between 11.35 to 15.63% on chilli powder basis (Table 1). Higher oleoresin content was observed for whole chillies than slit chillies. This variation on the basis of physical treatment given was found to be statistically significant ($p \leq 0.05$). Sun dried chillies had lesser oleoresin content as compared to improved sun dried chillies and mechanically dried chillies. Mechanical dried chillies at 70ºC had the minimum oleoresin content, followed by mechanical dried chillies at 60ºC whereas mechanical dried chillies at 50ºC had the maximum oleoresin content out of all the mechanically dried chillies. This variation on the basis of drying technique used was found to be statistically significant ($p \leq 0.05$)

If the interaction between these two factors is found out statistically, i.e. the effect of both the factors (physical treatment and the drying technique) together is considered on the oleoresin content, the interaction between these two factors was found to be statistically non significant ($p \leq 0.05$).

Kalpana (2003) also showed that shade drying followed by electrical tray drying retained higher oleoresin yield as compared to other drying techniques.

CONCLUSION

Mechanical drying technique at 50ºC was the best drying technique in terms of quality parameters followed by

mechanical drying technique at 60ºC. Improved sun drying technique was better than sun drying technique and was comparable to mechanical drying technique at 50ºC in terms of quality parameters. Mechanical drying technique at 70ºC had the worst quality in terms of quality parameters. But was better than sun drying technique.

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Assessing and Prioritizing Training Needs of Shrimp Farmers of Palghar District, Maharashtra

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Abstract: Study was conducted with the objective of assessing and prioritizing training needs of shrimp farmers of Palghar district in Maharashtra. Palghar ranks first in terms of shrimp production and number of shrimp farms. Out of 65 registered shrimp farmers in Palghar district, information was collected from 55 shrimp farmers. An expert group of 30 comprising of academicians, extension workers, aqua feed industry representatives, government officials and progressive shrimp farmers were asked to locate potential training areas from the ten heads of Best Management Practices **(**BMPs**)** and also suggest any other training areas. A total of 40 potential training areas were suggested amongst which 11 were related to BMPs and 29 were outside the framework of BMPs. Importance Weightage (IW) was computed for the training areas and the score ranged from 0 to 1. Training areas which had IW score of 0.5 or more were selected and thus 22 areas were identified. Using Borich Need Assessment Model, shrimp farmers were asked to rate these 22 training areas on a 5 point Likert scale for their perceived importance and competency. Mean Weighted Discrepancy Score (MWDS) was computed to rank and prioritize the training areas. MWDS was highest for training areas *viz*. shrimp diseases, symptoms, identification, prevention and management, nursery system and management, feeding management, use of biosecurity measures and farming with biofloc technology and thus were prioritised. Training needs assessment has revealed that farmers prioritized six training areas from specific ten frameworks of BMPs. In addition, four training areas not in the framework of BMPs were also given high priority. It is concluded that to design any capacity development programme, it is necessary to do training need assessment with reference to importance and competency and training areas should be accordingly prioritized.

Keywords: Training needs, Shrimp farmers, Prioritizing, Need assessment model, Palghar district

Among various fish production enterprises, shrimp farming provide gainful employment and steady income to fish farmers. Shrimp aquaculture is one of the fastest growing forms of aquaculture but has witnessed many ups and downs during 1990 −2000. Shrimp farming industry was at its peak around 1991 throughout India, but saw its decline mainly due to the White Spot Syndrome Virus (WSSV) disease, However, in 2008, Government of India permitted use of Specific Pathogen Free (SPF) stock of *Litopenaeus vannamei* for culture. This resulted in revival of shrimp farming along the coast of Andhra Pradesh, Maharashtra as well as other states. Maharashtra state has about 52,001 ha of potential brackish water area all along its coastline and adjacent creeks. Out of this area, 10,400 ha is reported to be suitable for shrimp farming as per the survey conducted by Government of Maharashtra in 2008. However, only 1356 ha is used for shrimp farming as per MPEDA (2016) and 9044 ha area is left which can be utilized for shrimp farming. Per hectare shrimp productivity of Maharashtra is 4.51 MT/ha/year, whereas national average is 6.87 MT/ha/year. With a gap of 2.36MT/ha/year there is of improvement in the five coastal districts i.e., Palghar, Thane, Raigad, Ratnagiri and Sindhudurg.

Amongst these districts, Palghar ranks first in shrimp farming area and total shrimp production. Here the total area under shrimp farming is 733 ha and shrimp production is 2710 tons. However, per hectare shrimp production in Palghar district is 3.69 tons/ha which is less that the state average of 4.73 tons/ha. Ratnagiri district has highest per hectare shrimp production of 6.56 MT/ha/year DoF (2016). It is clear that Palghar district has relatively less average and thus there are gaps which need to be addressed.

In a study by Gawde et al (2006) done in Ratnagiri and Sindhudurg districts, it has been reported that lack of awareness being one of the main reasons for non-adoption of certain good management practices by shrimp farmers for which training is needed. Studies performed in east and west coasts of India by Kumaran et al (2017) have also reported that there is a need for trained shrimp farmers regarding the Best Management Practices (BMPs) to achieve sustainable production. From the study done by Basavakumar and Yaliger (2000) in Karnataka it is clear that trainings have helped shrimp farmers to acquire more knowledge on technical aspects and has resulted in achieving higher

production for farmers. By this review, it is clear that training is an important component for adoption of BMPs. To have sustainable shrimp farming, it is necessary that shrimp farmers have necessary skills to adopt the BMPs. Thus, there is a need to assess on which specific areas of BMPs and other fields, shrimp farmers need trainings. Accordingly a study was done with the objective of assessing and prioritizing the training needs of shrimp farmers of Palghar district, Maharashtra.

MATERIAL AND METHODS

Maharashtra has five coastal districts, out of which Palghar district ranks first in terms of shrimp production and number of shrimp farms (MPEDA 2016). Out of 65 registered shrimp farmers in Palghar district, information was collected through an interview schedule from 55 shrimp farmers from three coastal tehsils namely Vasai, Palghar and Dahanu. With reference to training need assessment BMPs were taken as a broad framework to locate the training areas for shrimp farmers. Coastal Aquaculture Authority (CAA) has provided guidelines for shrimp farmers and has framed BMPs. BMPs have 10 sub frame works i.e. site selection and construction, preparation of shrimp farms, water quality management, seed selection and stocking, feed and feed management, health management, use of chemicals and drugs, harvest and post-harvest management, waste water management and farm hygiene and management. An expert group of 30 comprising of academicians, extension workers, aqua feed industry representatives, government officials and progressive shrimp farmers were asked to locate potential training areas from the ten heads of BMPs. They were also asked to suggest additional training areas other than those listed in BMPs. A total of 40 potential training areas were suggested by the experts in which 11 were related to BMPs and 29 were listed outside the framework of BMPs. Based on this, all the potential training areas were listed. These training areas were scored on a five point Likert scale on how important they were perceived to achieve sustainable production. The five point continuum scale were very important, important, somewhat important, little important and not important with scores of 4, 3, 2, 1 and 0, respectively. Further Importance weightage (IW) was computed as the ratio of actual total score obtained to the maximum obtainable total score. Thus IW ranged from 0 to 1.

Kendall's coefficient of concordance (W) was used to test the hypothesis if the experts were in agreement among sets of rankings. Value of W was 0.65 which was acceptable. As per Siegel (1989) if perfect agreement exists between experts W equals 1 and if maximum disagreement exists then W equals to 0.

The training areas, which had IW score of 0.5 or more were selected as important and thus 22 training areas were identified. Within the framework of BMPs, 11 training areas scored more than 0.5 which are listed here. Under the head "site selection and construction", the training area suggested was site specific approach in selection, design and construction of shrimp farm. Under "farm preparation", pond preparation and pre-stocking management was the area identified. Under "water quality management", water quality and pond bottom management was the area suggested. Seed selection, packing, transportation, acclimatization and stocking was the area suggested under the head "seed selection and stocking". Under the head, "feed and feed management", feeding management was the training area identified. In "health management", shrimp diseases, symptoms, identification, prevention and management was the area identified. Use of drugs and chemicals during culture was the training located by experts. Under the head, "harvest and post harvest", two training areas *viz*. harvesting techniques and post harvest handling of farmed shrimps were identified. In "waste water management", effluent and solid waste management was the area identified. Farm hygiene and management was also a training area identified.

In addition to these, other training areas apart from those listed in BMPs which scored high on importance were shrimp nursery system, biosecurity measures, use of biofloc technology, marketing management, human resource management, project formulation, climate change and shrimp farming, schemes and policies for shrimp farming, ICT based trainings and aeration system in shrimp farming. Borich Need Assessment Model (1980) was used to assess the farmers perceived level of importance for each training area and their competency in that field. Using this model, training needs of shrimp farmers were prioritized. Shrimp farmers were asked to rate these 22 training areas with respect to how important it was perceived by them on a five point Likert scale (0 : not important and 4: extremely important). Similarly, each training area was rated with respect to how the shrimp farmers perceived their competency on it. Five point Likert scale (0: not competent to 4: extremely competent) was used.

Reliability of the scales was tested using test-retest method. The scale was administered to 15 farmers and then repeated after 15 days. Reliability coefficient which is a measure of how consistent the results are over time was found to be 0.80 and 0.85 respectively for two scales, and thus the same were considered reliable (Webb et al 2006).

Mean Weighted Discrepancy Score (MWDS) was calculated to rank and prioritize the training areas as follows.

Discrepancy score (DS) = I −C

Weight Discrepancy score (WDS) = I (I −C)

Mean Weight Discrepancy score (MWDS) = ∑I (I −C)/n

Where, I is Importance level, C is Competence level and n is number of shrimp farmers.

RESULTS AND DISCUSSION

All shrimp farmers of Palghar district were men and practiced *Litopenaeus vannamei* culture. All were educated, had experience above 5 years. About half i.e., 52.73 % of the shrimp farmers had their own ponds and 47.27% had taken ponds on lease basis for shrimp culture. A total of 40, 32.73 and 14.55 percent of shrimp farmers were having farm area in between 2-5 ha, up to 2 ha, between 5-10 ha and 12.75% farmers had above 10 ha of farm area. Majority (94.55%) of shrimp farmers were taking two crops/year. About half (47.27%) were maintaining stocking density between 16-25 nos/m^2 followed 26-50 nos./m^2 (34.55%).

Borich Need Assessment Model (1980) was used to assess the farmers perceived level of importance and competency for each training area. Shrimp farmers rated the 22 training areas with respect to how important it was perceived by them and how competent they were for each training area. Using importance and competency scores, MWDS scores was calculated (Table 1).

Seven training areas scored above 3.0 and were considered important training areas by shrimp farmers. Out of these seven training areas, three training areas i.e. nursery system and management, use of bio-security measures and *Litopenaeus vannamei* farming with biofloc technology are not included in BMPs.

With reference to competency, none of the training areas shrimp farmers scored 3 or above. However, shrimp farmers scored between 2.02 to 2.51 (moderately competent) for four training areas i.e. seed selection, packing, transportation, acclimatization and stocking, pond preparation and pre-stocking management, harvest and post harvest handling of farmed shrimps and water quality and pond bottom management during shrimp culture.

Table 1. Perceived level of importance, competency and MWDS for training areas

Training areas	Mean score of importance	Mean score of competency	MWDS	Ranking based on MWDS
Shrimp diseases, symptoms, identification, prevention and management	3.75 ± 0.52	0.56 ± 0.88	12.24	1
Feeding management	3.62 ± 0.62	1.42±1.03	8.29	3
Water quality and pond bottom management	3.55 ± 0.74	2.02±0.83	5.87	7
Nursery management	3.53 ± 0.54	0.93 ± 0.94	8.96	2
Use of bio-security measures	3.24 ± 0.54	1.15 ± 0.65	7.15	4
Seed selection, packing, transportation, acclimatization and stocking	3.16 ± 0.57	2.55 ± 0.98	2.31	13
Litopenaeus vannamei farming with biofloc technology	3.05 ± 0.91	1.27±1.08	6.51	5
Pond preparation and pre-stocking management	2.87 ± 0.43	2.51 ± 0.96	0.42	19
Use of drugs and chemicals	2.87 ± 0.98	1.15 ± 0.62	5.91	6
Site specific approach in selection, design and construction of shrimp farm	2.87 ± 0.64	1.13 ± 0.90	5.38	8
Effluent and solid waste management	2.85 ± 0.78	1.42 ± 1.03	4.49	9
Market and marketing management	2.82 ± 0.72	1.78 ± 0.74	3.47	10
Harvesting techniques	2.73 ± 0.71	1.98 ± 0.83	2.56	12
Harvest and post harvest handling	2.60 ± 0.85	2.16 ± 0.94	1.87	15
Human resource management	2.51 ± 0.92	1.78 ± 0.85	2.67	11
Financial management	2.15 ± 1.11	1.76 ± 0.77	2.00	14
Project formulation and management	2.13 ± 0.86	1.51 ± 1.00	1.82	16
Climate change and shrimp farming	1.89 ± 0.92	1.65 ± 1.09	1.49	17
Schemes and policies for shrimp farming	1.58 ± 0.94	1.69 ± 0.96	0.55	18
Farm hygiene and management	1.35 ± 0.82	1.98 ± 1.01	0.27	20
Aeration system in shrimp farming	1.20 ± 0.87	1.71 ± 1.07	0.16	21
ICT based trainings	0.75 ± 1.04	1.91 ± 0.97	0.16	21

Shrimp farmers scored between 1.13 to 1.98 (less competent) in 16 training areas. Out of these 16 training areas, six training areas were from BMPs. Shrimp farmers were not at all competent in two training areas i.e. nursery system and management and shrimp diseases, symptoms, identification, prevention and management. On scales of importance, these two areas scored above 3 revealing significant discrepancy. As expected, a negative correlation was found between importance and competence scores. Many training areas are considered important for farmers but they lacked competency in those areas like nursery system and management and shrimp disease, symptoms, identification, prevention and management.

Prioritizing training needs: The MWDS was highest for training areas like shrimp diseases, its symptoms, identification, prevention and management, nursery system and management, feeding management, use of biosecurity measures and shrimp farming with biofloc technology. Each training area which had high MWDS is discussed further. Disease management is a field, which has been given high importance. CAA has highlighted significance of disease management in shrimp farming. Shrimp culture industry was at its peak around 1991 throughout India, but collapsed after that mainly due to WSSV disease. To make shrimp farming sustainable, it is necessary to give stress on health management. Hence, shrimp farmers ranked shrimp disease, symptoms, identification, prevention and management as a first priority training area with MWDS of 12.24. Shrimp nursery system scored second in priority for training. Islam and Alam (2008) have reported that, nursery of post larvae is one of the important culture tools for promoting survival rate and enhancing production. Major reason for low survival and less production is inadequate conditioning of post larvae to pond water and improper nursery at initial stage. Farmers have realized that direct stocking of post larvae in grow out ponds leads to low survival but nursery system increases the survival, provides better control over predators and water quality and optimal feed utilization. Farmers ranked this as second priority. Management of feed is one of the most important aspects of successful shrimp production and thus feed rationing and feeding management for shrimps scored third. FAO (2007) have reported that feed contributes nearly 60-80% of operational costs. Therefore, feeding management was third in priority with MWDS of 8.29. Use of biosecurity measures was fourth in priority. Biosecurity is one of the most important tools to prevent the outbreak of many infectious diseases. Khairnar et al (2009) have reported that major cause for potential economic losses in shrimp industry was disease outbreaks and this economic loss can be minimized through use of biosecurity measures. Therefore shrimp farmers ranked this as a priority training area. Bossier and Eksari (2017) have stressed that biofloc technology is an emerging avenue in aquatic animal health care and nutrition. If *Litopenaeus vannamei* is cultured at higher stocking densities it will lead to environmental degradation and disease outbreak. Stocking density up to 30 PL/m^2 is preferred for better management of pond conditions. Most of the shrimp farmers in Palghar district maintained stocking density above 30 PL/m^2. Anjalee and Kurup (2015) have reported that biofloc technology can reduce the cost and improves pond hygiene. Hence, shrimp farming with biofloc technology scored fifth on priority.

Use of drugs and chemicals during shrimp culture was sixth prioritized training area. Some of the chemicals and antibiotics can accumulate in the flesh of shrimp and represent a potential health hazard to the consumer. Hence, shrimp farmers reported training on use of drugs and chemicals during shrimp culture. Other preferred training areas by shrimp farmers were water quality and pond bottom management during shrimp culture. Site specific approach in selection, design and construction of shrimp farm was also prioritized training area with MWDS of 5.38 as suitable site selection is an important process in aquaculture as this can often decide the success or failure of shrimp aquaculture. Effluent and solid waste management was also preferred training area by shrimp farmers. Effluent released from shrimp farm has notable environmental impacts once released, it adds acid and salt to soil, often making affected land unsuitable for plants. Therefore, effluent and solid waste management was prioritised training area by shrimp farmers. Market and marketing management were another preferred training area by shrimp farmers.

MWDS for human resource management, harvesting techniques, seed selection, packing, transportation, acclimatization and stocking, financial management, post harvest handling and project formulation and management was less than three and ranged between 1.82 to 2.67. It can be inferred that they were given low priority by shrimp farmers. Training on climate change had a low score with MWDS of 1.49. There are evidence that changes in climatic variables have detrimental effects on the ecosystem of shrimp farms, and thus, severe effects on survival, growth, and production of shrimp. However, it scored low on priority by the farmers. Other low priority training areas with MWDS less than one were schemes and policies of government for shrimp farming, pond preparation and pre-stocking management, farm hygiene and management, aeration system and ICT based trainings.

A total of ten areas were given high priority. It is clear from this study that training is an important component.

Training needs assessment has revealed that farmers prioritized six training areas from specific ten frameworks of BMPs. In addition, four training areas not in the framework of BMPs were also given high priority.

CONCLUSIONS

To design any capacity development programme, it is necessary to do training need assessment with reference to the importance as perceived by experts and the farmers. In addition, it is necessary to study the competency level of the farmers in the important training areas. Based on the importance and competency level, training areas should be prioritized. The institutes / organizations responsible for conducting training programmes should have this database and these needs to be updated from time to time. Certain training area considered to be important by experts scored low in farmers priority. To avoid this disconnect, it is necessary that information has to be collected at field level from farmers. In case experts feel that in some areas like farm hygiene and management training is necessary, then importance of subject needs to be taught to shrimp farmers. The shrimp diseases, symptoms, identification, prevention and management, nursery system and management, feed rationing and feeding management, use of biosecurity measures and shrimp farming with biofloc technology are prioritized training need. The study has also revealed that along with some areas of BMPs farmers also need training on new technologies like biofloc, biosecurity, nursery management etc.

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Assessment of Nutrition Knowledge of Elite Athletes and their Coaches in Punjab

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Abstract: Research study for the assessment of nutrition knowledge of 120 (16-25 years) elite athletes and their coaches, selected from 5 universities and participating in 4 sports *viz.* hockey, athletics, badminton and lawn tennis was carried out. The knowledge, attitude and practice (KAP) score of athletes along with the KAP score of coaches regarding sports nutrition was assessed. A statistically significant difference was observed in the KAP score of male and female athletes of hockey and lawn tennis. However, the KAP score of overall male and female athletes was observed to be statistically non-significant. Majority of coaches (96.7%) had no formal training in sports nutrition and 90% of them had no access to registered dietician. KAP score data of the coaches revealed that 10% had excellent KAP score; 53% had a very good score; 30% had good KAP and 6.7% had average to poor score. A positive significant ($p \leq 0.05$) correlation between KAP score of coaches and their years of experience was observed. KAP score of athletes had a significantly positive correlation with the KAP score of coaches.

Keywords: Elite athletes, Knowledge Attitude and Practice (KAP) score, Nutrient intake

An elite athlete is defined as one who has previously or currently competed as a state player, varsity player (individual or team), a professional player or a national or international level player. Nutrition, from decades, has been recognized to play an important role in attaining high level of achievements in sports (Alexopoulas and Frazier 2012). According Purcell (2013), adequate calorie intake, ample hydration and timing of meals is desirable to maintain lean tissue mass and an optimal athletic performance. Inadequate calorie intake leads to a condition in which the body uses fat and lean tissue mass as fuel, resulting in loss of muscle mass, thus compromising strength and endurance. There has been a direct correlation between healthy food choices and an athlete's nutrition knowledge and it was revealed that majority of athlete population had a dearth of basic nutrition knowledge (Dunn et al 2007, Supriya and Ramaswami 2013). Delivering nutrition education resulted in a significant increase in sports nutrition knowledge accompanied by increased intake of energy, carbohydrates and protein (Burns et al 2004, Rodriguez et al 2009, Walsh et al 2011, Valliant et al 2012, Devlin and Belski 2015). The educational resources for low income community athletes are less, resulting in insufficient knowledge about nutrition and sports supplements (Peerkhan and Srinivasan 2010). Participation in various competitions and tournaments increases nutrition knowledge of athletes as they gain experience in their sport. The nutrition knowledge of athletes pursuing physical education course at their institutions is better. A majority of athletes also highlighted the importance of breakfast (Aziz et al 2010). Assessing knowledge of coaches regarding nutrition is important, as coaches are the first persons dealing with sportspersons. Coaches often receive nutrition knowledge from other coaches, their experiences and self-involvements in sports and competitions (Reade et al 2008). On the other hand, athletes considered coaches as their main source of sports nutrition knowledge (Sajber et al 2013). Dissemination of incorrect information regarding nutrition by professionals whose sports nutrition knowledge is deficient is a matter of concern. (McGehee et al 2012). Hence, in the present study, an attempt was made to obtain data regarding the objective of assessing the nutrition knowledge level of the selected athletes and coaches.

MATERIAL AND METHODS

The present study was conducted in five universities of Punjab namely, Punjab Agricultural University, Ludhiana, Guru Angad Dev Veterinary and Animal Sciences University, Ludhiana, Punjab University, Chandigarh, Guru Nanak Dev University, Amritsar and Punjabi University, Patiala.

Selection of subjects: A total of one hundred and twenty elite athletes (30 in each category) falling in the age-group of 16-25 years and their coaches (total 30 combined from all categories) were selected (Fig. 1) from five universities of Punjab who were participating in hockey, athletics, badminton and lawn Tennis.

The selection of subjects was independent of gender.

The athletes for the above mentioned sports were selected on the basis of their participation in state or national level tournaments such as open state, open national, inter-varsity and inter-agri.

Collection of data

General information of athletes and coaches: The information regarding general profile of subjects, socio-economic status of family, family composition, dietary habits, food intake on daily basis, pattern of physical activity and information pertaining to health and lifestyle of the athletes while information in addition to general profile and social and family composition, access to nutrition information and nutrition expert at personal or university level to coaches were collected.

Assessment of knowledge, attitude and practice (kap) score of athletes and coaches: The knowledge, attitude and practice (KAP) regarding role of nutrition in sports and its dietary management by the athletes and their coaches was assessed using KAP questionnaire which was distributed among selected one hundred and twenty athletes pursuing four different sports and also among selected thirty coaches who were providing coaching in the above mentioned sports.

Classification of knowledge, attitude and practice (kap) score of athletes and coaches: The scores of the athletes were categorized into excellent, very good, good and average to poor. Athletes scoring 30-35 were ranked as excellent, score of 25-29 was ranked very good, score of 20-24 was good and less than 20 was ranked as poor. The maximum score was taken to be 35.

RESULTS AND DISCUSSION

General profile: Majority of athletes belonged to nuclear family especially female athletes with 4 to 8 members in the family. Among these a major proportion (74.2%) of athletes belonged to high income group with a greater mainstream of males (81.5%). A majority of athletes (75.8%) were participating at national level, especially all the athletes of hockey. Furthermore, athletes used to spend 0-2 hours (34.1%) and 4-6 hours (34.2%) per day in workout while a very few (3.3%) male athletes, especially those pursuing athletics and lawn tennis spent 6-8 hours a day in workout. A considerable number of male and female athletes (50.8 and 65.5%) from all the sports in the study experienced feeling of fatigue specifically after their morning training session. Junk food consumption was found common among majority (87.3%) of female athletes, but the frequency of consumption was low i.e. once or twice a week.

Majority of athletes (53.3%) were non-vegetarian comprising males of athletics (71.4%) and males of badminton (92.8%). It also came into prominence that major fraction of selected athletes (66.7%) did not skip meals to maintain weight, which may be considered common among female athletes. Fifty-six percent female athletes rejected the notion of skipping meals, particularly female athletes (87.5%) of lawn tennis.

Knowledge, attitude and practice (KAP) of athletes knowledge: The knowledge score revealed no significant difference between all the male and female athletes of the selected sports with a good overall knowledge score

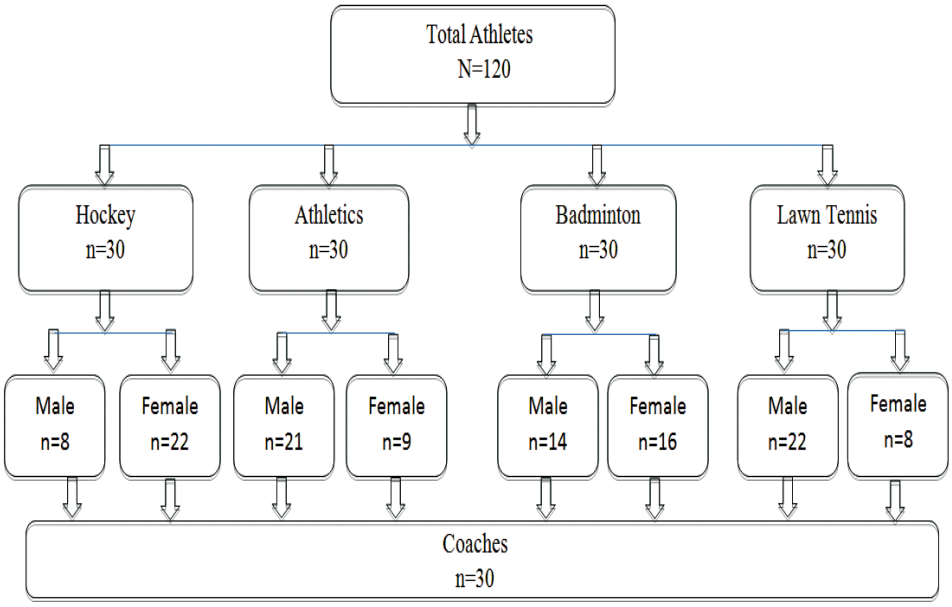

Fig. 1. Selection of subjects

(71.2%). However, Kong (2009) observed higher knowledge score of female as compared to their male counterparts.

Attitude: The attitude of elite athletes regarding sports nutrition revealed statistically significant higher score of male athletes of hockey as compared to female while male and female athletes of other sports did not exhibit any significant difference with an average overall score (62%).

Practice: The practice score in male and female athletes of

Table 1. General profile of the athletes

Characteristics	Hockey		Athletics		Badminton		Lawn tennis		Total (%)		Total (%)
	Male (n=8)	Female (n=22)	Male (n=21)	Female (n=9)	Male (n=14)	Female (n=16)	Male (n=22)	Female (n=8)	Male (n=65	Female (n=55)	N=120
Family Size											
Nuclear	6 (75)	18 (81.9)	12 (57.1)	6 (66.7)	13 (92.8)	11 (68.8)	18 (81.8)	8 (100)	75.4	78.2	76.7
Joint	2 (25)	4 (18.2)	9 (42.9)	3 (33.3)	1 (7.14)	5 (31.3)	4(18.2)	0	24.6	21.8	23.3
Family composition											
Small (<4)	2 (25)	0	1 (4.76)	1 (11)	2 (14.3)	0	1(4.5)	1(12.5)	9.2	3.6	6.7
Medium (4 to 8)	6 (75)	18 (81.9)	16 (76.2)	7 (77.8)	12 (85.7)	11(68.8)	21(95.5)	7(87.5)	84.6	78.2	81.7
Large (>8)	0	4 (18.2)	4 (19)	1 (11)	0	0	0	0	6.2	9.1	7.5
Family income (Rs/ annum)											
Low (upto 50,000/-)	0	3 (13.6)	0	0	0	0	0	0	0	5.5	2.5
Medium (50,000 to 2,50,000/-)	2 (25)	2 (9.1)	3 (14.3)	2 (22.2)	1 (7.1)	8 (50)	6 (27.3)	4 (50)	16.9	29.1	23.3
High (>2,50,000/-)	6 (75)	17 (77.3)	18 (85.7)	7 (77.8)	13 (92.8)	8 (50)	16 (72.7)	4 (50)	81.5	65.5	74.2
Level of participation											
State	0	0	12 (57.1)	3 (33.3)	4 (28.6)	5 (31.3)	4 (18.2)	1 (12.5)	30.8	16.6	24.2
National	8 (100)	22 (100)	9 (42.9)	6 (66.7)	10 (71.4)	11 (68.8)	18 (81.8)	7 (87.5)	69.2	83.6	75.8
Time spent in workout (in hours)											
0-2	1 (12.5)	8 (36.4)	4 (19.0)	6 (66.7)	6 (42.9)	7 (43.8)	7 (31.8)	2 (25)	27.7	41.8	34.1
2-4	3 (37.5)	2 (9.1)	8 (38.1)	1 (11)	2 (14.3)	3 (18.8)	9 (40.9)	6 (75)	33.8	21.8	28.3
4-6	4 (50)	12 (54.5)	7 (33.3)	2 (22.2)	6 (42.9)	6 (25)	4 (18.2)	0	32.3	36.4	34.2
6-8	0	0	2 (9.5)	0	0	0	2(9.1)	0	6.15	0	3.3
Feeling of fatigue											
Yes	4 (50)	16 (72.7)	15 (71.4)	6 (66.7)	3 (21.4)	9 (56.3)	11 (50)	5 (62.5)	50.8	65.5	57.5
No	4 (50)	6 (27.3)	6 (28.6)	3 (33.3)	11(78.6)	7 (43.8)	11 (50)	3 (37.5)	49.2	34.5	42.5
Junk Food											
Yes	2 (25)	18 (81.8)	14 (66.7)	8 (88.9)	12 (85.7)	14 (87.5)	15 (68.2)	8 (100)	66.2	87.3	75.8
No	6 (75)	4 (18.9)	7 (33.3)	1 (11)	2 (14.3)	2 (12.5)	7 (31.8)	0	33.8	12.7	24.2
Food habits											
Vegetarian	6 (75)	16 (72.7)	5 (23.8)	5 (55.6)	1 (7.1)	8 (50)	9 (40.9)	4 (50)	32.3	60	45
Ovo-Lactovegetarian	0	0	1 (4.76)	0	0	1 (6.3)	0	0	1.5	1.8	1.7
Non-vegetarian	2 (25)	6 (27.3)	15 (71.4)	4 (44.4)	13 (92.8)	7 (43.8)	13 (59.1)	4 (50)	66.2	38.2	53.3
skipping meals											
Yes	4 (50)	15 (68.9)	7 (33.3)	3 (33.3)	5(35.7)	5 (31.3)	1(4.5)	1(12.5)	26.2	43.6	34.2
No	4 (50)	7 (31.8)	14 (66.7)	6 (66.7)	9 (64.3)	11 (68.8)	21 (95.5)	7 (87.5)	73.8	56.4	66.7

*Figures in parenthesis represent percentages

athletics as well as lawn tennis showed a statistically significant difference, where male athletes of athletics scored higher as compared to their female counterparts whereas, female athletes of lawn tennis scored higher as compared to male athletes of lawn tennis. The athletes of other two sports did not show any significant difference between males and females. The overall male athletes and female athletes showed non-significant difference.

KAP score: The overall KAP score exhibited a significant difference between male and female athletes particularly among athletes of hockey and lawn tennis because of their significant difference in practices regarding sports nutrition. A similar result was observed where male athletes of hockey scored higher compared to their female counterparts, whereas female athletes of lawn tennis scored higher KAP score than male athletes. The difference between overall male and female athletes was observed to be statistically non-significant. Also, the overall percent KAP marks of a total of 120 athletes were found to be good (69.9%). Low mean KAP scores of both male and female adolescent cricketers were also reported by Sobana (2016) and suggested a necessity for continuous nutrition education particularly through a sports nutritionist.

Classification of KAP level of athletes

The athletes were categorized into having excellent, very good, good, average to poor KAP regarding sports nutrition on the basis of their achieved scores (Table 4), which revealed that overall a few fraction of athletes (4.2%) had excellent KAP score which comprised male athletes of hockey, athletics and lawn tennis (12.5, 14.3 and 4.5% resp.) and no female athlete fell in this category. Twenty-five percent of male athletes had very good KAP score while 30.9% of female athletes secured very good knowledge score.

A significant proportion of athletes (46.7%) had good nutrition KAP score comprising male athletes and female athletes (49.2 and 43.6%). The highest percentage (63.6 and 66.7%) of athletes who scored good KAP score were female

Table 2. Knowledge, attitude and practice score of athletes

Particulars	Hockey			Athletics			Badminton			Lawn tennis			Total		
	Male	Female	t-value	Male	Female	t-value	Male	Female	t-value	Male	Female	t-value	Male	Female	t-value
Knowledge	11	10.3	1.2^{NS}	10.4	9.7	1.4^{NS}	9.1	9.8	0.8^{NS}	9.7	10.7	0.8^{NS}	10.05	10.1	0.9^{NS}
Attitude	6.12	4.3	3.2*	5.0	5.7	0.9^{NS}	6.8	7.4	0.3^{NS}	7.2	6.8	0.8^{NS}	6.28	6.05	0.1^{NS}
Practice	8.12	8.2	0.1^{NS}	9	7.1	3.3*	8.1	8.4	0.4^{NS}	7.4	9	2.2*	8.17	8.18	0.0^{NS}
KAP score	25.3	22.9	1.9*	24.3	22.4	1.5^{NS}	24	25.6	1.2^{NS}	24.3	26.5	2.7*	24.5	24.4	0.1^{NS}

Values are Mean, *Significant at 5% level, NS-non significant

Table 3. Knowledge, attitude and practice score of athletes (%)

Particulars	Total Score	Hockey		Athletics		Badminton		Lawn tennis		Total (%)		Total (%) N=120
		Male (n=8)	Female (n=22)	Male (n=21)	Female (n=9)	Male (n=14)	Female (n=16)	Male (n=22)	Female (n=8)	Male (n=65)	Female (n=55)	
Knowledge	14	78.6	73.7	74.3	69.3	65	70	69.3	76.4	71.8	72.1	71.2
Attitude	10	61.3	43	50	57	68	74	72	68	63	61	62
Practice	11	73.8	74.5	81.8	64.5	73.6	76.4	67.3	81.8	74.3	74.4	74.3
KAP Score	35	72.1	65.4	69.4	64	68.6	73.1	69.4	75.7	70	69.7	69.9

Table 4. Classification of KAP level of athletes

KAP	Hockey		Athletics		Badminton		Lawn tennis		Total		Total N=120
	Male (n=8)	Female (n=22)	Male (n=21)	Female (n=9)	Male (n=14)	Female (n=16)	Male (n=22)	Female (n=8)	Male (n=65)	Female (n=55)	
Excellent (30-35)	1 (12.5)	0	3 (14.3)	0	0	0	1 (4.5)	0	5 (7.7)	0	5 (4.2)
Very good (25-29)	5 (62.5)	5 (22.7)	6 (28.6)	1 (11.1)	3 (21.4)	7 (43.8)	3 (13.6)	4 (50)	17 (25.2)	17 (30.9)	34 (28.3)
Good (20-24)	2 (25)	14 (63.6)	10 (47.6)	4 (44.4)	6 (42.9)	4 (66.7)	14 (63.6)	2 (25)	32 (49.2)	24 (43.6)	56 (46.7)
Average to poor (Score:< 20)	0	3 (13.6)	2 (9.5)	2 (22.2)	5 (35.7)	5 (31.3)	4 (18.2)	2 (25)	11 (16.9)	12 (21.8)	23 (19.2)

*Figures in parenthesis represent percentages

athletes of hockey and badminton respectively while majority of male athletes of lawn tennis (63.6%) scored good KAP score. Nineteen percent of the total athletes scored an average KAP score including male and female athletes (16.9 and 21.8%).

Comparison of KAP score of athletes of various sports: There was statistically significant difference in KAP score of hockey and badminton, athletics and badminton and athletics and lawn tennis (Table 5). A significant difference in nutritional knowledge between athletes of different fields of sport was also reported by Mardani et al (2017).

General profile of coaches: The general information of the coaches is given in Table 6 and 7. It was revealed that majority of total coaches (56.7%) from all the sports belonged to nuclear family while a significant fraction of them (43.3%) belonged to joint family. Seventy percent of all the coaches had medium family consisting of 4 to 8 members. Sixty-three percent coaches fall in medium income group and several (36.7%) belonged to high income group. The majority of coaches (53.3%) had an experience of < 10 years, 10 to 20 years (33.3%) and an experience of > 20 years (13.3%) which included substantial proportion of hockey and badminton coaches (28.6 and 25%). Majority of the coaches (43.3%) were undergraduate while others were post−graduate and 10+2 (33.3 and 23.3%) (Table 6).

Majority of coaches did not have any formal training regarding sports nutrition (96.7%). Only a few of the badminton coaches (12.5%) had formal training of one year duration. Ninety percent of sports coaches did not have an access to dietitian or nutritionist, while only a little proportion of coaches (3.3%) had this service which included hockey and lawn tennis coaches (14.3 and 20%). Seven percent of dietitians available were post-graduate while a few (3.3%) had diploma in nutrition. Majority of coaches revealed that they themselves were the major source of dissemination of sports nutrition knowledge to their athletes (70%) while other sources included parents, magazine or internet, books, media and doctor etc. Study of Zinn et al (2006) further supports the argument stating that a major proportion of

Table 5. Comparison of KAP score of athletes of various sports

Sport-1	Sport-2	t-value
Hockey 23.5	Athletics 23.7	0.3^{NS}
	Badminton 21.5	1.9*
	Lawn Tennis 21.4	1.54^{NS}
Athletics 23.8	Badminton 21.5	2.03*
	Lawn Tennis 21.4	1.69*
Badminton 21.5	Lawn Tennis 21.4	0.07^{NS}

*Significant at 5% level
NS-Non-significant

Table 6. General profile of coaches

Characteristics	Hockey (n=7)	Athletics (n=5)	Badminton (n=8)	Lawn tennis (n=10)	Total (N=30)
Family size					
Nuclear	4 (57.1)	2 (40)	5 (62.5)	6 (60)	17 (56.7)
Joint	3 (42.9)	3 (60)	3 (37.5)	4 (40)	13 (43.3)
Family composition					
Small (<4)	1 (14.3)	0	1 (12.5)	3 (30)	5 (16.7)
Medium (4 to 8)	5 (71.4)	4 (80)	6 (75)	6 (60)	21 (70)
Large (>8)		1 (20)	1 (12.5)	1 (10)	3 (10)
Family income (Rs/ annum)					
Medium (50,000-2,50,000/-)	3 (42.9)	5 (100)	6 (75)	5 (50)	19 (63.3)
High (>2,50,000/-)	4 (57.1)	0	2 (25)	5 (50)	11 (36.7)
Years of coaching					
< 10 years (1)	3 (42.9)	1 (20)	4 (50)	8 (80)	16 (53.3)
10-20 years (2)	2 (28.6)	4 (80)	2 (25)	2 (20)	10 (33.3)
>20 years (3)	2 (28.6)	0	2 (25)	0	4 (13.3)
Level of education					
Matric (0)					
10+2 (1)	2 (28.6)	1 (20)	1 (12.5)	3 (30)	7 (23.3)
UG degree (2)	1 (14.3)	3 (60)	3 (37.5)	6 (60)	13 (43.3)
PG degree (3)	4 (57.1)	1 (20)	4 (50)	1 (10)	10 (33.3)

*Figures in parenthesis represent percentages

sports coaches (84%) provided nutrition advice to their players without the guidance of any nutritionist or a dietitian.

Knowledge, attitude and practice (KAP) of coaches: There was no statistical significant difference in the sports nutrition knowledge of all the sports coaches of the selected sports (Table 8). The highest knowledge score (77.1%) was scored by hockey coaches among all selected coaches. There was a statistically significant difference in the attitude score of coaches of different sports. Coaches of lawn tennis had the highest score (68%), followed by hockey (54%) and athletics coaches (46%). The reason for the difference in the score could be their higher education and more experience. The overall practice score of the coaches did not show any statistically significant difference among all the selected coaches. A good total average practice score (82%) was achieved by sports coaches with a highest practice score (85.5%) by badminton coaches.

Overall KAP score: The total average KAP score showed no significant difference between all the coaches of selected sports (Table 8). Individually, highest score (76.3%) was achieved by lawn tennis coaches due to their high knowledge and practice score followed by hockey and badminton coaches (71.1 and 69.7%) and athletics coaches (69.1%). Cockburn et al (2014) observed that majority of coaches (60%) correctly responded to all knowledge questions irrespective of them disseminating their knowledge to

Table 7. Qualification/ Training regarding sports nutrition by the coaches

Characteristics & Sport	Hockey (n=7)	Athletics (n=5)	Badminton (n=8)	Lawn tennis (n=10)	Total (N=30)
Formal Training in Sports Nutrition					
Yes	0	0	1 (12.5)	0	1 (3.3)
No	7 (100)	5 (100)	7 (87.5)	10 (100)	29 (96.7)
If yes,					
Training Institute	0	0	Prakash Padukone academy	0	1 (3.3)
Duration	0	0	1 Yr	0	1 (3.3)
Sponsored by Department/Institution					
Yes	0	0	1 (12.5)	0	1 (3.3)
No	0	0	0	0	0
Access to Registered Dietician/ Equivalent					
Yes	1 (14.3)	0	0	2 (20)	3 (3.3)
No	6 (85.7)	5 (100)	8 (100)	8 (80)	27 (90)
Qualification of Dietician					
Diploma	0	0	0	1 (10)	1 (3.3)
UG Degree	0	0	0	0	0
PG Degree	1 (14.3)	0	0	1 (10)	2 (6.7)
Other sources of nutrition knowledge					
Coach	4 (57.1)	5 (100)	6 (75)	6 (60)	21 (70)
Parents	1 (14.3)	0	1(12.5)	1 (10)	3 (10)
Internet/ Magazine/other media	2 (28.6)	0	1 (12.5)	2 (20)	5 (16.7)
Doctor	0	0	1 (12.5)	0	1 (3.3)

*Figures in parenthesis represent percentages

Table 8. Knowledge, attitude and practice score of coaches

Particulars	Total Score	Hockey (n=7)	Athletics (n=5)	Badminton (n=8)	Lawn tennis (n=10)	Total (%) (N=30)	Significance
Knowledge	14	10.9 (77.9)	10.8 (77.1)	10.6 (75.7)	10.6 (75.7)	76.6	0.06^{NS}
Attitude	10	5.4 (54)	4.6 (46)	4.4 (44)	6.8 (68)	53	3.4*
Practice	11	8.6 (78.2)	8.8 (80)	9.4 (85.5)	9.3 (84.5)	82	0.84^{NS}
KAP Score	35	24.9 (71.1)	24.2 (69.1)	24.4 (69.7)	26.7 (76.3)	71.6	1.0^{NS}

Values are mean, *Significant at 5% level, NS-non significant, *Figures in parenthesis represent percentages.

Table 9. Classification of KAP level of coaches

KAP Total Score (35)	Hockey (n=7)	Athletics (n=5)	Badminton (n=8)	Lawn Tennis (n=10)	Total (N=30)
Excellent (30-35)			1 (12.5)	2 (20)	3 (10)
Very Good (25-29)	4 (57.1)	2 (40)	3 (37.5)	7 (70)	16 (53.3)
Good (20-24)	3 (42.9)	3 (60)	3 (37.5)	0	9 (30)
Average to Poor (< 20)	0	0	1 (12.5)	1 (10)	2 (6.7)

*Figures in parenthesis represent percentages

Table 10. Correlation of KAP score of coaches and athletes with other factors

Factor-1	Factor-2	Correlation coefficient (r)
KAP score of coaches	Qualification of coaches	0.20^{NS}
KAP score of coaches	Sports experience of coaches	0.74*
KAP score of coaches	KAP score of athletes	0.79*

*Significant at 5% level, NS-Non-significant

athletes or not. In this study it was also revealed that the coaches who had attended formal nutrition training scored higher than those who did not have.

Classification of KAP level of coaches: Only a few coaches (10%) had excellent sports nutrition knowledge, attitude and practice score. Fifty-three percent of coaches were having very good while a significant fraction (30%) had good KAP. Very less proportion of coaches (6.7%) had average to poor knowledge, attitude and practice towards sports nutrition.

Correlations of KAP scores of coaches with other factors: KAP score of coaches was non-significantly correlated with their qualification. However, a positively significant correlation ($p \leq 0.05$) was observed with the years of experience, indicating that as the experience of the coaches increases, they tend to acquire more knowledge. Furthermore, KAP score of athletes had a significantly ($p \leq 0.05$) positive correlation with the KAP score of coaches which associates well with the earlier finding of this study that coaches are the main source of nutrition knowledge for their athletes. Correlation of KAP score of coaches and athletes with other factors has been displayed in Table 10.

The overall KAP score of all the male and female athletes did not show any significant difference. Majority of selected coaches (96.7%) had no formal training in sports nutrition while ninety percent of them did not have any access to registered dietician or equivalent. Furthermore, the coaches stated self as the chief source of nutrition information to their athletes with their KAP score being positively correlated with their experience and KAP score of athletes. Coaches are observed to be the primary source of nutrition knowledge for the athletes; hence their functional efficiency needs to be enhanced by providing them formal trainings regarding sports nutrition. Hence, there should be a provision of sports nutritionists/dietician in sports departments and universities of the country.

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Fixed-Bed Biosorption of Nitrate using Tamarind Fruit Shells

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Abstract: This study focuses the removal of nitrate (NO_3^-) from the concocted water environment using Tamarind Fruit Shell (TFS) with Fixed Bed Reactor (FBR) system under room temperature. The settled bed ponders secured the huge analyses, such as, eneration of breakthrough curvess (counting the impacts of beginning NO3$^-$ fixation, TFS size, and stream rate) and bed-profundity benefit time (BDST) approach. From the FBR studies, the pattern of breakthrough curves were almost similar and consistent, but marginally deviated from the typical S-shaped curve. The breakthrough time was inversely proportionate to flow rate, initial NO_3^- concentration and size of TFS, but directly proportionate to bed depth. The head loss problem was not encountered in any of the fixed-bed studies. The biosorptive capacity of TFS in FBR was approximately 7 to 8 times higher than those in CMBR studies. BDST approach was highly suitable for NO_3^- removal by TFS; and yielded higher bed efficiency of 99%. The biosorptive capacity of TFS was shown to be directly proportionate to the initial NO_3^- concentration ($N_o = 0.09C_o$).

Keywords: Nitrate, Tamarind Fruit Shell, Fixed Bed Reactor, Bed-depth Service Time, Biosorptive Capacity

The ground and surface water were highly contaminated due to toxic pollutants like inorganic anions, metal ions and synthetic xenobiotic etc due to industrialization. Among the large number of inorganic species, nitrate (NO_3^-) is challenging and hectic problem that has to be tackled in an indigenous manner. Because of its inadequate holding with soil grid and moderately high dissolvability in water, the elevated amounts of NO3$^-$ in consumable water is accounted for to be capable in causing numerous natural and general wellbeing dangers like eutrophication, methamoglobinemia, soundness of live stocks (counting dairy cattle), growth of nutritious channel and cyanosis among kids. According to the Seems to be: 10500–1995 proposal, the most extreme allowable utmost for NO3$^-$ in drinking water is 50 to 45 mg/l.Significant efforts has been taken in recent years to remove NO_3^- from water using various biological and physiochemical processes such as denitrification, reverse osmosis, ion exchange and electrodialysis etc. The slower reduction rate, complexity in process and expensive nature of above said processes made the researchers still anxious to overcome this problem. Amith and Sillanpaa (2011) usedsorption for the evacuation of F–, bromate, perchlorate, and arsenate, from water; in view of its accommodation, simple task, straightforwardness of outline and well-suited for low to direct convergences of sorbates (under 100 mg/l), recuperation and recovery of spent sorbent.

Even though biosorption is quite popular and effective in removing NO_3^- (concentrations less than 25 mg/l) from water environment; in so far, no specific biosorbent was emerged as overall successful due to certain disadvantages like: their local availability, occurrence in varied size ranges, availability of certain diversified functional groups, pore size and its distribution, poor mechanical strength, handling and operational difficulties, practicability at real time applications, presence of other competitive species and complete understanding of sorption mechanism. So, there is a continuous search to choose an appropriate biosorbent to effectively Sorb NO_3^- from various aqueous phases. In this direction, the Tamarind Fruit Shell (TFS) was first time investigated as novel biosorbent in removing NO_3^- from concocted water spiked with 10 to 100 mg/l of NO_3^-, in CMBR system (Prabhu 2012). The current study proposes to develop a fixed-bed correlation models in removing NO_3^- by TFS as biosorbent through various factors like flow-rate, initial sorbate concentration, biosorbent sizes, and bed–depths on breakthrough of No_3^-.

MATERIAL AND METHODS

Biosorbent: The TFS was obtained from Erode District, Tamilnadu, India and pounded to various sizes by going through I.S strainers, for example, 1.41 mm, 0.71 mm, 0.5 mm and 0.32 mm individually. It was altogether washed in refined water to expel remote materials and broiler dried to a temperature of 110° C for 10 hours, at that point cooled in the

desiccator, and put away in impenetrable plastic holder.

Chemicals: A stock arrangement of NO3⁻ (1000 mg/l) was set up by dissolving 1.6307 g of KNO3 (because of its generally high dissolvability concerning NaNO3 in refined water) in without pyrogen doubly-refined water and in this way weakened by the test conditions. The refined water had a normal pH of 6.6 and electrical conductivity under 10µS/cm.

Water: All experiments were conducted in tap water (Bhavani water), and its average physicochemical parameters are shown in Table 1.

Analysis of No_3^-: The NO_3^- was analysed by single beam UV-VIS Spectrophotometer (Systronics-117, India) with 10 mm path length high quality quartz cuvettes at a wavelength of 220 nmλ.3

Characterization of biosorbent: The physicochemical characteristics of the TFS were determined in the Table 2. The specific surface area (m^2/g) and BET surface area (m^2/g) are measured by Filtrasorb-II: 2300 (Micromeritics Instruments Corporation; USA); and the pH of zero point charge (pH_{zpc}) was analyzed by the instrumental method (zeta potential meter; UK) and standard titrimetric method (as per Huang and Ostovic, 1978) (at the Metallurgical Consultancy Services, Peenya, Bangalore, Karnataka). These results are shown in Table 3. Although the detailed characteristics along with functional groups present on the TFS are Reported (Popuri et al 2007), the SEM and FTIR results are underway of experimentation.

Experimental procedure: Fixed bed examines were performed for TFS, utilizing faucet water composed with NO3⁻. A glass segment of interior breadth of 3 cm was properly stuffed with TFS for a required profundity vital for the analysis, by slurry pressing strategy (Keerthinarayana 1994). The bed was sand-witched between two layers (2 cm to finish everything and base) of common cotton, to avert passageway and leave stream unsettling influences. The influent and gushing examples were gathered intermittently and investigated for NO3⁻ buildups. Test achievement bends were acquired for: (I) four distinctive introductory centralizations of NO3⁻ (60, 40, 20, and 10 mg/l), (ii) four unique sizes of TFS (1, 0.60, and 0.32 mm), (iii) three diverse stream rates (100, 80, and 50 ml/min), and (iv) five diverse bed profundities (30, 24, 18, 12, and 5 cm).

Also for to the assessment of movement of mass-transfer zone within the fixed-bed, multiple port sampling in the fixed-bed column packed with 0.32 mm size TFS for about a depth of 40 cm was adopted. In this, samples were periodically collected from three different ports, and analysed for NO_3^-.

Breakthrough curves: At the point when an answer is gone through a stationary sorber, shaky state condition wins in that the sorbent keeps on sorbing consistently expanding measures of sorbate over the whole time of activity. With proceeding with stream of arrangement, the sorption zone in harmony with the influent fixation moves descending in the bed. As this zone ways to deal with the base of bed, convergence of sorbate in the emanating increments. The breakpoint is characterized as the volume of the arrangement go through the bed before a greatest gushing fixation is achieved (Pirbazari et al 1991) In FBR studies, the breakthrough curve (the plot of fractional sorbate concentration at any time t, with respect to C_0 versus service time or contact time t) analysis is an essential part of operation and design of columns. The breakpoint (usually a theoretical value of 10% or 0.1) not only dictates the termination of FBR process but also, indicates the point at which regeneration of the bed is required. Further, the

Table 1. Physicochemical parameters of bhavani water

Physicochemical parameters	Results
pH	7.55
Turbidity, NTU	≤1
TDS, mg/l	55
Conductivity, µS/cm	28
Alkalinity as $CaCO_3$, mg/l	38
Hardness as $CaCO_3$, mg/l	35
Calcium as Ca^{2+}, mg/l	7
Magnesium as Mg^{2+}, mg/l	3.65
Sodium as Na^+, mg/l	12
Chlorides as Cl^-, mg/l	29
Sulphates as SO_4^{2-}, mg/l	19

Table 2. Physicochemical characteristics of TFS

Parameter	Result
pH	3.96
Specific gravity	1.20
Bulk density	0.53 – 0.57
Porosity (mechanical)	0.25 – 0.30
Loss of weight after washed with 4 litres of distilled water	3.5 %
Dissolved organic matter from TFS	1 %
Ash content	6.4 %

Table 3. Surface areas and pH_{zpc} of TFS

TFS size, mm	Specific surface area m^2/g	BET surface area* mg/g	pHzpc	
			Instrument based	Titrimetric based
0.32	26.3	74.6	4.63	4.72
0.6	24.6	69.1	4.61	4.81
1	20.8	62.9	4.65	4.75

appearance of breakpoint in any FBR system depends on several factors like flow rate, sorbent size, sorbate concentration, bed depth, pH, temperature, nature of isotherm and others.

In order to appropriately select the flow rates in different FBR studies, effluent flow measurements were adopted as per Geresh (2009), for different sizes of TFS of depth 30 cm. It was seen that at 5 and 60 cm depths of water above the bed, the effluent flows varied between 95 and 213 ml/min (for 0.32 mm size), and 224 and 320 ml/min (for 0.6 mm size). Since effluent flow rate was critical, even at 30 cm depth of TFS of size 0.13 mm, an appropriate flow rate of 50 ml/min was fixed in biosorption of NO_3^- by different sizes in FBR.

RESULTS AND DISCUSSION

Breakthrough curves based on bed depth and service time: Dale et al (1946) determined the bed depth, which is hypothetically adequate to counteract entrance of focus in overabundance of C_b at zero time, is characterized as basic bed profundity and is resolved from when t=0

$$Z_0 = \frac{v}{KN_0} In[\frac{C_0}{C_b} - 1] \qquad (1)$$

Where, t = service time, h; v = linear flow rate, cm/h; Z = depth of bed, cm; K = rate constant, $cm^3/mg/h$; N_0 = sorptive capacity, mg/cm^3; C_0 = influent concentration, mg/cm^3; and C_b = allowable effluent concentration (breakthrough concentration), mg/cm^3.From Eq. 1, sorptive capacity N_0 can be determined from the slope of a linear plot t versus Z. The rate constant K is then computed from the intercept of this plot:

$$b = -\frac{1}{KC_0} In[\frac{C_0}{C_b} - 1] \qquad (2)$$

Hutchins (1973) exhibited an adjustment to Bohart−Adams condition which requires just three settled bed tests to gather the vital information. This is called bed profundity benefit time (BDST) approach. Then, the Bohart−Adams equation (Eq. 1) can be expressed as

$$t = aZ + b \quad (3)$$

Where a is slope = $N_0/(C_0v)$ and b is intercept = $-1/KC_0 ln[C_0/C -1]$.

The design parameters calculated according to BDST TFS bed through which the liquid concentration approach represented the biosorption of fluctuates from 95 to 1.7% of the feed focus, and afterward this zone is planned by the even separation between these two lines in the BDST plot (Fig. 5). From Figs. 1-3, it is seen that the breakthrough curves of NO_3^- sorption by TFS for various depths and operating at various flow rates are almost similar. But, the two lines in the BDST plot (Fig. 5) were not parallel. So, the depth of biosorption zone of 21 cm was assessed based on average distance between the two lines (at the center). The respective equations for the two straight lines are:

$$t = 10.6Z + 4.8 \text{ (at 1.7 \% saturation)} \qquad (4)$$

$$t = 13.5Z + 174.2 \text{ (at 95 \% saturation)} \qquad (5)$$

The Table 4 shows the respective slopes and intercepts, for various flow rates.

For the given flow rate 4.24 $m^3/m^2/h$, the new slope was calculated by the average slope of the two lines (12.05 min/cm) and as:

$$a_2 = a_1(\frac{F_{w1}}{F_{w2}}) \qquad (6)$$

The service time t, acquired from BDST configuration was essentially higher than trial leap forward time and ascertained bed effectiveness was as high as 95%, despite the fact that the achievement bends were not sharp after the break-point.

Bed performance with different flow rates: Based on the results of Fig. 1-3, a plot of service time versus bed saturation at breakthrough was dawn. The data points are slightly scattered (due to a particular point with 75 min and 43.15%), even though the existence of linearity in the original BDST model (Fig. 6). Further, this was also due to the variations of slope between 5.4 and 10.6 min/cm for the respective flows of 100 ml/min and 50 ml/min (as per Fig. 4). The service time is inversely proportional to the flow rate through the bed, for all the bed depths. In this regard, two prominent effects (Lee et al 2000) can be seen with respect to the mechanism of NO_3^- on TFS. Firstly, the higher stream rate diminishes the outer film mass-exchange opposition at the surface of TFS in view of the extra speed shear, in this manner decreasing the film thickness. Also, the habitation time of the influent inside the bed diminishes with higher stream rates. Along these lines, the NO3$^-$ particles have less time to infiltrate and diffuse into the focal point of TFS. In spite of very scanty availability of literature pertaining to NO_3^- removals from the biosorbents by aqueous phase, a fair comparison was made with the biosorption of single-component Cr^{6+} onto PATFS (Ramakrishnan 2010) in which, the BDST model could show almost similar correlation of results with the present investigation. In concise, the effect of flow rate on bed performance (BDST slope = m) can be related as per Eq.7.

$$F_w \propto 1/m \qquad (7)$$

Table 4. Values of slope and intercept for different flow rates

Flow Rate, ml/min	Bed Saturation, %			
	1.7 %		95 %	
	Slope	Intercept	Slope	Intercept
50	10.6	4.8	13.5	174.2
80	7.05	-0.9	13.4	96
100	5.4	4.8	13.95	25.1

Bed performance with different initial concentrations: The service time (at 1.7% saturation level) is inversely proportional to the initial NO_3^- concentration. The variation of the biosorptive capacity (N_o) (from the BDST model) with service time and the initial concentration of NO_3^- are respectively shown in Fig. 8 and 9. As the initial NO_3^- concentration increases, the service time was decreased (Fig. 8 and 9) and hence, the biosorptive capacity has linearly increased (Fig. 9). This can be clarified by the administering mass-exchange condition (i.e.) the mass-exchange motion is reliant on mass-exchange coefficient, territory opposite to the mass transition, and the focus slope. Higher beginning fixation prompts higher focus inclination. Henceforth, this high mass-exchange main impetus yields a bigger rate of

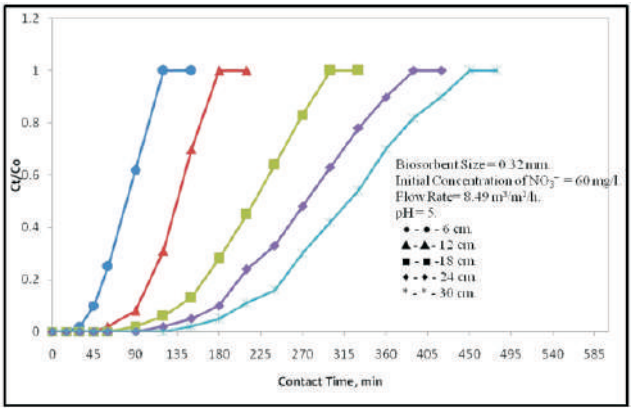

Fig. 1. Breakthrough curves for different bed depths-100 ml/min flow rate

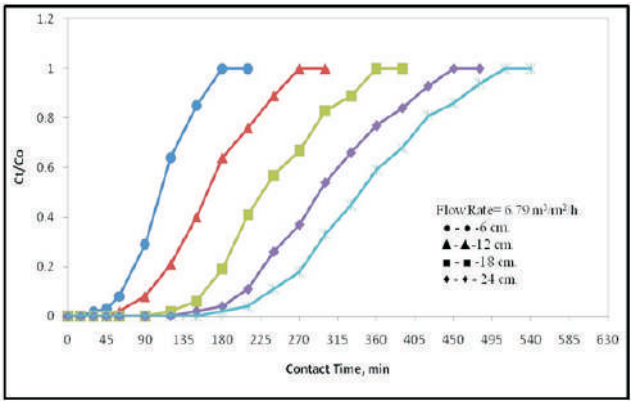

Fig. 2. Breakthrough curves for different bed depths-80 ml/min flow rate

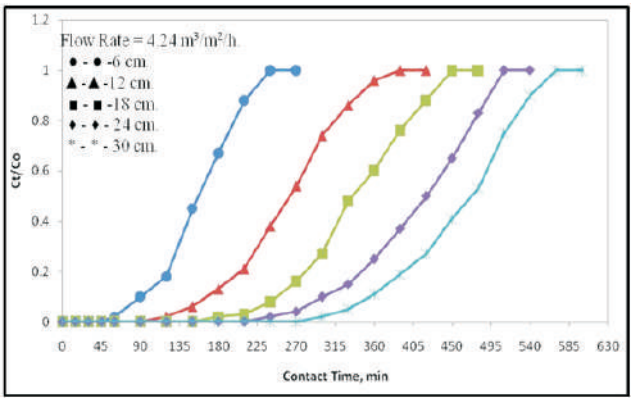

Fig. 3. Breakthrough curves for different bed depths-50 ml/min flow rate

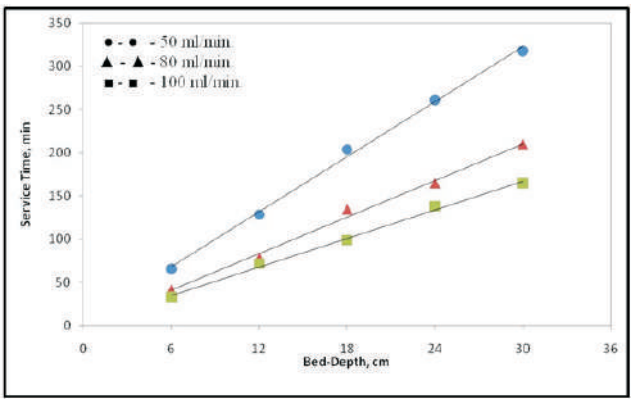

Fig. 4. Bed depth Vs service time

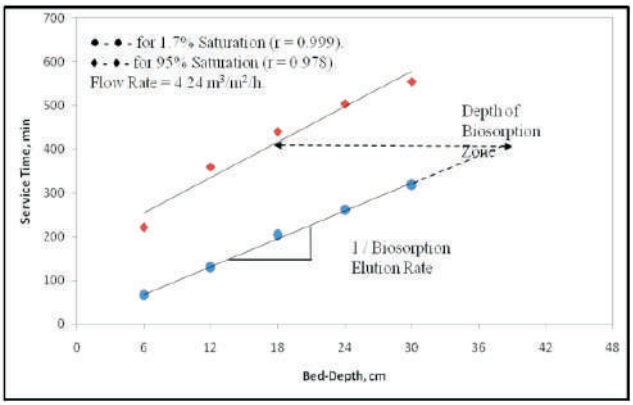

Fig. 5. Bed depth Vs service time design curves

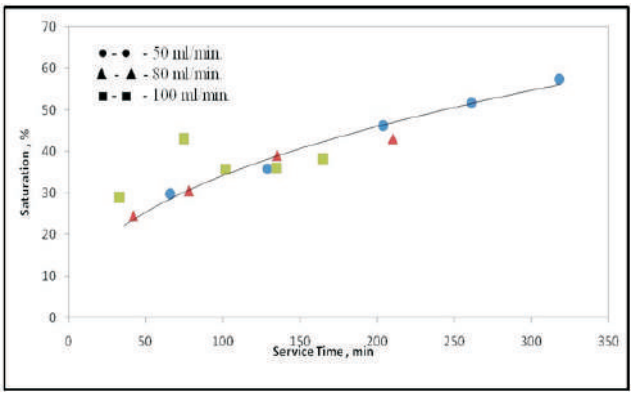

Fig. 6. Plot of bed saturation Vs service time

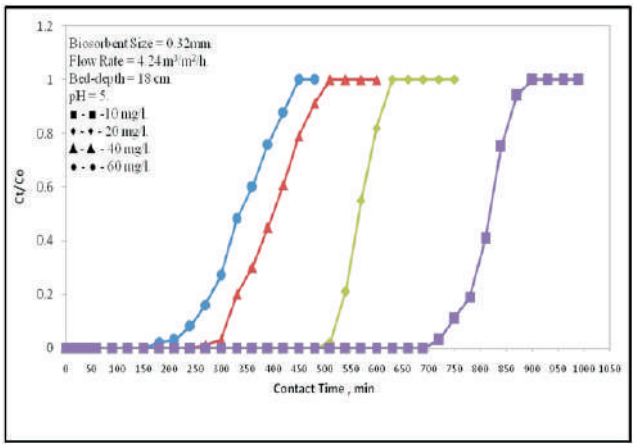

Fig. 7. Performance of TFS column for different initial concentrations of NO_3^-

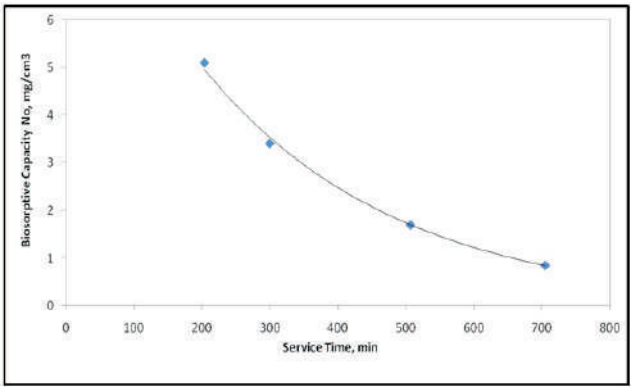

Fig. 8. Plot of biosorptive capacity Vs service time

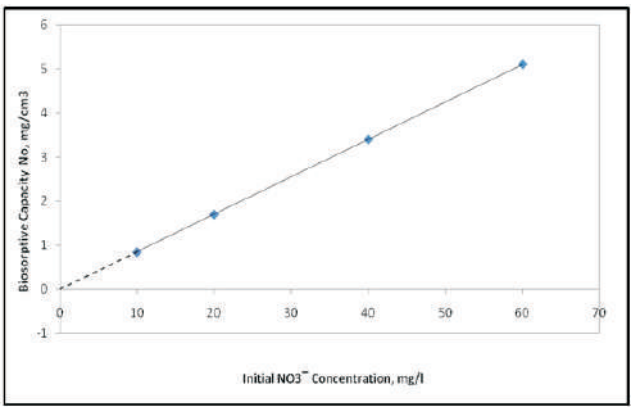

Fig. 9. Plot of biosorptive capacity Vs initial concentrations of No_3

progress in bed limit regarding administration time of the beds. Further, a relationship was developed between initial concentration of NO_3^- and biosorptive capacity of NO_3^- and shown in Eq. 8.

$$N_o = 0.09C_o \quad (8)$$

Bed performance with different particle sizes: The

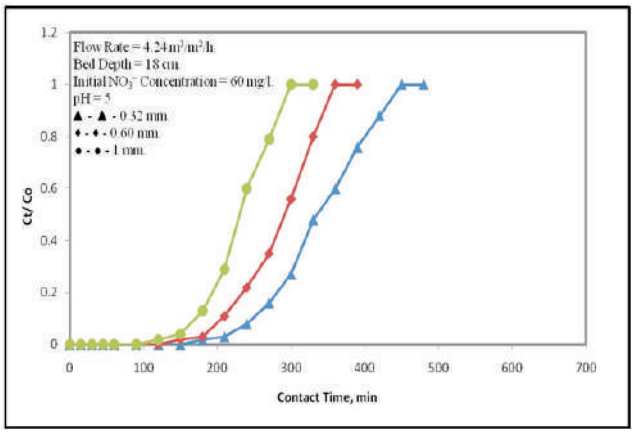

Fig. 10. Performance of TFS column for different particle sizes

biosorbent size in FBR operation not only affects the bed porosity, but also greatly influences the flow rate it can be seen that the service time (at 1.7% saturation level) is increased with decrease in the geometric mean particle size. Since experimental Reynolds number (R_e) varied between 0.39 and 1.21 (with sphericity constant, $\varphi = 0.9$, $\rho_w = 1000$ kg/m^3, $v = 1.18\times10^{-3}$ m/s, particle sizes; 0.32, 0.60, and 1 mm, and $\mu = 0.88\times10^{-3}$ Ns/m^2) shown in Fig.10, the Wilson and Geankoplis correlation model (Geankoplis, 1993) (for R_e between 0.0016 and 55) can be used to explain the effect of particle size on NO_3^- removal in FBR. As per the model;

$$J_d = (1.09\times R_e^{-2/3})/\varepsilon \quad (9)$$

Where, J_d is the mass-transfer factor (dimensionless) and ε is the bed void fraction or bed porosity (dimensionless). From Eq. 9, the J_d value varies from $2.04\varepsilon^{-1}$ (for 0.32 mm size) to $0.96\varepsilon^{-1}$ (for 1 mm size). As the bed porosity decreases with decrease in size of TFS, the respective J_d values will increase marginally (although the actual bed porosity was not available or not measured), and hence, bed capacity of TFS is increased. This was in accordance with the removal of Cr^{6+} by PATFS in FBR (Ramakrishnan 2010).

CONCLUSION

Based on the investigation relating to the biosorption of $NO3^-$ by TFS in FBR frameworks, The TFS is a decent biosorbent in expelling $NO3^-$ from fluid stage and exceedingly appropriate in FBR frameworks, for all size ranges between 0.32 and 1 mm. In all fixed bed studies, the pattern of the breakthrough curves is fairly different with respect to a typical S-shaped curve and the biosorption of NO_3^- by TFS can be best explained by BDST model. The head loss and swelling of TFS particles are insignificant during the fixed bed studies hence the biosorptive capacity of TFS is directly proportional to the initial feed concentration of No_3^-

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Genetic Diversity for Yield and Its Attributes in Barley (*Hordeum vulgare* L.) under Irrigated Condition

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Abstract: Genetic diversity among 87 barley genotypes comprised of two and six row types was carried out for 10 characters using Mahalanobis D^2 statistics. All the genotypes were assigned into eight distinct clusters depending upon the similarity in the expression of their genetic divergence. Maximum number of genotypes were grouped in cluster VI (20) followed by cluster VII (15), IV (13), III (12), VIII (10), II (8) and clusters V and I had six and three genotypes, respectively. Highest intra−cluster distance was observed for cluster V (3.360) followed by cluster VI (3.312) and cluster VII (3.304) whereas it was recorded minimum for cluster VIII (2.553).The average inter-cluster distance was found to be highest between the cluster I and VII (6.722) followed by between cluster I and VIII (5.534) while the lowest inter-cluster distance was observed between clusters III and IV. The contribution of number of grains per spike was maximum (32.24%) towards divergence out of 10 characters studied, followed by 1000-grain weight (24.73%), plant height (13.79%), days to heading (8.26%) and number of tillers per meter row (7.38%), whereas the remaining characters contributed very little to diversity. The improvement in six rowed barley could be achieved through the use genotypes assigned in clusters I and II, whereas the genotypes which contained in cluster VI might be considered as potential parents for two rowed barley to obtain high heterotic response and consequently better segregants for grain yield.

Keywords: Genetic diversity, Barley, Cluster

Barley (*Hordeum vulgare L.*), cereal plant of the grass family *Poaceae* and is edible grain. It is the fourth largest grain crop globally, after wheat, rice, and corn grown in a variety of environments. Commonly used in breads, soups, stews, and health products, though it is primarily grown as animal fodder and as a source of malt for alcoholic beverages, especially beer. Because of its hardiness, in many countries around the world, it is often considered the only possible rainfed cereal crop under low input and stressful environment. In India, the area under barley is around 0.69 million hectares with the production and productivity of 1.78 million tons and 2580 kg ha^{-1}, respectively. Haryana state achieved a productivity level of 3475 kg ha^{-1} on 40,000 hectares (Anonymous 2017).

Genetic diversity is essential for genetic improvement of a given crops. If the information on genetic diversity is not enough to utilize, the available genetic diversity study should be crucial (Addisu and Shumet 2015). The clustering of parents based on genetic diversity is a pre-requisite for a successful hybrid breeding program. The use of diverse parents gives better opportunities to a breeder for selection and development of superior varieties (Singh et al 2013). Criteria for the estimation of genetic diversity can be different: pedigree records, morphological traits, biochemical markers and molecular markers (Eshghi and Akhundova 2010). According to Muhe and Assefa (2011), knowledge of the genetic diversity and agronomic potential of barley landraces in variable environments is an important task to design strategic utilization of germplasm. High magnitude of genetic association may be due to pleiotropy rather than linkage. By improving the characters which are directly and positively correlated with yield will ultimately improve the yield (Singh et al 2014). The information on genetic diversity would be useful for selection parameters to plan crosses and maximize the use of genetic diversity and expression of heterosis in barley breeding program for yield improvement (Yadav et al 2015).

The present study, therefore, was undertaken with the aim of examining the magnitude of genetic diversity and characters contributing to divergence among barley genotypes.

MATERIAL AND METHODS

The experimental material consisted of 87 diverse genotypes including 47 two rowed and 40 six rowed barley. The material was evaluated in randomized block design with three replications at CCS Haryana Agricultural University, Hisar during *rabi* 2016−17. Each genotype was grown in six rows with a plot size of 5 x 1.38 m^2. Recommended package of practices were followed to raise the good crop. The observations were recorded for 10 quantitative traits *viz*.,

days to heading, days to maturity, plant height (cm), ear length (cm), number of tillers per meter row, number of grains per spike, 1000-grain weight (g), harvest index (%), biological yield (kg/plot) and grain yield (kg/plot). Five randomly selected competitive plants in each replication were recorded for all the traits under study except of days to heading, days to maturity, biological yield and grain yield which were recorded on plot basis. Further, the value of harvest index was calculated as per the formula given by Donald and Humblin (1976).

The mean performance of each genotype was embayed for statistical analysis. Analysis of variance to test the significance for each character was carried out as per methodology given by Panse and Sukhatme (1967). To quantify genetic divergence between any two genotypes or group of genotypes, Mahalanobis′ D^2 statistics (1936) as described by Rao (1952) was used and the genotypes were grouped into different clusters on the basis of Ward′s minimum variance method (Spark 1973).

RESULTS AND DISCUSSION

Significant differences were observed among the genotypes for all the character studied indicating considerable amount of variability among them. Genetic divergence (D^2) is the basis of variability and helps to craft the designed genotypes as per the requirement. Based on the results of cluster analysis, 87 genotypes were grouped into eight clusters in such a way that the genotypes within a cluster had a small D^2 values than those of in between the clusters. The cluster membership profile (Table 1 and Fig.1) revealed that cluster VI had the largest number of genotypes (20) followed by cluster VII (15), IV (13) and cluster III (12), while the cluster I was smallest with three genotype only. The clustering pattern showed that two rowed genotypes got distributed in three clusters *viz*., cluster VI, VII and VIII except two genotypes namely BH 16-36 and BH 16-39. Singh et al (2013) also studied the genetic divergence among 108 barley germplasm collections on the basis of 10 quantitative characters and grouped the genotypes into 11 clusters revealing the presence of considerable amount of genetic diversity in the material.

The inter-cluster distance was higher than the intra-cluster, indicating wide genetic diversity among the genotypes (Table 2 and Fig. 2). The maximum intra-cluster distance was recorded for clusters V (3.360) followed by cluster VI (3.312) and cluster VII (3.304). On the other hand, minimum intra-cluster distance (2.553) was observed in cluster VIII. It was reported that genotypes within the cluster with high degree of divergence would produce more desirable breeding materials for achieving maximum genetic advance (Singh et al 2014).

The highest inter-cluster distance was observed between clusters I and VII (6.722) followed by between clusters I and VIII (5.534) whereas it was minimum between clusters III and IV. The inter-cluster values that indicated close relationship were to be considered that hybridization among the genotypes of these clusters would not provide good levels of segregation. It is well recognized that greater the distance between clusters, wider the genetic diversity would be between the genotypes. Therefore, highly divergent genotypes would produce a broad spectrum of segregation in the subsequent generations enabling further

Table 1. Cluster membership profile of different genotypes

Clusters	Genotypes	No. of genotypes
I	BH 10-11 (1), BH393 (41), BH 16-40 (81)	3
II	BH 12-46 (4), BH 7-35 (19), BH 15-02 (14), BH 16-44 (85), BH 946 (38), BH 7-34 (18), BH 15-06 (25), BH 15-07 (15)	8
III	BH 13-22 (6), BH 14-44 (23), BH 15-30 (17), BH 16-10 (51), BH 16-43 (84), BH 15-39 (33), BH 14-01 (8), BH 14-13 (11), BH 15-37 (31), BH 14-42 (13), BH 15-25 (30), BH 16-45 (86)	12
IV	BH 15-16 (28), BH 16-18 (59), BH 16-20 (61), BH 16-33 (74), BH 902 (37), BH 16-06 (47), BH 16-07 (48), BH 16-42 (83), BH 16-13 (54), BH 16-11 (52), BH 16-30 (71), BH 16-17 (58), BH 16-29 (70)	13
V	BH 10-03 (34), BH 16-38 (79), BH 16-36 (77), BH 16-39 (80), BH 16-37 (78), BH 16-41 (82)	6
VI	BH 12-29 (3), BH 15-17 (16), BH 15-11 (26), BH 16-34 (75), BH 16-35 (76), DWRB 92 (40), BH 16-12 (53), BH 14-07 (10), BH 14-25 (12), BH 10-30 (2), BH 14-17 (20), BH 15-05 (24), DWRUB 52 (39), BH 14-43 (22), BH 16-25 (66), BH 14-06 (9), DWRB 101 (35), BH 885 (36), BH 16-21 (62), BH 15-38 (32)	20
VII	BH 13-20 (5), BH 16-19 (60), BH 15-24 (29), BH 16-05 (46), BH 13-26 (7), BH 14-40 (21), BH 15-12 (27), BH 16-27 (68), BH 16-08 (49), BH 16-24 (65), BH 16-26 (67), BH 16-31 (72), BH 16-03 (44), BH 16-32 (73), BH 16-04 (45)	15
VIII	BH 16-01 (42), BH 16-22 (63), BH 16-15 (56), BH 16-14 (55), BH 16-16 (57), BH 16-46 (87), BH 16-23 (64), BH 16-28 (69), BH 16-02 (43), BH 16-09 (50)	10

Values in parenthesis indicates serial number of genotypes

selection and improvement. The hybrids developed from the selected genotypes within the limit of compatibility of these clusters may produce desirable transgressive segregants of high magnitude of heterosis. Manjunatha et al (2007), Shakhatreh et al (2010), Ebrahim et al (2015), Yadav et al (2015) also found similar results of diversity in barley.

The eight clusters showed considerable differences in mean values for the characters under study (Table 3). Cluster I comprised of three genotypes, exhibited minimum number of days to head and maturity, shortest plant height and ear length, and had moderately high cluster means for grain yield as well as harvest index. The genetic distance value of these genotypes was 2.653. Cluster II consisted of 8 genotypes including national check variety BH 946, characterized by high 1000-grain weight among the clusters had six rowed genotypes with highest grain yield and biological yield. The genotypes of this cluster showed genetic distance of 2.995. Cluster III had 12 genotypes having characteristic features of highest number of grains per spike, lowest 1000-grain weight with highest number of days to head. The genetic distance value of these genotypes was 3.002.

Cluster IV, contained 13 genotypes including national check BH 902, recorded moderately high number of days to maturity and plant height with minimum number of tillers per meter row. The genetic distance value of these genotypes was 3.109. Six genotypes constituted cluster V and characterized by high number of tillers per meter row among the clusters having six row type barley, highest harvest index with minimum biological yield. Maximum genetic distance (3.360) was observed between genotypes of this cluster. The clusters VI, VII and VIII were assigned with two row barley genotypes. Cluster VI which consisted of 20 genotypes being largest one included national check varieties *viz*., DWRUB 52, DWRB 101, DWRB 92 and BH 885, exhibited maximum

Table 2. Estimates of intra-and inter-cluster distances

Clusters	I	II	III	IV	V	VI	VII	VIII
I	2.653	4.156	4.972	5.129	4.844	4.768	6.722	5.534
II		2.995	4.194	3.809	4.860	4.262	5.281	5.282
III			3.002	3.568	4.219	4.965	4.641	4.884
IV				3.109	4.565	4.823	4.419	4.715
V					3.360	5.142	5.492	5.365
VI						3.312	4.539	4.026
VII							3.304	3.908
VIII								2.553

Diagonal: Intra-cluster distances; Off-diagonal: Inter-cluster distances

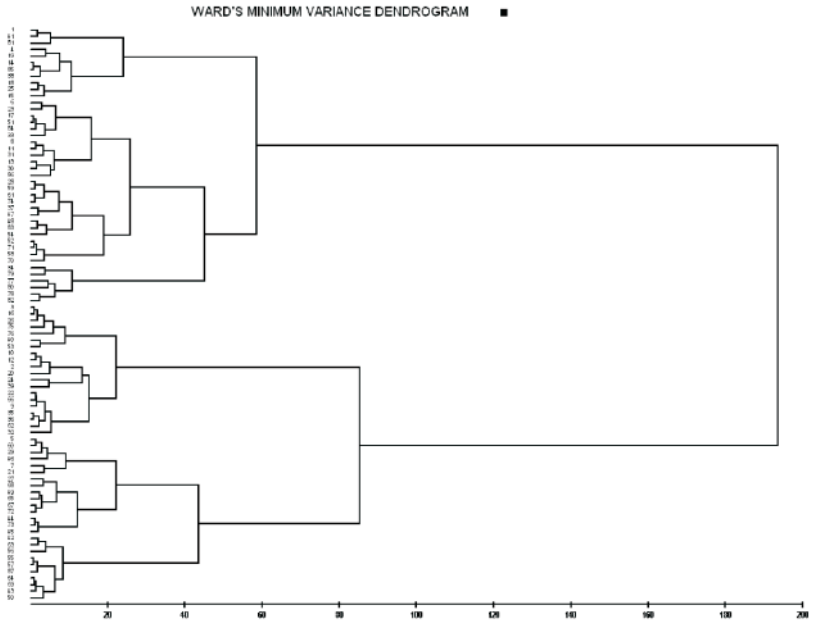

Fig. 1. Clustering by Ward′s minimum variance method

number of tillers per meter row, highest grain yield, biological yield as well as harvest index among two rowed clusters. The genotypes of this cluster showed genetic distance of 3.312.

Cluster VII had 15 genotypes was responsible for maximum number of days to mature and also showed highest plant height. The genotypes of this cluster showed genetic distance of 3.304. Cluster VIII contained 10 genotypes observed with highest ear length, 1000-grain weight and had lowest grain yield with genetic distance of 2.553. Several genetic diversity studies have been conducted on barley based on quantitative traits in order to select genetically distant parents for hybridization (Sharma et

Table 4. Contribution of different characters towards divergence

Source	Times ranked 1st	Contribution towards divergence (%)
Days to heading	309	8.26
Days to maturity	151	4.04
Plant height (cm)	516	13.79
Ear length (cm)	54	1.44
No. of tillers per meter row	276	7.38
No. of grains per spike	1206	32.24
1000-grain wt. (g)	925	24.73
Grain yield (kg/plot)	162	4.33
Biological yield (kg/plot)	133	3.56
Harvest index (%)	9	0.24

Table 3. Average performance of different clusters for yield and its attributes in barley

Characters	Clusters							
	I	II	III	IV	V	VI	VII	VIII
Days to heading	77.11	80.96	84.39	81.59	84.33	80.47	83.93	78.87
Days to maturity	118.11	122.50	122.53	124.77	123.44	121.33	124.80	120.47
Plant height (cm)	83.67	103.29	97.64	108.26	88.22	97.47	110.73	106.10
Ear length (cm)	5.97	6.29	6.92	6.45	6.78	6.37	7.01	7.15
No. of tillers per meter row	97.33	95.75	97.44	90.67	98.94	132.13	125.64	125.30
No. of grains per spike	63.68	61.17	65.79	63.64	50.79	24.37	26.71	25.27
1000-grain wt. (g)	40.13	44.36	37.84	43.04	39.46	50.39	51.08	52.29
Grain yield (kg/plot)	2.75	3.11	2.22	2.29	2.15	2.69	2.03	1.85
Biological yield (kg/plot)	7.93	9.33	8.71	8.47	6.13	8.79	8.70	7.66
Harvest index (%)	35.09	33.75	25.65	27.36	35.42	31.21	23.33	24.49

Table 5. Diverse and superior genotypes with desirable traits selected from different clusters

Characters	Desirable genotypes
Days to heading (Early)	Six rowed: BH 393, BH 10-11, BH -35, BH 16-40 Two rowed: BH 14-06, BH 16-09
Days to maturity (Early)	Six rowed: BH 10-11, BH 393, BH 13-22 Two rowed: BH 16-23, BH 16-09, BH 16-22
Plant height (Medium Dwarf)	Six rowed: BH 16-40, BH 10-03, BH 393, BH 10-11, BH 13-22 Two rowed: BH 16-35, BH 16-36, DWRB 92, BH 14-06, BH 10-30, DWRUB 52, BH 14-25, BH 14-17
Ear length (cm)	Six rowed: BH 14-44, BH 16-37, BH 13-22 Two rowed: BH 14-40, BH 16-36, BH 13-26, BH 16-19, BH 16-12
No. of tillers per meter row	Six rowed: BH 12-46, BH 7-35, BH 16-29, BH 15-25 Two rowed: BH 14-40, BH 14-07, DWRB 92, BH 14-25, BH 10-30
No. of grains per spike	Six rowed: BH 15-30, BH 13-22, BH 16-43, BH 16-17 Two rowed: BH 13-20, BH 16-19, BH 16-28, BH 14-40
1000-grain wt. (g)	Six rowed: BH 15-06, BH 15-02, BH 7-34, BH 15-07 Two rowed: BH 16-09, DWRB 92, BH 16-12, BH 15-11
Grain yield (kg/plot)	Six rowed: BH 15-07, BH 15-06, BH 946, BH 15-02, BH 393, BH 7-34, BH 7-35, BH 16-44 Two rowed: BH 14-17, BH 14-07, BH 10-30, BH 16-12, DWRUB 52, DWRB 92, BH 14-25, BH 13-26
Biological yield (kg/plot)	Six rowed: BH 15-07, BH 14-13, BH 902, BH 15-06 Two rowed: DWRUB 52, BH 15-05, BH 13-26, BH 14-40, BH 15-12
Harvest index (%)	Six rowed: BH 946, BH 16-40, BH 16-38, BH 15-02, BH 10-03 Two rowed: BH 16-35, BH 10-30, BH 16-36, BH 14-17

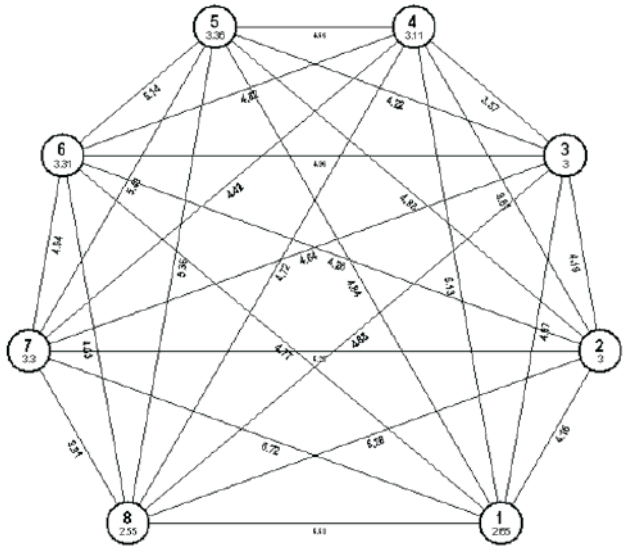

Fig. 2. Euclidean Distances in barley genotypes

al 2014, Dyulgerova et al 2016, Sarkar et al 2014).

Out of 10 traits studied, contribution of number of grains per spike towards divergence was maximum (32.24%) followed by 1000-grain weight (24.73%), plant height (13.79%) and days to heading (8.26%), whereas, the remaining traits like number of tillers per meter row (7.38%), grain yield (4.33%), days to maturity (4.04%), biological yield (3.56%), ear length (1.44%) and harvest index (0.24%) contributed very little to divergence (Table 4).The contribution of various characters towards the expression of genetic divergence should be taken into account as a criterion for choosing parents for crossing programme for the improvement in such characters. Similar findings have also been corroborated by Singh et al (2014) in barley. Hailu et al (2016) also showed the presence of high genetic divergence among barley genotypes based on cluster and principal component analyses for breeding strategies. Most diverse and superior genotypes with desirable traits selected from different clusters are represented in Table 5.

Therefore, it can be concluded that clusters I and II for six rowed and cluster VI for two rowed might be considered desirable for selecting genotypes which may be used as promising parents for hybridization. The genotypes, which fall in these clusters could be used in crossing programme to obtain high heterotic response and thus better segregants in subsequent generations for higher grain yield in barley.

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Quality Evaluation of Elephant Foot Yam (*Amorphophallus paeoniifolius* Dennst- Nicolson) Cultivars during Growth and Development

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Abstract: Eleven cultivars of elephant foot yam were evaluated and variability was observed at monthly intervals within the cultivars. In cv. NDA-9 and AC-28 amount of dry was more at 100 and 250 DAP respectively. The TSS was higher in cultivar NDA-9 and BCA-5 and BCA-2 and total sugar in BCA-5 and BCA-2 .The range of titrable acidity was 0.064-0.160 % at different stages during growth and development. Significant increase was in dry weight, total soluble solids, total sugar and titrable acidity during growth and development period at monthly intervals.

Keywords: Elephant foot yam, Cultivar, TSS, TS, Acidity

Amorphophallus paeoniifolius Dennst-Nicolson known as Elephant foot yam is a highly potential tropical tuber crop of Areace family (Jansen et al 1996). It is regarded as "King of tuber crops" due to its higher biological efficiency as a food producer and possesses higher productivity in a short growing season as well as confers high returns (Nedunchezhiyan 2014, Singh et al 2017). Root and tubers are the most important food crops since time immemorial in the tropics and subtropics (Behera et al 2009). The tubers are rich in nutrients and is a natural product that is high in fiber, rich in potassium, calcium (50 mg g^{-1}), phosphorus (34 mg g^{-1}) vitamin A (260 IU g^{-1}), vitamin B6, as well as with trace minerals like selenium, zinc and copper It is difficult to ascertain whether the tubers can be relied upon as good sources of minerals because of the presence of anti-nutrition substances (oxalate), which render the minerals, in them unavailable to the consumers (Onwuka 2005). These corms are consumed by many people as a food and widely used in many ayurvedic preparations (Angayarkanni et al 2007) because it contains different bioactive components like alkaloids, flavonoids, phenols, vitamins, minerals etc. (Dey et al 2010). For this study, elephant foot yam cultivars were evaluated for horticultural and nutritional parameters, to provide information to the breeders to develop desirable cultivars having a high yield and a better nutritional profile.

MATERIAL AND METHODS

Collection of samples: The experiments were carried out at Bidhan Chandra Krishi Viswavidyalaya, India during 2010-2012 with a view to analyze the physico-chemical characteristics of fresh harvested corms of elephant foot yam at monthly intervals. Eleven cultivars of elephant foot yam were procured from state agricultural universities and research institutes under the Indian council of agricultural research, India and cultivated at horticultural research station Mondouri, BCKV, India. The samples were collected in the month of December and stored at ambient condition, while planting has been done at 5th and 16th of April 2011 and 2012, respectively. The monthly data was recorded from 100 days after planting to 250 DAP. Climatically the region located at 23.5 ^{o}N latitude and 89 ^{o}E longitudes with an altitude of 9.75 m above mean sea level. The soil was a slightly acidic (pH 6.5) with sandy loam and climatic condition was tropical humid with rainfall of 0.00 to 264.00 mm, temperature maximum 37.59 ^{o}C and minimum 9.62 ^{o}C along with RH (%) 96.87 to 36.74 (Annual average).

Physico-chemical analysis: The physic-chemical traits of elephant foot yam were recorded from 10 randomly selected plants from each replication in both year at monthly intervals during growth and development by mentioned methods *viz.*, total sugar (Moorthy and Padmaja 2002), total soluble solids by Pocket refractometer, titrable acidity by titration method

(AOAC 1990) and dry weight by total moisture content of fresh corms weighing 100 g was calculated from loss in weight during drying at 70 °C for 48 hrs.

RESULTS AND DISCUSSION

Dry Weight: Dry weight content of corm was significantly influenced by cultivars during maturity stages (Table 1). In cultivar NDA-9 and AC-28 dry matter contents were 21.11 and 38.82 % at 100 DAP and 250 DAP ,respectively. The lowest amount was in cultivar BCA-4 (17.49 %) and NDA-5 (26.56 %) at 100 and 250 DAP respectively. A wide range of dry weight content was also observed by Panja et al 2017 in elephant foot yam corms during storage.

Total soluble solids: The total soluble solids (TSS °Brix) content of elephant foot yam corms increased throughout the growing periods in both the years. The highest TSS content

Table 1. Changes in dry weight and TSS contents in elephant foot yam corms in different cultivars

Cultivars	Dry Weight (%)						TSS (°Brix)					
	100	130	160	190	220	250	100	130	160	190	220	250
BCA-1	19.15	22.50	26.74	29.36	35.83	36.70	6.00	7.10	7.40	7.90	8.40	8.50
BCA-2	18.53	20.29	22.54	23.89	27.09	27.90	5.40	5.70	6.50	6.90	7.30	7.50
BCA-4	17.49	18.95	24.84	27.92	29.45	30.81	4.90	5.60	7.40	8.00	8.50	8.70
BCA-5	20.49	20.75	25.33	29.74	31.33	33.24	5.10	6.00	6.80	8.30	8.70	8.90
BCA-6	19.64	19.95	23.04	23.95	27.32	29.33	5.20	5.90	7.30	7.90	8.20	8.40
NDA-4	20.41	22.13	26.19	29.28	33.15	35.50	5.80	6.30	6.80	7.70	8.10	8.30
NDA-5	19.41	19.60	20.25	23.95	25.55	26.56	5.70	6.10	7.00	8.00	8.40	8.60
NDA-9	21.11	22.45	25.11	29.44	32.98	34.73	6.50	7.00	7.60	8.20	8.70	8.80
AC-28	20.02	20.73	26.66	30.08	35.52	38.82	5.10	5.70	6.10	6.50	7.30	7.40
IGAM-1	19.56	22.64	27.16	29.12	33.06	34.29	5.30	5.90	7.00	7.80	8.60	8.80
Gajendra	19.32	20.26	24.51	26.36	27.64	29.74	5.80	6.20	7.00	7.50	8.20	8.30
Mean	19.56	20.93	24.76	27.56	30.81	32.51	5.50	6.10	7.00	7.70	8.20	8.40
	CD (p=0.05)						CD (p=0.05)					
C	1.84	1.87	1.82	1.84	1.87	1.61	1.15	1.10	1.21	1.09	1.41	1.14
Y	0.78	0.80	0.78	0.78	0.79	0.69	0.49	0.47	0.52	0.46	0.63	0.48
CY	2.60	2.65	2.58	2.60	2.64	2.28	1.63	1.56	1.72	1.54	2.00	1.61

Days after planting

Table 2. Changes in total sugar (%) and titrable acidity (%) contents in elephant foot yam corms in different cultivars

Cultivars	Total Sugar (%)						Titrable Acidity (%)					
	100*	130	160	190	220	250	100	130	160	190	220	250
BCA-1	0.54	0.95	1.04	1.29	1.53	1.58	0.088	0.110	0.122	0.130	0.140	0.150
BCA-2	0.68	0.95	1.17	1.40	1.66	1.69	0.096	0.114	0.125	0.132	0.139	0.148
BCA-4	0.56	0.78	1.04	1.23	1.60	1.64	0.064	0.098	0.114	0.122	0.131	0.143
BCA-5	0.68	0.87	1.04	1.24	1.53	1.56	0.096	0.113	0.124	0.132	0.140	0.150
BCA-6	0.57	0.89	1.03	1.25	1.54	1.58	0.096	0.118	0.128	0.136	0.141	0.153
NDA-4	0.61	0.90	1.00	1.22	1.48	1.51	0.080	0.102	0.112	0.119	0.126	0.137
NDA-5	0.53	0.88	0.98	1.19	1.33	1.35	0.096	0.113	0.124	0.132	0.141	0.152
NDA-9	0.61	0.85	1.01	1.25	1.63	1.67	0.096	0.099	0.109	0.118	0.127	0.141
AC-28	0.60	0.72	0.94	1.21	1.46	1.50	0.096	0.135	0.125	0.133	0.140	0.152
IGAM-1	0.50	0.82	0.98	1.30	1.35	1.40	0.080	0.097	0.108	0.122	0.129	0.131
Gajendra	0.61	0.79	0.93	1.18	1.59	1.63	0.109	0.123	0.132	0.139	0.146	0.160
Mean	0.59	0.85	1.01	1.25	1.52	1.55	0.091	0.109	0.120	0.128	0.136	0.147
	CD (p=0.05)						CD (p=0.05)					
C	0.35	0.26	0.38	0.35	0.39	0.36	0.03	0.04	0.03	0.03	0.03	0.03
Y	0.15	0.11	0.16	0.15	0.16	0.15	0.01	0.02	0.01	0.01	0.01	0.01
CY	0.49	0.36	0.54	0.49	0.55	0.51	0.04	0.05	0.04	0.04	0.04	0.04

Days after planting

were in cultivar NDA-9 (6.5 °Brix) and BCA-5 (8.9 °Brix) at 100 DAP and 250 DAP respectively. While, cultivar BCA-4 (4.9 °Brix) and AC-28 (7.4 °Brix) content lowest amount of TSS at 100 and 250 DAP respectively (Table 1). The increase in TSS might be due to depletion of moisture in the form of water from elephant foot yam corms during growth and development stage. A similar finding was reported by Shirke et al (2002) in sweet potato.

Total sugar: Cultivars also produced significant effect on total sugar and it showed a increasing trend from 100 days after planting to 250 DAP. The highest total sugar content was in cultivar BCA-2 and BCA-5 (0.68 % each) at 100 DAP, while in BCA-2 (1.69 %) at 250 DAP (Table 2). The lowest total sugar content was in cultivar NDA. It could be due to hydrolysis of polysaccharides. The increase in total sugar was reported by Panja et al 2017 in elephant foot yam corms during storage from harvest to 90 days of storage.

Acidity: There was a continuous increase in the acid content of corm during growth and development in both years (Table 2). The highest content of titrable acidity was in cultivar Gajendra at 100 and 250 DAP (0.109 and 0.160 % respectively). The lowest content of titrable acidity was in cultivar BCA-4 (0.064 %) and IGAM-1 (0.131 %) at 100 and 250 DAP, respectively. Panja et al (2017) reported similar trends in elephant foot yam corms during storage. The NDA-9, AC-28 and BCA-5 were best performing cultivars among the eleven cultivars during research period.

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