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Wild Edible Plant Resources of Kedarnath Valley, Garhwal Himalaya, India

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Abstract: The Kedarnath valley of Garhwal Himalaya is very rich in wild edible plant resources. A total of 20 villages were surveyed during the study period from May 2016 to August 2017 for potential use of wild edible plants of Kedarnath Valley. Information on the use of wild edible plant resources were conducted through questionnaire based survey, reconnaissance survey, semi-directive interview and market survey. The study documented 72 wild edible plant species belong to 59 genera and 44 families of trees, shrubs, herbs and climbers plant species. Herb contributed the largest proportion with 25 species (34%), followed by tree with 23 species (33%), shrub of 18 species (25%), climbers of 4 species (8%) and one species of fungi. Wild edible plant parts contributed by fruits (25%), leaves (25%) and branches (14%). These edible plant species are sold in the market by the local inhabitants for their livelihood. Utilization of these edible plant resources for food, medicines and livelihood should be promoted for meeting the needs of the people in Kedarnath Valley.

Key words: Kedarnath Valley, Livelihood, Traditional knowledge, Wild edible plant resources.

Wild edible plant resources are the chief source of nutrients and have the potential to sustain human health and their livelihood. Income from the edible fruits and other parts of the wild plants can be the main source of household income for rural communities. Rural people utilized wild plants for their livelihood; the scientists have recently realized the importance of such plants in rural economy. Uttarakhand, a Himalayan state of India, is known for its biodiversity as well as rich heritage of wild edible plants. Uttarakhand has a total area of 53,483 km^2 of which 86 per cent is mountainous and 65 per cent is covered by forest (FSI 2011). Forests play a key role in the life of tribal as well as other communities; as they provide significant ecosystem services in the form of food, fodder, fruits, timber and medicine (Panday and Joshi 2016). Forest are the integrate part of the sustainable development. In Uttarakahnd, wild edible plant resources of Garhwal Himalaya play an important role in providing supplementary food requirements. Wild edible plant resources are widely consumed in the rural areas of Garhwal Himalaya and are also used in folk traditional medicines. Several decades ago, the idea that indigenous people and other societies were exemplary conservationists gained widespread publicity in popular media as well as academic circles (Smith and Wishnie 2000). Traditional resource management and life support systems have evolved through trial and error throughout history and are sustainable when operated within the carrying capacity of the ecosystem (Ramakrishnan et al 1994, Rao and Saxena 1994, Hoon 1996). Hence, keeping in view the importance of the edible plant resources, the present investigation on the diversity, availability of fruits, traditional medicinal use and livelihood support of wild edible plant resources of Kedarnath Valley was undertaken.

MATERIAL AND METHODS

Study area: The Kedarnath Valley is located in the Rudraprayag district of Garhwal Himalaya, Uttarakhand. The survey of wild edible plant resources was done from lower altitude of 864 m above m.s.l to alpine meadow of Kedarnath-Tunganath (3,680-4,000 m above m.s.l). The current study was carried out in 20 villages of Kedarnath valley in Ukhimath tehsil between latitude 30°23'0.04" to 30°48'33.79" N and longitude 78°54'15.52" to 79°21'30.00" E. The forest area of the Kedarnath Valley is rich in the species of Deodar (*Cedrus deodara*), Kail (*Pinus walichiana*), Oak (*Qurcus incana*, *Quercus leucotricophora*). Buransh (*Rhododendron arboretum)*, Thuner (*Taxus baccata),* Chil *(Pinus roxburghii*), Akhrot (*Junlans regia*), etc. in the higher reaches. Kedarnath valley is very rich in edible plant resources. Kedarnath valley is also famous for alpine grasslands (*Bugyals)*.

Collection of data: Twenty villages were surveyed for the study. Only those local people were selected who have rich knowledge about wild edible plants of the area. The study was conducted from May 2016 to August 2017 in Kedarnath, Gaurikund, Triginarayan, Taushi, Shearsi, Barsau, Tarsali, Narayankoti, Guptakashi, Kabiltha, Kalimath, Ukhimath, Sari, Karokhi, Chupta, Tungnath, Ransi, Gundar, Bhiri and

Chandrapuri. Data for the study were collected from primary as well as secondary sources.

Questionnaire based survey: Household survey was conducted using individual personal surveys meetings and group discussions as well as field survey in Kedarnath Valley. Based on baseline information, detailed questionnaire was designed for household level survey. In the study area, 409 households from 20 villages were randomly surveyed. Interviews with the local population about the traditional knowledge were also conducted during the survey.

Reconnaissance survey: Pre-reconnaissance survey was carried out prior to the present study. The main objectives of the survey were to get an idea for inventorization and characterization of wild edible plant resources of the Kedarnath Valley. The attempts were made to include more number of females in interviews as they have more involvement in collection of wild edible plant resources. During the field investigation, discussions were carried out with the users using semi-structured questionnaires and open ended interviews to understand livelihood support to the rural communities in the study area.

Semi-directive interview: The semi-directive interview was more conversation than a questions and answer session with the villagers of Kedarnath Valley. For personal interviews of household's, semi structured questionnaire was used to collect relevant information on wild edible plant resources. Adult female members from the household, who were responsible for food preparation, were considered as the key respondent. Later on, extensive field study was carried out to ascertain the correct identity of the wild edible plant resources.

Market survey: Market survey was carried out by selecting the main market (Gaurikund, Sonprayag, Phata, Guptakashi, Ukhimath) in the Valley by visiting frequently during the study period. Occasional visits were also made to other markets of the remaining villages in the Valley. Data on price of raw wild edible fruit bearing plants/kg and value added products at the level of collector, whole seller and retailer were gathered by using structured questionnaire. Based on that, gross income of the each seller and buyer was calculated. The selected markets which are permanent in nature were selected.

RESULTS AND DISCUSSION

The present study in the Kedarnath Valley, documented 72 species belonging to 59 genera and 44 families. With respect to families, Rosaceae contributed the largest proportion, with 8 species, followed by *Berberidaceae, Ericaceae, and* Moraceae with 4 species, *Arecacea* and Convallariaceae with 3 species. *Caesalpiniaceae, Dryopteridaceae, Elaeagnaceae*, *Fabaceae*, Fagaceae, *Myricaceae,* Pinaceae, Polygonaceae, *Sapindaceae* and *Urticaceae* were represented by two species each and the remaining families were monotypic (Table 1). Forty-six *species of* plants are used as medicine, 36 edible and 32 fuels. They were also used in making agriculture tools, vegetables, religious, fodders and for preparation of juice, sauce, jam and jellies (Fig. 1). The herbs contributed the maximum with 24 species (33%), followed by trees, shrubs, climbers and fungi. Fruit is the frequently used part, followed by leaves, branches, barks, stems, roots, flowers, seeds, whole plants, shoots, bulb and twigs (Fig. 2). Ballabha et al (2013) documented 82 species of wild edible plants of Lobha Range of Kedarnah Forest Division. Many other authors also documented approximately 350 wild edible plants from the different parts of Garhwal Himalaya (Gairola and Biswas 2008, Singh et al 2008, Mehta et al 2010, Tiwari et al 2010, Chandra et al 2013, Bohra et al 2017).

Market potential of wild edible plant resources for sustaining livelihood: The local communities are not only using the wild edible plants as food, but they are also using some of these wild edible plants for their livelihood. In 20 surveyed villages, 90 household from 17 villages sale wild edible plants and its products in markets (Table 2). In most of the villages, fruits and its products of wild plants were used only for their own consumption. Among the recorded wild edible plant resources, five wild edible plant species (*Rhododendron arboretum, Myrica esculenta, Grewia optiva, Phyllanthus emblica* and *Diplazium esculentum)* were sold in market by the villagers for their livelihood. Among the surveyed villages in Kedarnath Valley, 56 per cent of villages used *Rhododendron arboretum*, 22 per cent of villages used

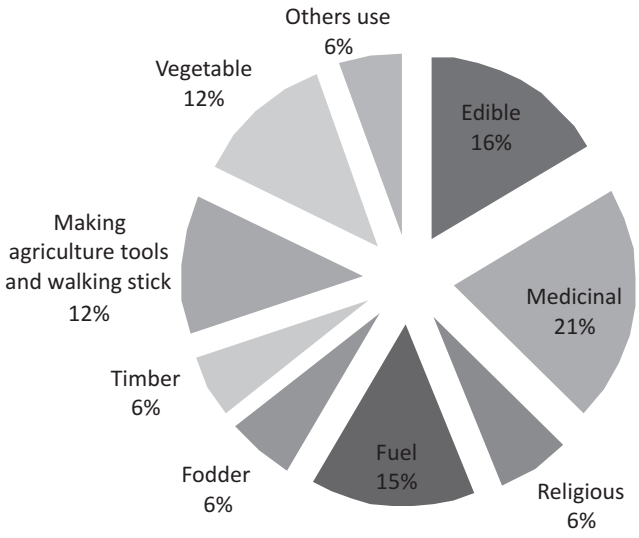

Fig. 1. Percentage composition of wild edible plant resources used in different purpose

Table 1. Wild edible plant diversity, life forms, flowering, fruiting periods, plant parts use, traditional use, conservation status and altitudinal range

Botanical name	Local name	Life form	Flowering/growing period	Fruiting/collection periods	Plant part used	Traditional use	Conservation status	Altitudinal range (m)
							IUCN	
Agaricaceae								
Agaricus campestris L.	Mushroom	Fungi	June – July	July- September	Carpophores	Vegetable, medicinal	-	1,200-2,500
Amaranthaceae								
Amaranthus bilatum L.	Jangli chulai	Herb	June – July	July - August	Leave, seed	Vegetable	-	1,500-2,500
Amaryllidaceae								
Allium carolianum DC. in Red.	Faran	Herb	Feb- March	April-June	Whole	Vegetable, medicinal	-	2,500-4,000
Apiaceae								
Angelica glauca Edgew.	Choru	Herb	May-June	June-October	Leaves and roots	Vegetable, flavor, medicinal	Endangered	2,500-4,000
Aprocynaceae								
Carissa spmarum L	Karonda	Shrub	July - August	November-December	Fruits, leaves	Edible , medicinal	-	900-1,600
Arecacea								
Arisuema totuosum (Wall.) Schot	*Bagmungari*	Herb	May-June	July-Aug	Fruits, leaves	Medicinal	-	1,000-3,000
Colocasia esculenta Schott	*Pindalu, Arbi*	Herb	June – July	September –November	Young leaves, stem,	Vegetable, religious	LC	1,200-2,000
Phoenix pusilla Roxb.	*Khajoor*	Shrub	November-December	January-February	Fruits, roots, leaves,	Edible, medicinal , making broom, religious	-	870-1,300
Berberidaceae								
Berberis aristata Roxb.ex.DC.	*Kilmor*	Shrub	Mar-April	May –June	Fruits, bark, stem roots	Edible, fuel, medicinal, making agriculture tool	-	1,000-3,000
Berberis asiatica Roxb.ex.DC.	*Kilmor, Kirmor*	Shrub	Mar-April	May –June	Fruits, stem, roots bark	Edible, fuel, medicinal, making agriculture tool	-	1,000-3,000
Berberis jaeschkeana DC.	*Kilmor*	Shrub	Mar-April	May –June	Fruits, stem, roots bark	Edible, fuel, medicinal, making agriculture tool	-	3,000-3,300
Berberis lyceum L.	*Kilmori*	Shrub	Mar-April	May –June	Fruits, stem, roots bark	Edible, medicine, making agriculture tool and fuel	-	1,500-3,000
Buxaceae								
Sarcococca saligna (D.Don)	*Geru, Paliyala*	Shrub	July-August	April-May	Fruits, leaves, bark	Medicinal	-	1,500-3,000

Cont...

Caesalpiniaceae								
Banhinia variegata L.	*Kachnar*	Tree	February -March	March- May	Young leaves, fruits	Vegetable, pickle, medicinal, fuel, making agriculture tools, walking stick	-	870-1,300
Caesalipinia decapetala (Roth) Alston	*Kingari, Kunju*	Climber	May-June	July- August	Fruits, stem, roots	Medicinal, fodder, fuel	-	1,100-3,000
Cannabinaceae								
Cannabis sativa Linn.	*Bhang*	Herb	May-June	August-September	Seeds, leaves, and bark	Edible, medicinal, religious	-	1,100-2,500
Caprifoliaceae								
Viburmum mullaha Buch. –Ham.ex D.Don	*Malyo*	Tree	May-June	July- August	Fruits, leaves, stem and branches	Edible, jam, making walking sticks, agriculture tools, fodder, fuel	-	1,000-2,500
Chenopodiaceae								
Chenopodium album L.	*Bathua*	Herb	May –June	June- August	Leaves, young shoot	Vegetable	-	1,200-3,000
Convallariaceae								
Polygonatum cirrifolium Wall.		Herb	November-December	Jan-May	Leaves, stems, and rhizomes	Vegetable, medicinal	-	2,000-3,500
Polygonatum verticillatum L		Herb	January- February	March-June	Young leaves	Vegetable, medicinal	-	2,400-3,700
Smilacina purpurea Wallich		Herb	February -March	March- May	Fresh leaves	Vegetable	-	2,800-3,600
Cucurbitaceae								
Trichosanthes tricuspidata Lour.	*Elaru*	Climber	July – August	September –October	Fruit seed	Medicinal	-	870-1,350
Deoscoreaceae								
Dioscorea belophylla (Prain) Haines Syn.	*Tedu*	Climber	February - March	March-April	Bulb	Vegetable, religious	-	1,200-2,000
Dryopteridaceae								
Diplazium esculentum (Retz.) SW.	*Lingra*	Herb	March-April	April-July	Young frond	Vegetable	LC	1,300-3,000
Diplazium L.	*Lingra*	Herb	March-April	April-July	Young frond	Vegetable	LC	1,300-3,000

Elaeagnaceae								
Elueagnus parvifolia Wall.ex Royal	*Giwain*	Shrub	May-June	July- August	Fruits, branch	Edible, fuel	-	1,200-3,000
Hippophae salicifolia D.Don		Tree	April-May	September - October	Fruits, branch	Edible, medicinal, fuel, making agriculture tools and walking stick	-	2,000-2,600
Ericaceae								
Rhododendron anthopogon D.Don	*Burans*	Herb	February -March	July- August	Flowers, leaves	Religious	-	3,500-4,200
Rhododendron arboreum Sm.	*Burans*	Tree	February -March	July- August	Flowers, leaves, branch	Juice, sauce, jam, jellies and refreshing drinks , medicinal, religious, fuel and making walking sticks and agriculture tools	-	870-2,200
Rhododendron barbatum	*Burans*	Tree	February-March	July- August	Flowers, leaves, branch	Juice, sauce, jam, jellies and refreshing drinks , religious, medicine, fuel, making walking sticks and agriculture tools		-
Rhododendron campanulatum D.Don	*Burans*	Shrub	February-March	July-August	Flowers, leaves, branch	Juice, sauce, jam, jellies and refreshing drinks , religious, medicinal, fuel and making walking sticks and agriculture tools	-	2,500-3,400
Fabaceae								
Lathyrus spp. L.	*Kurfalya*	Herb	January-February	February-March	Pods and small leaves	Edible, fodder	NT	1,000-2,022
Crotalaria medicaginea Lam.	*Ban methi*	Herb	August-September	February-March	Root , seeds	Vegetable, medicinal	-	1.200-1,500
Fagaceae								
Castanopsis spp L.	*Pangar*	Tree	May –June	July – August	Fruits, branches	Edible, fuel, medicinal and making agricultural tools, vegetable oil	-	1,300-1,700

Quercus leucotrichophora L	*Banj likwal*	Tree	April May	September - October	Fruit, leaves, branch, bark	Medicine, fodder, fuel making agricultural tools and walking stick.	-	900-2,400
Juglandaceae								
Juglans regia L.	*Akhrot*	Tree	April-May	July- August	Fruit, leaves, branches, stem, fruit cover	Medicinal, edible, timber, making agricultural tools and religious	NT	900-1,560
Lauraceae								
Cinnamomum tamala (Buch.-Ham.) Nees	*Dalcheeni/ Tejpat*	Herb	January-December	January-December	Leaves, bark	Vegetable, medicinal	-	1,000-1,500
Loranthaceae								
Taxillus vestitus (Wall.) Danser	*Bandu*	Tree (Parasite with Oak)	July- August	September - October	Fruits, leaves, stems	Edible and fodder and medicine	-	1,300
Moraceae								
Ficus auriculata Lour.	*Timla*	Tree	Mar-April	July- August	Fruits, leaves branches, bark	Edible, fodder vegetables, medicinal, religious, making agricultural tools and walking stick , fuel	-	900-1,300
Ficus palmate Forsk.	*Bedu*	Tree	Mar-April	July- August	Fruits, leaves, branches	Edible, fodder medicinal, making agricultural tools and walking stick , fuel	-	1,300-2,000
Ficus semicordata Buch.-Ham.ex J.F.Smith	*Khenu*	Tree	May-June	June-October	Fruit, leaves, branch, bark	Edible, vegetable, making agriculture tool, walking stick, fuel and medicine	-	870-1,500
Morus serrata Roxb.	*Keemu, sehtut*	Tree	February-March	May –June	Fruits, leaves, branches, bark	Edible, fodder, Fuel, source of silk, medicinal, making agricultural tools, walking stick	-	1,,200-2,300
Myricaceae								
Myrica esculenta Buch. -Ham.ex D.Don	*Kafal*	Tree	April-May	May –June	Fruits, leaves, branches	Medicinal, edible, juice, medicinal, making agricultural tools, walking stick and fuel	-	870-2,300
Syzygium cuminii (L.) Skeels	*Jamun*	Tree	March - April	July- August	Fruits, leaves, stems	Edible, making jam, squash, vinegar and jellies medicinal, fuel	-	900-1,600
Oxalidaceae								
Oxalis corniculata L.	*Bhilmori*	Herb	Most of the year	Most of the year	Whole plant	Vegetable, salad, fodder and medicinal	-	1,200-2,000

Paeoniaceae								
Paeonia emodi Royal	*Dhanduru*	Herb	December - January	January -May	Leaves, seeds, stems, roots	Edible, vegetable, medicinal	-	1,000-2,500
Phyllanthaceae								
Phyllanthus emblica L.	*AmlaMa Amla*	Tree	October– Nov ember	December - Jan	Fruits, leaves, seed, branch	Edible, medicinal, making pickle, marmalade, juice, hair oil, and shampoo and fuel	-	1,300
Phytolaccaceae								
Phytolacca acinosa Roxb.	*Jagra*	Herb	February-March	March- June	Fresh young leaves	Vegetable	-	870-1,500
Pinaceae								
Pinus roxburghii Sarjent	*Kulain*	Tree	April-May	June-July	Fruits, leaves, twigs, stems	Edible, medicinal, fuel, timber and religious, making turpentine oil	LC	1,000-2,000
Pinus walchiyana A.B. Jacks	*Kulain*	Tree	April-May	June-July	Fruits, leaves, twigs, stems	Edible, medicinal, fuel, timber and religious, making turpentine oil	LC	1,000-2,000
Poaceae								
Bambusa vulgaris Schrad. ex J.C. Wendl	*Bans*	Herb	August - September	September - October	Young shoot, stems, leaves	Vegetable, pickle, fuel, fodder, walking sticks, agriculture tools	-	870-1,500
Podophyllaceae								
Podophyllum hexandrum Royle	*Ban kakdi*	Climber	May-June	July- August	Whole plant	Edible, fodder, medicinal	-	1,300-2,200
Polygonaceae								
Rumex dentatus L.	*Jangli palak*	Herb	June –July	August-September	Young leaves	Vegetable,	-	1,500-3,000
Rumex hastatus D.Don	*Almora*	Herb	All months	March -October	Young leaves	Vegetable, edible	-	1,200-1,500
Rosaceae								
Duchesnea indica (Andrcos) Th.Wolf	*Bhina kafal*	Herb	March-April	May –June	Whole	Edible, fodder, medicinal	-	1,200-1,800
Prisepia utilis Royle	*Bhenkul*	Shrub	March-April	May –June	Fruits, branch bark	Medicinal, fuel	-	1,200-2,200

Prunus cerasoides D.Don	*Panya*	Tree	November - December	March-April.	Fruits seed, bark, branch, twig, leaves	Edible, fuel, medicinal, religious, making walking sticks, agriculture tools, fuel wood	LC	900-2,200
Pyracantha crenulata (D.Don) M.Roem.	*Ghingaru*	Shrub	May-June	July- August	Fruits bark, branch, leaves	Edible, juice fuel, medicinal	-	1,600-2,200
Pyrus pashia Buch. –Ham.ex D.Don	*Mol*	Tree	May-June	July- August	Fruits, leaves, branches	Edible, fuel, medicinal, making walking sticks, agriculture tools, religious	-	1,200-2,500
Rosa spp. L.	*Jangali gulab*	Shrub	August-September	September - October	Fruits, Stems	Juice and medicinal		1,400-3,200
Rubus ellipticus Sm.	*Hinsalu*	Shrub	March-April	May –June	Fruits, root	Edible, medicinal	-	1,000-2,000
Rubus niveus Thunb.	*Kali Hisar*	Shrub	May-June	July- August	Fruits, root	Edible, medicinal	-	1,500-2,500
Rutaceae								
Zanthoxylum armatum DC	*Timaru*	Shrub	March-April	June- October	Whole	Medicinal, religious, fuel, making a walking stick and agriculture tools and fuel	-	1,000-1,500
Sapindaceae								
Sapindus mukorossi Gaertn	*Reetha*	Tree	July-August	November - December	Fruits, seeds	Hair wash, laundry, medicine, making a walking stick, agriculture tools and fuel	-	870-1,500
Aesculus indica (Wall.ex Camb.) Hook	*Pangar*	Tree	May-June	July-August	Fruits, leaves, stems, branch	Medicine, timber, making a walking stick, agriculture tools and fuel	-	1,500-2,200
Smilacaceae								
Smilax aspera L.	*Kukardara*	Climber	May-June	July-August	Whole	Medicine	-	8,00-1,500
Solanaceae								
Solanum nigrum L.	*Makoi*	Herb	June-July	October-November	Whole	Edible, medicinal	-	1,650-2,200
Taxaceae								
Taxus baccata L.	*Thuner*	Tree	May-June	November - December	Fruits, bark, stems, branch	Medicinal, timber, religious, making a walking stick, agriculture tools	LC	2,500-3,000

Thymelaeaceae								
Daphne papyracea Wall.		Herb	November - December	April-May	Fruit, stem	Medicinal, fuel	-	800-2,300
Tiliaceae								
Grewia optiva J. R. Drumm. ex Burret	*Bhimal*	Tree	April - May	September - October	Fruit. Leaves, branches, bark	Edible, fodder, timber, , making agriculture tools, baskets, ropes and fuel	-	870-2,500
Urticaceae								
Debregeasia longifolia (Burm.F.) Wedd.	*Syanru*	Shrub	December - January	Mar-April	Fruits, leaves, branches	Edible, medicinal, making agricultural tools, walking stick and fuel	-	1,100-1,600
Urtica dioica L.	*Kandali*	Shrub	All months	November-February	Leave, flower, fruit	Vegetable, fodder	LC	870-3,500

Fig. 2. Percentage compositions of wild edible plant resources

Myrica esculenta, 8 per cent of villages used *Phyllanthus emblica,* 7 per cent of the villages used *Diplazium esculentum* and 7% of the villages used *Grewia optiva* for sustenance of their livelihood. From the surveyed villages, 19.5, 8.3, 2.4, 2.4 & 1.6 per cent of local populations were engaged on *Rhododendron arboretum, Myrica esculenta, Grewia optiva, Phyllanthus emblica* and *Diplazium esculentum* respectively for livelihood (Table 3).

However, local communities in Kedarnath Valley were mostly unaware of the economic potential of wild edible plant resources. People from 15 villages sell *Rhododendron* products (Juice, sauce, jam, jellies and refreshing drinks) in the market. The individual household sells around 20 liter juice and 5 kg jam, jellies in the whole year, earning of Rs. 5,00-2,000 at the rate of Rs 90-100 per liter and 80-100/kg, in a year. *Myrica esculenta* from 6 villages is sold. Every household sells around 15 kg earning Rs. 1,500-2,250 at the rate of Rs 100 -150 per kg. per year. The people from 2 villages sell *Diplazium esculentum* in the market. Every household sells around 300-500 bunch earning Rs 5,000 at the rate of Rs 10per bunch in a year, *Phyllanthus emblica* sold by 2 villages in the market. Every household sells about 15 kg and earns Rs 300-450 at the rate of Rs 30 per kg in a year and pickle sells about 5 kg earning 250 at the rate of Rs 50 per kg per year. Two villages of Kedarnath valley sold *Phyllanthus emblica* product in the market. Every household

Table 2. Number of households surveyed and number of households selling wild edible plants and their product

Name of villages	Elevation above mean sea level (m).	Total households surveyed	Total households selling wild edible plants and their products
Chandrapuri	864	26	6
Bhiri	972	28	4
Kalimath	1,251	20	6
Narayankoti	1,396	26	7
Ukhimath	1,402	27	4
Kabiltha	1,408	19	5
Guptakashi	1,455	25	6
Karokhi	1,634	20	4
Gaundar	1,653	20	4
Sersi	1,655	18	3
Barasu	1,664	36	5
Tarsali	1,805	16	6
Ransi	1,974	24	5
Sari	2,015	23	4
Gaurikund	2,156	16	3
Trijuginarayan	2,246	37	10
Tausi	2,325	26	8
Chopta	2,862	-	-
Kedarnath	3,568	-	-
Tungnath	3,660	-	-
Total		409	90

Table 3. Number of villages engaged in selling product of wild edible plant and dependent on them for livelihood in the villages of Kedarnath Valley

WEP species used	Local name	No. of villages selling	Total number of household used for selling		Market rate Rs. kg/liter/bunch/ products		Total annually selling kg./ liter/bunch/ products/ households	Total income /households
Rhododendron arboretum	*Buransh*	15	80	19.55%	Juice	90-100	5-20	1,500-2,000
					Jam, jellies	80-100	3-5	400-500
Myrica esculenta	*Kafal*	6	34	8.31%	100-150		5-15	1,500-2,250
Diplazium esculentum	*Lingra*	2	10	2.44%	10		300-500	5,000
Phyllanthus emblica	*Amla*	2	10	2.44%	Amla	20-30	5-15	300-450
					Pickle	50	3-5	250
Grewia optiva	*Bhimal*	2	6	1.46%	Ropes	50	5-10	500

sells about 10 ropes, at the rate Rs 50 per unit, earning Rs 500 a year (Table 3).

During market survey, it was revealed that if other people of the village bring their product to the market for sale, they can easily be sold at good prices, if the product is very popular: Thus, people can increase their livelihood. Some photographs of the important wild edible plants from the Kedarnath valley have been provided (Fig. 3).

CONCLUSION

The traditional knowledge of wild edible plant resources is still practiced and used by the local people of Kedarnath valley. These wild edible plants and their products can be used during the time of food shortage and increasing

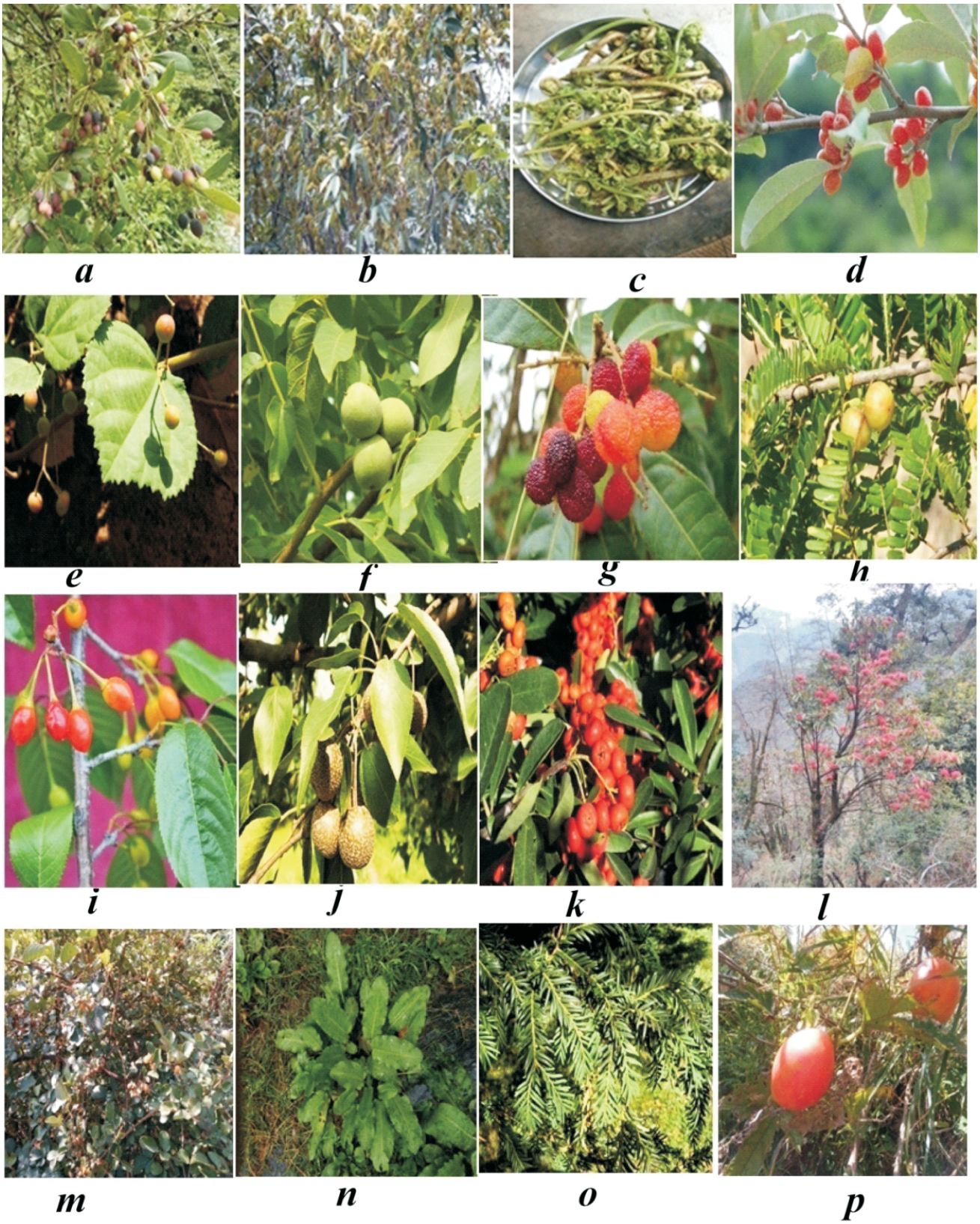

Fig. 3. Wild edible plants: **a.** *Berberis asiatica,* **b.** *Castanopsis* spp, **c.** *Diplazium esculentum,* **d.** *Elueagnus parvifolia,* **e.** *Grewia optiva,* **f.** *Juglans regia,* **f.** *Myrica esculenta,* **h.** *Phyllanthusemblica,* ***I.*** *Prunus cerasoides,* **j.** *Pyrus pashia,* **k.** *Pyracantha crenulata,* **l.** *Rhododendron arboretum,* **m.** *Rubus elliptic,* **n.** *Rumex dentatus* **o.** *Taxus baccata*, **p.** *Trichosanthes tricuspidata*

inflation. These species can become an important option for generating income. Moreover, many of these edible plants of Kedarnath Valley are rapidly shrinking due to ecodisaster, landslides, soil erosion, high forest fire, heavy rainfall and heavy hailstorm, overexploitation, uses in making houses, construction of roads and agriculture. Efforts should be made to preserve traditional knowledge of wild edible plant resources. The people should be encouraged to promote the cultivation of these wild edible plants.

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Anthropogenic Transformation of Hydrological Regime of The Dnieper River

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Abstract. Problems of rational water use and water quality assessment are the priorities of many states, especially in the basins of transboundary rivers. Creation and functioning of the cascade of Dnieper reservoirs led to a radical transformation of the hydrological regime of the Dnieper River. As a result, there occurred a significant deterioration of the physical, chemical and biological characteristics of surface water quality, increase of its trophic state, reduction of the efficiency and stability of the aquatic ecosystem of the Dnieper basin, which is largely determined by anthropogenic factors. As a result of interpretation the series of space images (August, 1986-2016) of the satellites Landsat- 5, Landsat- 7 and Landsat-8 with a spatial resolution of 30 meters, the spatio-temporal trend of changes in physical (water transparency), hydrochemical (general phosphorus concentration in water), biological (chlorophyll-a) properties of water areas of reservoirs was determined. In studies trophic state index developed by the Florida Department of Environmental Protection was used to classify all types of water surface, including rivers. It is established that the value of trophic state index in reservoirs is distributed unevenly from 26.5 to 56.5. Continuous water eutrophication processes are intensified by the deterioration of self-purification of the river, lack of effective anti-erosion organization of areas, and climate change. Long strengthening of the eutrophication of the reservoirs of the Dnieper cascade contributes to the increase of the concentration of nutrients, predominance of blue-green algae phytoplankton, reduced transparency, increased content of organic matter, significant deterioration of the aquatic ecosystem and reduced biological productivity of the Dnieper River. The studies of the trophic state of the cascade of the Dnieper reservoirs are of high scientific and practical value for the identification of the consequences of a powerful anthropogenic influence on the hydroelectric system and the identification of problem aspects of their water areas and the further priority development of substantiated spatially adaptive complex and systematic environmental protection measures, enhancement of ecological sustainability, and gradual improvement of ecosystem of the Dnieper River basin.

Keywords: Hydrological Regime, Trophic state, Dnieper River, Dnieper reservoirs, Spatio-temporal changes, Remote sensing

The deterioration of the ecological status of water bodies leads not only to their degradation, but also to the problems of their water management. This occurs against the background of reducing the observations network in the state monitoring system and weakening control over the impact of human activity on water objects. Therefore, effective water management is one of the important global challenges facing humanity. Problems of rational water use and water quality assessment are the priorities of many states, especially in the basins of transboundary rivers. Water quality studies are conducted on the basis of regular in-situ measurement, which is a labor-intensive and cost-intensive process that does not cover the entire area of the water object; besides, observations are discrete and, given interpolation of experimental data, the results have low spatial accuracy. System use, along with in-situ measurements of multispectral satellite images is necessary to optimize the researches and expand the data array on the status of water bodies (Tikhomirov at el 2016). Therefore, in the monitoring of the ecological condition of water objects, the application of data of space remote sensing of the earth (Earth remote sensing) is a promising area, providing a unique opportunity for contactless research and large-scale spatio-temporal assessment of the state of water objects to create an information base for specialized water geoinformation systems. The ecological state of the water body is characterized by a number of features that are easily detected and quantitatively measured with multispectral space images. For most reservoirs, the actual problem of deterioration of water properties as a result of eutrophication is a sharp increase in the biological productivity of green algae (mostly caused by anthropogenic activities), which leads to negative consequences for the entire ecosystem of the reservoir. Selective field researches conducted in the water area, allow proceeding with numerical indicators of the volume of suspended matter in the case of mechanical and

biological contamination. Biological contamination of water bodies is determined by the accumulation in the water mass of so-called biogenic substances - compounds of phosphorus and nitrogen, which cause sharp decrease in oxygen content in water, pH increase, calcium carbonate and magnesium hydroxide precipitation. The content of all these substances is direct or inverse spatial correlation with the amount and degree of biological water contamination across the waters of the reservoir, and can be estimated and recorded using cartographic methods on the basis of selective sampling for chemical analysis (Abrosimov et al 2009).

Scientific papers of many scientists (Zagorodnyaya et al 2010, Silkin et al 2012, Bocharov et al 2015, Pichura et al 2015, Gryshchenko et al 2016) present methodological approaches, algorithms for processing the data of the earth remote sensing, prospects for their use and their practical advantages for assessing changes in the coastal zone of reservoirs, complex study of changes in properties and environmental status of water objects (temperature of warming, turbidity, transparency, concentration of chlorophyll-a, biogenic substances, trophic state, etc.), including individual reservoirs of the Dnieper river.

The purpose of the research is to determine the spatio-temporal tendency of the change in the trophic state of the Dnieper reservoirs over the past 30 years on the basis of the data of the earth remote sensing satellite images.

MATERIAL AND METHODS

The study used the Trophic State Index (TSI), which was developed by the Florida Department of Environmental Protection and is used to classify all types of water surfaces, including rivers. The scale of this index is a numerical one (Table 1) and each major area of the trophic division represents a doubling of the concentration of the surface biomass of phytoplankton, which makes the classification of the trophic state more acceptable. Quantitative description of the status of a reservoir is extremely important when choosing a strategy for protecting its ecosystem. Most lake ecosystems divide the continuum of the trophic state of reservoirs into five classes: ultra-oligotrophic, oligotrophic, mesotrophic, eutrophic, and hypertrophic [Henderson-Sellers et al 1987].

TSI value can be calculated by three parameters: physical (water transparency, which is determined by the Secchi index-TSD), hydro-chemical (concentration of total phosphorus in water-P), biological and biochemical (chlorophyll-a-Chla, biomass of phytoplankton-B_P) [Carlson 1977].

The value of total phosphorus content makes it possible to determine and assess the impact of different anthropogenic sources on biogenic contamination and eutrophication process in all types of water objects. This makes it possible to predict the potential biomass of primary production in reservoirs as a result of anthropogenic eutrophication with the use of earth remote sensing. The decoding of space images is based on the study of light absorbing and light dispersive properties of natural waters; the degree of transparency of water provides an opportunity to determine the trophic state of reservoirs' cascade.

Table 1. Trophic state index (TSI) and correlation of the trophic state indicators of water objects

Type of trophic state	TSI	Transparency of water determined by Secchi disc (TSD), m	Phosphorus (P), μg/dm ^{3}	Chlorophyll-a (Chla), μg/dm ^{3}
Ultra-oligotrophic, very pure	0	64	0.75	0.04
	10	32	1.5	0.12
	20	16	3	0.34
	30	8	6	0.94
Mesotrophic, slightly contaminated	40	4	12	2.6
	50	2	24	6.4
Eutrophic, moderately contaminated	60	1	48	20
	70	0.5	96	56
Hypertrophic, dirty	80	0.25	192	154
	90	0.12	384	427
	100	0.062	786	1183
Calculation of TSI on the basis of separate indicators		Calculation of trophic state indicators of water objects on the basis of TSI		
TSI=60-14.41 Ln (TSD) TSI=4.15+14.42 Ln (P) TSI=30.6+9.81 Ln (Chla)		TSD=64.31 exp (-0.0695 TSI) P=0.748 exp (0.0694 TSI) Chla=0.042 exp (0.1025 TSI)		

Antropogenic eutrophication of reservoirs is manifested in spatial heterogeneity of planktonic algae, leading to a significant reduction in water clarity, which is mainly caused by the content of different colored dissolved and suspended substances. Variation in the concentration of chlorophyll-*a* changes the reflection capacity of water – increase in its concentration lowers the reflection capacity of water in blue wavelengths and increases in green wavelengths. The trophic state index of the cascade of the Dnieper reservoirs is calculated by F.T. Shumakov's formula [Shumakov 2011]:

$TSI = 82.02 – 31.88TM1/TM2 + 1.13TM4$; $r=0.85$, $r^2=0.73$

where TM1 and TM2, TM4 mean the value of the brightness of the reflecting channel.

The spatio-temporal estimation of the trophic state is based on interpretation of a series of space images (August, 1986-2016) of Landsat-5, Landsat-7 and Landsat-8 satellites with a spatial resolution of 30 meters. Licensed software products ENVI + IDL 4.4 and ArcGIS 10.1 have been used to interpret and create thematic maps.

RESULTS AND DISCUSSION

Prior to the reservoirs cascade creation, the change in water level in the Dnieper River was characterized by a pronounced high spring flood, low stand of level in summer and winter limits, and low autumn floods, but the creation of a cascade in reservoirs with a total water-surface area of 6981 km^2 fundamentally changed the hydrological regime of the Dnieper River, which gained lake properties. The water reservoirs are indicated in the direction of the Dnieper River flow: Kyiv (filled in 1964-1966, area 922 km^2) →Kaniv (filled in 1974-1976, area 675 km^2) → Kremenchuk (filled in 1959-1961, area - 2252 km^2) →Dniprodzerzhynsk (built in 1964, area - 567 km ^{2}) →Dnipro (built in 1932, restored after the Second World War in 1948, area - 410 km^2) →Kakhovka (filled in 1955-1958, area - 2155 km^2). In the reservoirs, the current speed dropped sharply - from 0.6-0.8 m/s to 0.3-0.02 m/s. Depending on the morphometric features, the location in the cascade of the reservoir, and the season, water exchange and flowage decreased up to 24 times, which caused the formation of static zones.

The increase in water temperature occurs from the upper Kyiv reservoir to the part of the lower Kakhovka reservoir near the dam. This increase in different months ranges from 0.2 to 7.4°C. The corresponding hydrological and temperature changes in the regime result in spatio-temporal intensification of the antropogenic impact on the eutrophication state of the reservoirs, which causes the development of planktonic algae, significant decrease in the transparency of water and the deterioration of the trophic state of reservoirs. The fundamental point in assessing the eutrophication process is to determine the trophic state of the reservoirs, which actually reflects the metabolism of the ecosystem (inflow, accumulation and energy consumption),

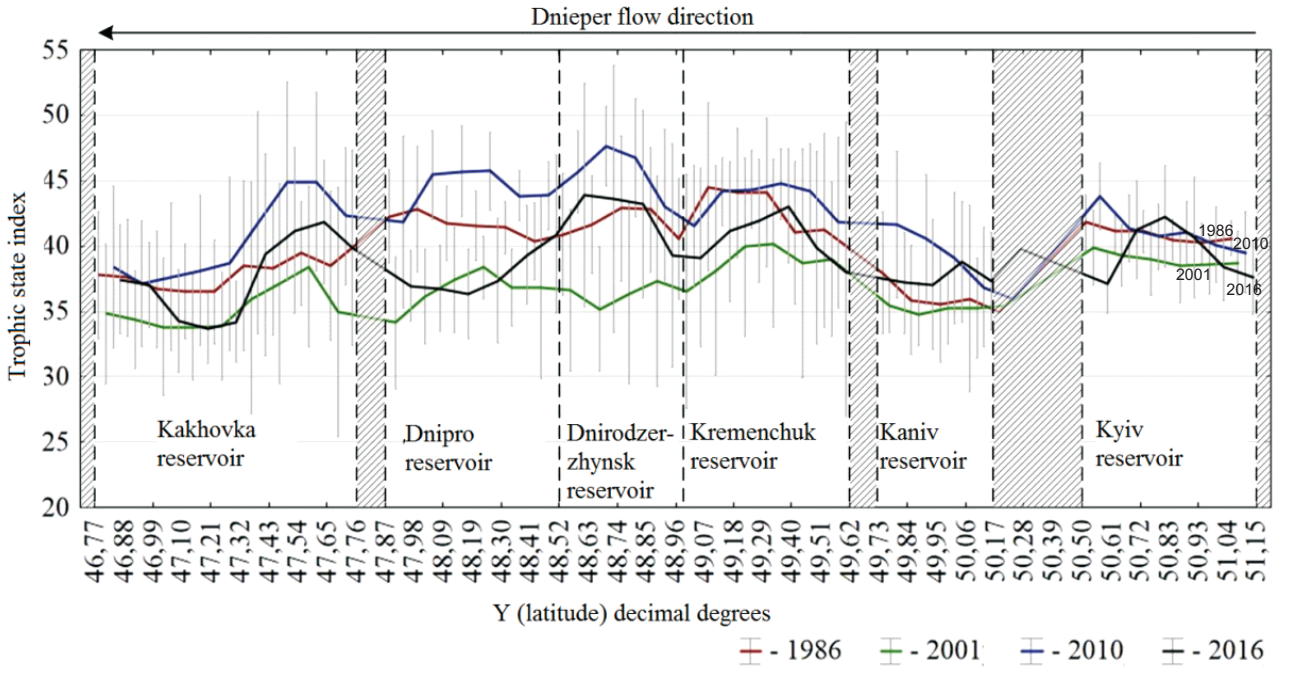

Fig. 1. Zonal distribution of trophic state index in cascades of Dnieper reservoirs for August 1986-2016 years

and shows its ecological state. The inflow of excessive amounts of nutrients as a result of anthropogenic contamination leads to significant changes in the ecosystems of reservoirs and acceleration of successive processes. Eutrophication of reservoirs depends not only on the load of biogenic substances on the water bodies, but also on the conditions of development of autotrophic hydrobionts, i.e., from climatic, hydrodynamic and morphological features of reservoirs. Low temperature, insufficient solar radiation, high flow velocities, high depth, turbidity of water and other environmental factors can limit blooms given sufficient concentration of nutrients. The most intensive eutrophication occurs in well-heated and lighted shoal areas, which occupy up to 40 per cent of the area of the cascade of the Dnieper reservoirs. The process of eutrophication is considered as a consequence of the violation of the stability of aquatic ecosystems, which fundamentally distinguishes it from the notion of pollution.

Today, the ecosystem of the Dnieper River is considerably damaged. High agricultural development, sewage treatment, intensive development of coastal strips and so leads to intensification of anthropogenic eutrophication in waters of Dnieper reservoirs cascade. If the necessary environmental protection measures are not taken, there will come a time when these processes will become irreversible. In reservoirs, processes of anthropogenic eutrophication reach limits that exceed the possibility of self-purification of natural waters in the process of natural biotic circulation.

One of the most informative indicators of evaluation and establishment of trophic state of water bodies is chlorophyll-a content. The most statistical codependence with remote sensing records was shown by chlorophyll-a - the main pigment in green plants, including single-celled algae (phytoplankton). Chlorophyll-a is assigned the most important role in photosynthesis among few tens of pigments contained in the photosynthetic apparatus of algae. Information about chlorophyll-a concentration and its changes in water bodies is a criterion for evaluation of production and phytoplankton biomass, as well as an indicator of water pollution. During the years of research, chlorophyll-a concentration (Chla) in August in the waters of the Dnieper reservoirs cascade ranged between 0.2-31.7 mg/dm^3 follwed by Kyiv (→ Kaniv) → Kremenchuk → Dniprodzerzhynsk →Dnipro →Kakhovka . Seasonal course of phytoplankton dynamics is an important characteristic that is used when assessing the trophic state of the reservoir. Thus, oligotrophic reservoirs are characterized by one small peak of biomass in the spring, mesotrophic – by a presence of depression at the beginning of the summer against the background of moderate algae development, and a significant biomass of phytoplankton can be observed throughout eutrophic waters throughout the season .

The content of the main pigment of green plants of chlorophyll-a is considered to be *a* general environmental and physiological characteristic of algae development and photosynthetic activity, allowing representing biomass in terms of the essential component of plant cell. Previously defined (Mineeva 2012) recommended calculation values of chlorophyll-a content per unit of phytoplankton biomass (Chl/B) for reservoirs of various trophies: for oligotrophic waters - 0.18; mesotrophic and eutrophic waters - 0.40; high-eutrophic or hypertrotrophic waters – 1.03.

Municipal and agricultural waste waters entering the reservoir contain significant concentrations of nitrogen and phosphorus, resulting in a significant amount of pollutants in the Dnieper reservoirs, which contributes to the "blooming" of water. Estimation of the trophic state of the reservoir, as a rule, is based on the quantitative dependencies of indicators of biological productivity of water on the content of mineral nutrition elements (nitrogen and phosphorus), the presence of which has a significant impact on the development and photosynthesis of phytoplankton (Naumenko 2007). The results of numerous studies on the eutrophication of natural waters show that priority is given to phosphorus in reservoirs – according to current estimates, primary production is limited by this element in more than 80 per cent of investigated reservoirs; besides, the decrease in the concentration of phosphorus in water bodies is not accompanied by a rapid fall in their biological productivity and intensity of exposure to the development of phytoplankton. According to the interpreted space photographs, during the research period, the concentration of phosphorus (P) in August in the waters of the cascade of the Dnieper reservoirs varied within the range of 2.5-66.4 μg/dm^3: Kyiv (P - 6.5-40.2 μg/dm^3) →Kaniv (P - 2,5-44,8 μg/dm^3) →Kremenchuk (P - 4,1-66,4 μg/dm^3) →Dniprodzerzhynsk (P - 4,1-4,4,4 μg/dm^3) → Dnipro (P - 3.8-45.7 μg/dm^3) → Kakhovka (P - 3.6-44.3 μg/dm^3). The total phosphorus intake in the Black Sea coastal waters from the Dnieper River inflow over the past 60 years has increased by 6.7 times (from 1.7 to 11.4 thousand tons/year) (Kresin et al 1987, Hydrometeorology and hydrochemistry of the seas of the USSR, 1992, The state of the environment of the Black Sea 2002), which is the result of enhanced eutrophication of Dnieper cascade reservoirs and maintaining of the necessary level of mineral nutrition of excessive phytoplankton.

Among the physical indicators, only the transparency of water is taken into account for assessing the trophic state of aquatic ecosystems, which is determined by the depth of

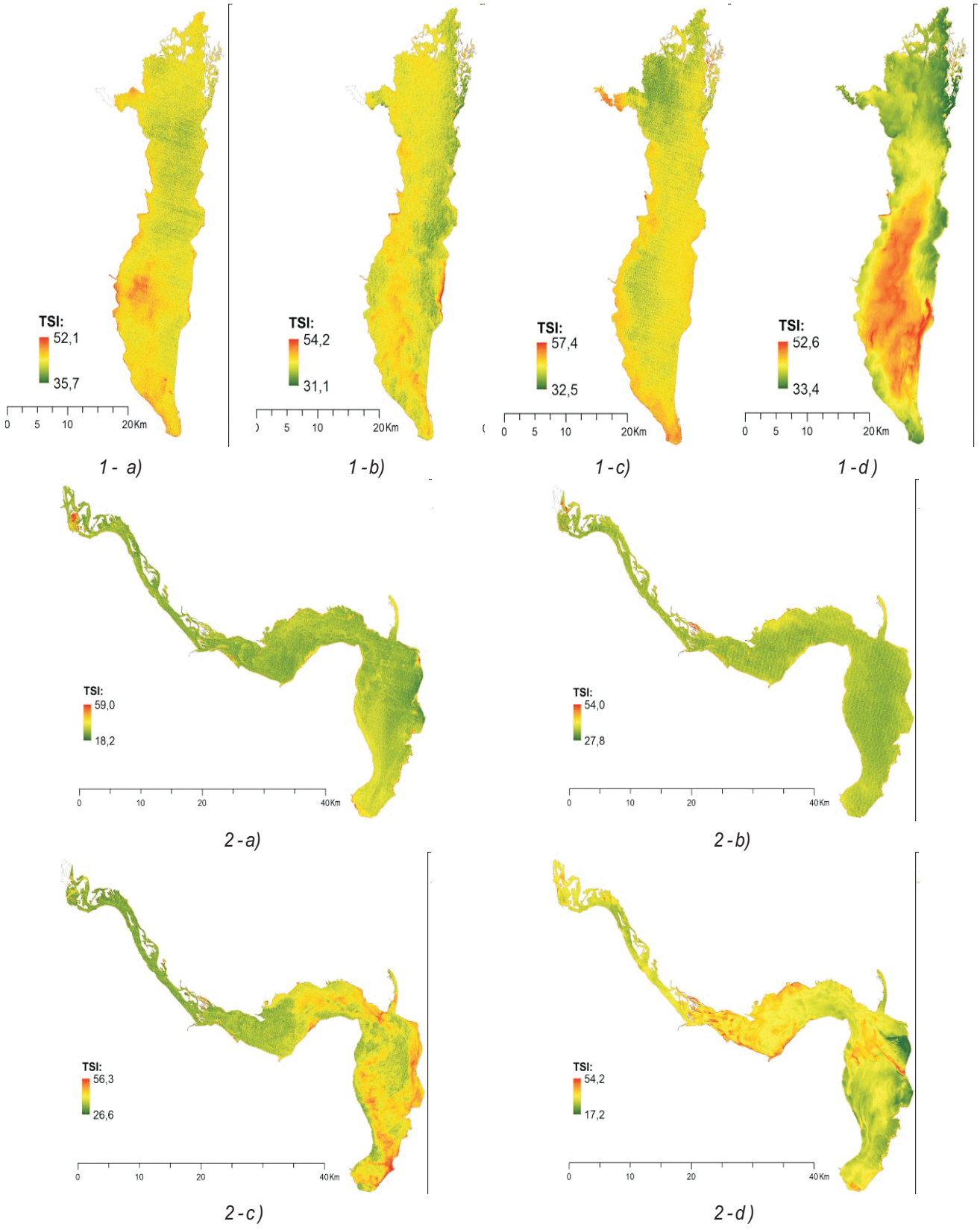

Fig. 2. The regularities of the spatio-temporal change in the trophic state index (TSI) in August in Kyiv (**1)** and Kaniv (**2)** reservoirs for 1986-2016 on the basis of remote sensing data: a) 1986, b) 2001, c) 2010, d) 2016, e) spatial distribution of TSI by the years of research

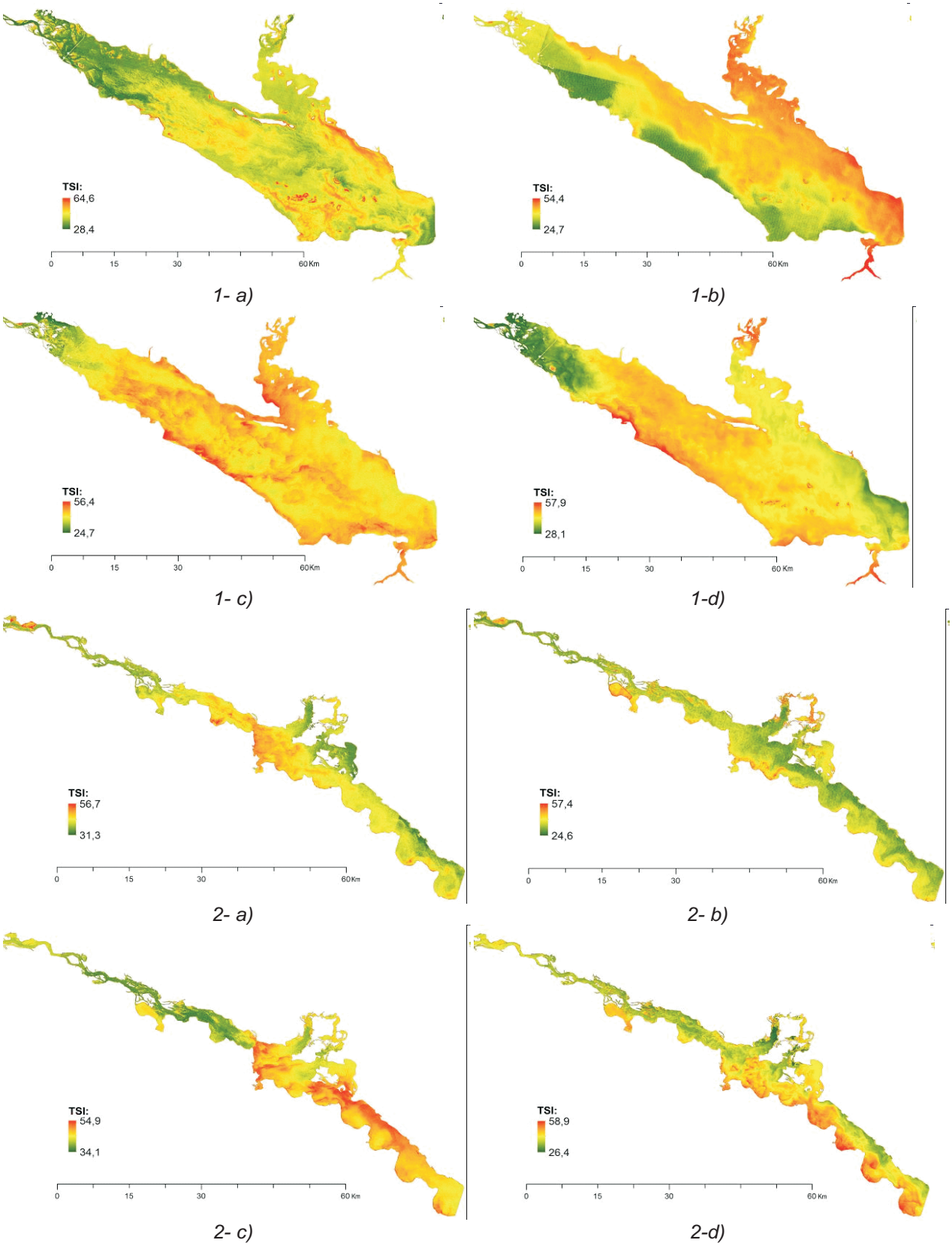

Fig. 3. The regularities of the spatio-temporal change in the trophic state index (TSI) in August in Kremenchuk (**1)** and Dniprodzerzhynsk (2) reservoirs as for 1986-2016 on the basis of remote sensing data: a) 1986, b) 2001, c) 2010, d) 2016, e) spatial distribution of TSI by the years of research

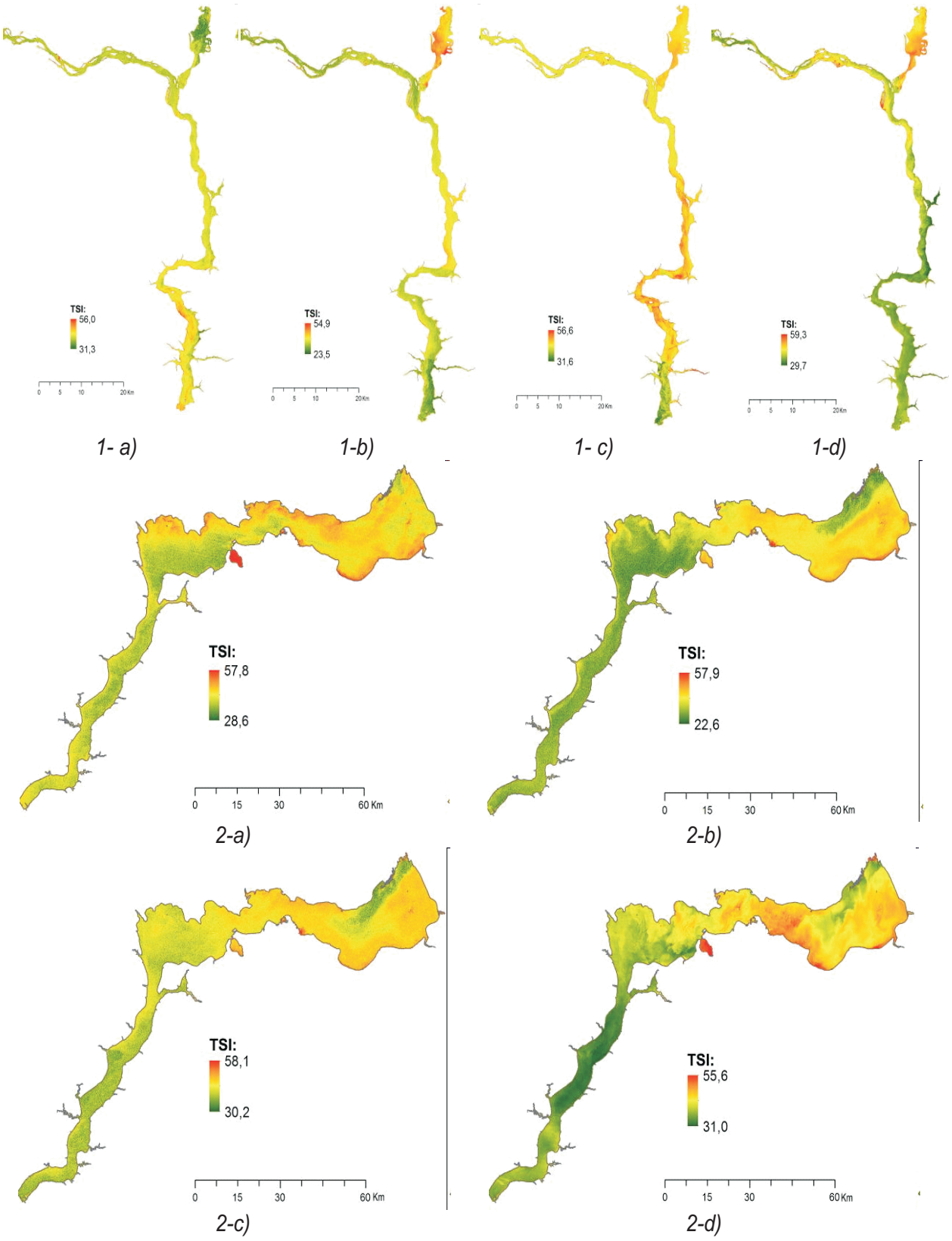

Fig. 4. The regularities of the spatio-temporal change in the of trophic state index (TSI) in August in Dnipro (1) and Kakhovka (2) reservoirs for 1986-2016 on the basis of remote sensing data: a) 1986, b) 2001, c) 2010, d) 2016, e) spatial distribution of TSI over the years of research

visibility of Secchi disc. Because of its simplicity, this method is widely used to approximately evaluate the status of reservoirs. The correlation of transparency, biological and hydrochemical indicators of the trophic state of water objects are comprehensively presented in the works of A.P. Musatov [Musatov 2001]. The statistical dependencies proposed by worker allow to describe the development of separate trophic chains of aquatic ecosystems based on various indicators of trophic state, energy flows through ecosystems, and the interconnections of individual parameters. According to interpreted aerospace photographs, it is determined that for 30 years in August transparency according to Secchi disc (TSD) of water in Dnieper reservoirs cascade ranged within 1.1 – 19.4 meters: Kyiv (TSD – 1.2-7.4 m.) →Kaniv (TSD – 1.1- 19.4 m.) → Kremenchuk (TSD – 0.7-11.6 m.) → Dniprodzerzhynsk (TSD – 1.1-11.6 m.) →Dnipro (TSD – 1.0-12.6 m.) →Kakhovka (TSD – 1.1 – 13.0 m.).

A series of thematic raster models and statistical characteristics of spatio-temporal nonuniformity of distribution of index and rate of trophic state of Dnieper reservoirs cascade in August are shown in Fig. 1-7. The use of cartographic material allowed tracking the process of spatio-temporal changes in the impact of anthropogenic activities on the trophic state of water in six reservoirs for 1986-2016. The zonal trend cyclical increase in trophic state index (Fig. 1) from the upper Kyiv reservoir to the part of the lower Kakhovka reservoir near the dam.

This is largely caused by the transfer of biogenic substances and their additional inflow from the Dnieper River as a result of economic activity. The largest values of TSI (from 39.57 to 45.25) throughout the cascade of reservoirs were observed in 2010, the smallest (from 35.12 to 39.42) - in 2001.

The hydrological regime of the Dnieper River in modern conditions has acquired lake properties as a result of artificial regulation. Moreover, constant processes of eutrophication of reservoirs are aggravated by the deterioration of the river self-cleaning process, lack of effective anti-erosion organization of the territories, and climate change [Lisetskiia et al 2016]. The colder water temperature and low TSI values indicate the presence of a current, while the water stagnation zones have an elevated temperature regime that stimulates the accumulation of nutrients, the active development of planktonic algae and the increase of TSI in water bodies. On the example of Kakhovka reservoir a strong power correlation dependence of the influence of air temperature (T) on the formation of trophic state (TSI) of reservoirs is observed, which has the form: $TSI = 7.95.10^{-15} T^{10,56} + 36,0$; $r^2=0.71$.

It has been established that the trophic state level within individual reservoirs is distributed unevenly: the TSI value varies from 26.5 to 56.5, this corresponds to oligotrophic (TSI $\leq$30), mesotrophic (30 < TSI $\leq$50) and eutrophic (50 < TSI $\leq$ 70) status of water objects. The average value ($\overline{X}$ (min-max)) and the level of variation (V,%) of the TSI in the cascade of Dnieper reservoirs during the years of research were: in Kyiv $\overline{X}$ - 38.8-40.7 (31.1-57.4), V -2, 12-6.34%; Kaniv $\overline{X}$ - 35.1-38.0 (17.2-59.0), V – 3.88-7.03%; Kremenchug X - 39.4-44.3 (24.7-64.6), V - 3.94-9.60%; Dniprodzerzhynsk $\overline{X}$ - 36.3-45.3 (24.6-58.9), V - 6.08-11.08%; Dnipro $\overline{X}$ - 36.8-44.3 (23.5-59.3), V – 4.97-8.10%; Kakhovka reservoir $\overline{X}$ - 36.8-43.3 (22.6-58.8), V – 6.58-10.45%. Changes in the trophic state of reservoirs are determined by the presence of currents, their speed and temperature regime. The lower reaches of the Dnieper River has a high degree of regulation. In some parts of the water area the index of trophic state exceeds the value of 70, which corresponds to hypertrophic state.

CONCLUSIONS

Continued intensification of eutrophication of water bodies of Dnieper cascade increases the concentration of biogenic substances, dominance of blue-green algae in phytoplankton, reduction of transparency, increase of soil organic matter, significant deterioration in the status of aquatic ecosystems and reduction of the biological productivity of the Dnieper River, making it impossible to provide favorable conditions by using water for drinking, household, recreational and fishery purposes. In order to protect the water objects of the Dnieper basin from contamination with biogenic substances in the conditions of agricultural activity, we suggest a complex of organizational and economic, agricultural and special measures. Organizational and economic measures - the establishment of an optimal ratio of agricultural land, rational use and protection of arable land against erosion by introducing field crop rotation; increase of productivity, rational use and protection of natural forage lands against erosion by introduction of haymaking turns, sowing of perennial grasses and others; regulation of drainage of thaw and storm water. Agro-technical measures – introduction of soil protecting crop rotation; using scientifically grounded systems of soil fertilization. Hydrotechnical and hydro-ameliorative measures – creation of anti-erosion hydraulic structures at the water-intake area, as well as in the upper and lower parts of the ravines; creation of storage ponds drainage; construction of bioengineering structures, use of drainage and wastewater for re-irrigation. Forest and ameliorative measures – creation of forest shelter belts, afforestation for

water protection in ravine systems, irrigated lands, on the banks of rivers and canals, near reservoirs, ponds, on drained lands and pastures; preservation and restoration of thickets of cane, typha, sedges and other plants on the banks of rivers and lakes, near water intake structures in the form of filtration belts, as well as the creation of such belts on the way of sewage and drainage water dumping.

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Tree Species Composition and Diversity in Tropical Moist Forests of Mizoram, Northeast India

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Abstract: The present study was carried out to assess tree species composition and diversity of a community reserve forest in Reiek village of tropical moist region *of Mizoram, Northeast India.* The estimation was made by laying 50 quadrats (10×10 m) placed at random locations during 2016-2017. A total of 125 tree species (≥10 cm dbh) belonging to 90 genera and 46 families were recorded from the study area. The tree density and total basal area of the present study were: 2145 individual ha^{-1} and 64.76 m^2ha^{-1} ,respectively. The value of Shannon-Weiner index (H') was 4.37 while Simpson index, evenness and Margalef species richness were: 0.03, 0.89 and 16.16, respectively. The population structure of tree species in the present study showed a reverse J-shaped population curve indicating good regeneration status and significant potential to develop the community forest. Further, log-normal species dominance-distribution curve showed stability of the forest community.This suggests that the villager selecting the mature trees for felling and managing the forest effectively. However, further studies on regeneration potential of tree species from the forest would assist us in scientific management and conservation of ecologically important species in the community forest.

***Keywords*:** Diversity, Tropical forest, Mizoram, Euphorbiaceae, *Eurya*

Over the world, vegetation cover under natural forests has been depleting rapidly, particularly in the tropical areas, and secondary forests are increasing in the dominance because of increasing demand for agriculture. In many tropical countries, forest destruction and conversion to agricultural land is continuing at a high rate that has been reported to affect the structure and functioning of forest ecosystems (Lewis et al 2015). Forest change quantification from 2010 to 2012 exhibited that among the four climatic domains (tropical, subtropical, temperate and boreal), the highest loss to gain ratio (3.6 for >50% of tree cover) was reflected by tropical forest. Further, it has been reported that the forests in tropics showed a considerable loss (i.e. 2101 km^2) in annual forest area (Hansen et al 2013). In South and Southeast Asia, the net forest loss has been reported to be about 25 per cent higher between 2010 and 2015 compared from 1990 (Keenan et al 2015). Therefore, it is critical to understand the human impact to prioritize conservation of tropical forest. The lowland rainforests are among the most species rich terrestrial ecosystem in the tropics of Southeast Asia (Whitmore 1996). They are widely distributed from Myanmar to the pacific islands and extend to continental Asia from Thailand to south China and to northeast India. Analyzing the cause of tropical forest deforestation and degradation is a prerequisite to manage these forests in a better way.

Biodiversity assessment has gained much attention due to its major impact on the practice of conservation (Naidu et al 2018). Tropical plant diversity assessment is an important tool for the quantitative analysis of bio-geographical patterns regionally (Gordon and Newton 2006).The northeast India includes an immense variety of plant and animal species and is one of the richest biodiversity centres of the Indian continent (Tynsong and Tiwari 2010) with rich species density and diversity (Nath et al 2005). Forests in the north eastern region of India are characterized by high rainfall and favourable temperature that supports luxuriant vegetation. Forests in these region falls under Indo-Burma global hotspot of biodiversity (Myers et al 2000). The state of Mizoram, located in the North eastern part of India, occurs in the Indo-Myanmar biodiversity hotspot, which is characterized by high endemism and high degree of threat to species. The state consists of a total of 2,358 species of plants out of which, 2141 species belong to angiosperm distributed over 176 families and 905 genera where about two third represent dicots and one third monocots (Singh 1997). Further, authors also reported that about 500 species belonging to 383 genera have ethno-medicinal properties. Tropical and subtropical forests of Mizoram, India are over-exploited for timber, fuel wood and common agricultural practice like shifting cultivation, which are responsible for the degradation of natural forest. The changes in species composition, diversity

and fine root biomass and production during the course of ecosystem development in Mizoram have been reported (Singh et al 2015, Singh and Tripathi 2017). The present study was carried out in a community reserve forest in the Reiek village with major objectives to analyze species composition, diversity, diameter and basal area distribution of tree species in different girth classes, and to suggest strategies to better manage this forest.

MATERIAL AND METHODS

The present study was conducted in Reiek community reserve forest (23°41.424'N latitude and 93°36.243'E longitude) in the Mamit district of Mizoram, India, at an elevation of around 1200 m amsl. The forest has been traditionally managed by villagers through selective felling, for example, harvesting of individuals of mature trees above certain diameter that varies from species to species, and leaving few mother trees to promote regeneration. The climate of the area is typically monsoonic with distinct season's *viz*., cold and dry winter (11 to 21°C; December-February), warm summer (20 to 30°C; March-June), humid monsoon period (July-September) and cool post-monsoon (October-November). The mean annual rainfall is around 2350 mm.

Vegetation analysis was done by randomly placed 50 quadrats of 10m×10m for tree species. Individuals of tree species with >10 cm girth at breast height (1.3 m above ground) were recorded. The tree species were identified with the help of herbarium present in the Mizoram University and herbarium of the Botanical Survey of India (BSI), Eastern circle, Shillong and counter checked with referring regional floras (Kanjilal et al 1934-1940, Haridasan and Rao 1985, Sawmliana 2013). The field data on vegetation was quantitatively analyzed for phytosociological attributes namely, frequency, density and abundance as proposed by Cutis and McIntosh (1950). The importance value index (IVI) was determined as per Phillips (1959). Species diversity and dominance indices were determined following the methods as outlined by Misra (1968), Mueller- Dombois and Ellenberg (1974).

RESULTS AND DISCUSSION

A total of 125 tree species belonging to 90 genera of 46 families (Table 1) recorded in the present study were broadly comparable to 123 species in tropical semi evergreen forest of Manipur (Devi and Yadava 2006) and considerably higher than 75 tree species present in Hollongapar Gibbon Wildlife Sanctuary, Assam (Sarkar and Devi 2014), and semi-evergreen (83 species) and evergreen forest (84 species) of Little Andaman Island, India (Rasingam and Parthasarathy 2009). However, the number of species present in the present forest is slightly less than the tropical deciduous forests (135 species and 105 genera of 45 families) of North central Eastern Ghats (Naidu et al 2018) and Nongkhyllem Wildlife Sanctuary, Meghalaya (127 woody species and 53 families) (Thapa et al 2011), and significantly less than that of a tropical wet evergreen forest (144 species) of Kalakad National Park in Western Ghats (Parthasarathy 1999). The tree density (2145 individuals/ha) recorded in the present was slightly more than twice as compared to the stand density of 996 trees ha^{-1} reported in tropical semi-evergreen forest in Nongkhyllem wildlife sanctuary in Meghalaya (Baishya et al 2009), whereas total basal area 64.76 $m^2 ha^{-1}$in the present study was marginally less (73.41 m^2 ha^{-1}) than that of Nongkhyllem wildlife sanctuary of Meghalaya. The tree density and total basal area of the presently studied forest were greater than tree density and basal area in tropical semi-evergreen forest of Hollongapar Gibbon Wildlife Sanctuary (Sarkar and Devi 2014), tropical semi evergreen forest of Manipur (Devi and Yadava 2006), tropical wet evergreen forest Namdapha National Park, northeast India (Nath et al 2005). Variation in tree density and basal area of different forest stand may be the result of altitudinal variation, species composition, age structure, successional stage of the forest and degree of disturbance (Swamy et al 2000). Basal area of a tree is an important feature to quantify the vegetation structure and site quality (Suthari 2013).

The Shannon-Weiner (H') index (4.37) of the present study site (Table 1) was towards the higher side of the range (0.67 to 4.86) reported for tropical forests of Indian sub-continent (Kumar et al 2010, Panda et al 2013). The diversity index (H') for Indian forests ranged from 0.83 to 4.1 (Singh et al 1984, Parthasarathy et al 1992, Vishalakshi 1995) and the value of diversity index of the present study reflects high tree diversity in the study site. High value of diversity index indicates that the present forest is species diverse system maintained by the management intervention of villagers by allowing sufficient number of trees in the lower girth class to promote natural regeneration of species in the forest. In general, high diversity is characteristics of tropical rainforest. Simpson's index values of different Indian tropical forests has been reported from 0.03 to 0.92 (Bhuyan et al 2003, Nath et al 2005, Devi and Yadava 2006, Deb and Sundriyal 2011, Kushwaha and Nandy 2012) with an average value of 0.06 (Knight 1975). The value of Simpson's index in the present study (Table 1) was towards the lower side of the range reported for other tropical ecosystems. Evenness index (0.89) was comparable with the tropical evergreen region (0.81) of Meghalaya (Tynsong and Tiwari 2011). The higher evenness index value reveals more consistency in species

Table 1. Tree community structure of tropical moist forest of Mizoram, Northeast India

Parameter	Value
No. of family	46
No. of genera	90
No. of species	125
Tree density (Indv ha^{-1})	2145
Tree basal area (m^2 ha^{-1})	64.76
Shannon-Wiener index	4.37
Simpson dominance index	0.03
Simpson index of diversity	0.96
Species richness (Margalef's index)	16.16
Evenness index (Pielou index)	0.89

distribution. The Margalef richness index of the sampled forest is 16.16 and well within the range of 4.54 - 23.41 for other tropical forests (Kumar et al 2010, Sathish et al 2013).

The distribution of the basal area using DBH class intervals revealed that the forest is characterized by dominance of smallest individuals as reflected by the increased number of individuals of lower diameter classes. In the present study, over half of the individuals (1297 approx. 60.5%) were represented by DBH class (10-20 cm) and remaining 848 individuals (39.5%) were >20 cm DBH. The population size class frequency distribution of the forest stand exhibited a tendency towards a reverse 'J' shaped for the distribution number and basal area. 'J' shaped distribution exhibits that the tree population was skewed towards younger trees, which indicate that older individuals were disproportionally represented in the population. The forest stand structure based on tree girth classes and basal area distribution revealed that the number of individuals across girth classes in forest decreased from the smaller to larger size classes (Fig. 1). Girth class frequency showed reverse 'J'-shaped population curve in our present study, which is similar to those reported from forest of North east India (Upadhaya et al 2004, Mishra et al 2005, Tynsong and Tiwari 2011), Eastern Ghats (Sahu et al 2012), Andaman Island (Rajkumar and Parthasarathy 2008, Rasingam and Parthasarathy 2009). Tree density distribution across different girth classes indicates how well the growing forest is utilizing the site resources. The species diversity is influenced by adaptation of species and increases with stability of community.

The species with the highest importance value (IV) in the community was *E. acuminata* representing 5.15 per cent of the IVI and other species like *L. xylocarpus*, *A. penunculata*, *M. hodgsonii*, *C. tribuloides* and *H. excelsa* all together representing 21.4% of the total IVI (Table 2). IVI value of any species indicates the dominance of species in a mixed population and it gives a total picture of the community structure of species in a community that can be used to form an association of dominant species (Parthasarathy and Karthikeyan 1997). *E. acuminata* (5.15%) records highest IVI value emerging as the dominant tree species which was followed by *L. xylocarpus*, *A. penunculata*, *M. hodgsonii*, *C. tribuloides*, *H. excelsa.* The observation indicates that the present forest harbours rich tree diversity providing habitat and food resources to large number of fauna. High species richness means greater diversity which leads to a higher community stability (MacArthur 1955). However, the anthropogenic activities like firewood and timber collection

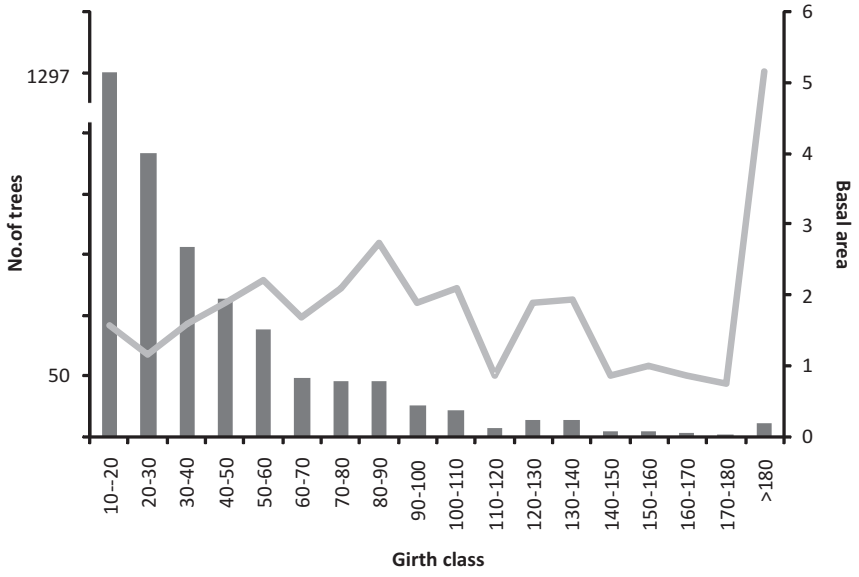

Fig. 1. Basal area (m^2ha^{-1}) and girth class distribution of tree species of tropical moist forest of Mizoram, Northeast India

Table 2. Species composition of tropical moist forest of Mizoram,Northeast India

Name of species	Family	IVI
Eurya japonica Thunb.	Pentaphylacaceae	15.45
Litsea salicifolia (J. Roxb. ex Nees) Hook. f.	Lauraceae	10.82
Acrocarpus fraxinifolius Arn.	Leguminosae	9.96
Magnolia hodgsonii (Hook.f. & Thomson) H. Keng	Magnoliaceae	9.64
Canarium bengalense Roxb.	Burseraceae	9.42
Heteropanax fragrans (Roxb.) Seem	Araliaceae	9.07
Garcinia xanthochymus Hook.f.ex T. Anderson	Clusiaceae	8.12
Ocotea lancifolia (Schott) Mez	Lauraceae	8.09
Aegle marmelos (L.) Correa	Rutaceae	8.07
Macropanax dispermus (Blume) Kuntze	Araliaceae	7.81
Calliandra umbrosa (Wall.) Benth	Leguminosae	7.41
Syzygium cumini (L.) Skeels	Myrtaceae	6.84
Bruinsmia polysperma (C.B.Clarke) Steenis	Styracaceae	6.72
Castanopsis indica (Roxb.exLindl.) A.DC.	Fagaceae	4.97
Albizia lucidior (Steud.) I.C.Nielsen	Leguminosae	4.75
Syzygium kurzii (Duthie) N.P.Balakr.	Myrtaceae	4.71
Choerospondia saxillaris (Roxb.) B.L. Burtt & A.W. Hill	Anacardiaceae	4.54
Mesua ferrea L.	Callophyllaceae	4.54
Embelia tsjeriam-cottam (Roem. & Schult.) A. DC.	Primulaceae	4.54
Pseudostachyum polymorphum Munro.	Poaceae	4.33
Aglaia edulis (Roxb.) Wall.	Meliaceae	4.12
Diospyros glandulosa Lace.	Ebenaceae	4.04
Ostodespaniculata Blume	Euphorbiaceae	3.94
Schizostachyum griffithii (Munro) R.B. Majumdar	Poaceae	3.76
Ficus hirta Vahl	Moraceae	3.54
Elaeocarpus floribundus Blume	Elaeocarpaceae	3.31
Alphonsea ventricosa (Roxb.) Hook.f. & Thomson	Annonaceae	3.26
Mangifera sylvatica Roxb.	Anacardiaceae	3.23
Alangium chinense (Lour.) Harms	Cornaceae	3.16
Colona floribunda (Kurz) Craib	Malvaceae	2.95
Symplocos cochinchinensis (Lour.) S. Moore	Symplocaceae	2.92
Elaeocarpus rugosus Roxb. ex G. Don	Elaeocarpaceae	2.87
Laurocerasus undulata (Buch.-Ham. Ex D. Don) M. Roem	Rosaceae	2.81
Anogeissus acuminata (Roxb. ex DC.) Wall. ex Guillem. & Perr.	Combretaceae	2.80
Schima khasiana Dyer	Theaceae	2.80
Oroxylum indicum (L.) Kurz	Bignoniaceae	2.74
Alphonsea lutea (Roxb.) Hook.f. & Thomson	Annonaceae	2.65
Olea europaea subsp. cuspidata (Wall. & G. Don) Cif.	Oleaceae	2.61
Memecylon celastrinum Kurz	Melastomaceae	2.61
Quercus glauca Thunb.	Fagaceae	2.56
Eurya acuminata DC	Pentaphylacaceae	2.47
Artocarpus nitidus Trécul	Moraceae	2.42
Lithocarpus xylocarpus (Kurz) Markgr.	Fagaceae	2.40

Cont...

Wendlandia budleioides Wall. Ex Wight & Arn	Rubiaceae	2.33
Diospyros lancefolia Roxb.	Ebenaceae	2.28
Dysoxylum excelsum Blume	Meliaceae	2.22
Lithocarpus dealbatus (Hook.f. & Thomson ex Miq.) Rehder	Fagaceae	2.21
Styrax serrulatus Roxb.	Styracaceae	2.15
Balakata baccata (Roxb.) Esser	Euphorbiaceae	1.96
Homalium ceylanicum (Gardener) Benth.	Salicaceae	1.94
Engelhardtia spicata Lechen ex Blume	Juglandaceae	1.92
Helicia excelsa (Roxb.) Blume	Proteaceae	1.87
Mangifera indica L.	Anacardiaceae	1.87
Castanopsis tribuloides (Sm.) A. DC.	Fagaceae	1.85
Toxicodendron succedaneum (L.) Kuntze	Anacardiaceae	1.82
Triadica cochinchinensis Lour.	Euphorbiaceae	1.58
Carallia brachiata (Lour.) Merr.	Rhizophoraceae	1.50
Fagraea ceilanica Thunb.	Gentianaceae	1.50
Bambusa longispiculata Gamble	Poaceae	1.45
Acronychia pedunculata (L.) Miq.	Rutaceae	1.34
Macaranga denticulata (Blume) Müll.Arg.	Euphorbiaceae	1.34
Stereospermum tetragonum DC.	Bignoniaceae	1.34
Stereospermum chelonoides (L.f.) DC	Bignoniaceae	1.33
Macaranga peltata (Roxb.) Mull. Arg.	Euphorbiaceae	1.23
Betula cylindrostachya Lindl. ex Wall.	Betulaceae	1.18
Ziziphus incurva Roxb.	Rhamnaceae	1.18
Camellia oleifera Abel	Theaceae	1.12
Cephalostachyum latifolium Munro	Poaceae	1.12
Calophyllum polyanthum Wall. ex Planch. & Triana	Clusiaceae	1.05
Schima wallichii Choisy	Theaceae	1.03
Cephalotaxus mannii Hook.f.	Taxaceae	0.90
Engelhardtia roxburghiana Lindl.	Juglandaceae	0.90
Eriobotrya bengalensis (Roxb.) Hook.f.	Rosaceae	0.90
Ficus religiosa L.	Moraceae	0.90
Murraya koenigii (L.) Spreng	Rutaceae	0.90
Vitex quinata (Lour.) F.N. Williams	Lamiaceae	0.90
Albizia richardiana (Voigt) King & Prain	Leguminosae	0.89
Atalantia simplicifolia (Roxb.) Engl.	Rutaceae	0.89
Clerodendrum glandulosum Lindl.	Lamiaceae	0.89
Croton wallichii Mull. -Arg	Euphorbiaceae	0.89
Terminalia myriocarpa Van Heurck & Mull. Arg.	Combretaceae	0.89
Toona ciliata M. Roem.	Meliaceae	0.89
Dalbergia stipulacea Roxb.	Leguminosae	0.87
Drimycarpus racemosus (Roxb.) Hook.f. exmarchand	Anacardiaceae	0.87
Magnolia doltsopa (Buch.-Ham. ex DC.) Figlar	Magnoliaceae	0.87
Sterculia villosa Roxb.	Malvaceae	0.87
Alseodaphne petiolaris Hook.f.	Lauraceae	0.69
Archidendron bigeminum (L.) I.C. Nielsen	Leguminosae	0.69
Croton lissophyllus Radcl.-Sm. & Govaerts ex Esser	Euphorbiaceae	0.69
Dalbergia pinnata (Lour.) Prain	Leguminosae	0.69

Cont...

Glochidion sphaerogynum (Mull.Arg.) Kurz	Phyllanthaceae	0.69
*Hydnocarpus kurzii (*King) Warb	Achariaceae	0.69
Neolamarckia cadamba (Roxb.) Bosser	Rubiaceae	0.69
Oreocnide integrifolia (Gaudich.) Miq.	Urticaceae	0.69
Pterospermum lanceifolium Roxb.	Malvaceae	0.69
P. semisagittatum Buch.-Ham. ex Roxb.	Malvaceae	0.69
Acer laevigatum Wall.	Sapindacedae	0.51
Aglaia spectabilis (Miq.) S.S. Jain & S. Bennet	Meliaceae	0.51
Artocarpus heterophyllus Lam.	Moraceae	0.51
Baccaurea ramiflora Lour.	Phyllanthaceae	0.51
Bombax insigne Wall.	Malvaceae	0.51
Bridelia tomentosa Blume	Phyllanthaceae	0.51
Callicarpa arborea Roxb.	Lamiaceae	0.51
*Cinnamomum tamala (*Buch.-Ham) T. Nees & Eberm	Lauraceae	0.51
C.verum J. Presl	Lauraceae	0.51
Ficus altissima Blume	Moraceae	0.51
F. auriculata Lour.	Moraceae	0.51
F. curtipes Corner	Moraceae	0.51
F. variegata Blume	Moraceae	0.51
Garcinia anomala Planch. & Triana	Clusiaceae	0.51
G.cowa Roxb.ex Choisy	Clusiaceae	0.51
Macaranga indica Wight	Euphorbiaceae	0.51
Machilus glaucescens (Nees) H.W. Li	Lauraceae	0.51
Magnolia champaca (L.) Baill. ex Pierre	Magnoliaceae	0.51
M. oblonga (Wall. exHook.f. & Thomson) Figlar	Magnoliaceae	0.51
Mallotus philippensis (Lam.) Müll. Arg.	Euphorbiaceae	0.51
*Neonauclea purpurea (*Roxb.) Merr.	Rubiaceae	0.51
Olea salicifolia Wall. ex G. Don	Oleaceae	0.51
Rhus chinensis Mill.	Anacardiaceae	0.51
Symplocos racemosa Roxb.	Symplocaceae	0.51
Syzygium ramosissimum (Blume) N.P. Balakr	Myrtaceae	0.51
Tarennoidea wallichii (Hook.f) Triveng. & Sastre	Rubiaceae	0.51
Trema orientalis (L.) Blume	Cannabaceae	0.51
Ulmus laceifolia Roxb.ex Wall.	Ulmaceae	0.51
Vernicia montana Lour.	Euphorbiaceae	0.51

by the local people to meet their requirement prevailing in the present study area causing disturbance and imposed threat to the survival and population structure of the species. The log-normal dominance-diversity curve (based on IVI) was found with a normal distribution (Fig. 2). The log-normal dominance distribution curve indicates stable community, similar trend has been found in other studies (Khera et al 2001, Sahu et al 2012, Lynser and Tiwari 2015).

Families with the highest species richness were Euphorbiaceae followed by Moraceae, Leguminosae with 10, 8 and 6 species. The most abundant families in the area with the highest density of individuals include-Fagaceae (258 individuals) followed by Pentaphylacaceae (193), Clusiaceae (146). Dipterocarpaceae, Euphorbiaceae, Anacardiaceae and Meliaceae were the dominant families reported from the northern eastern ghats (Panda et al 2013), while Mimosaceae, Euphorbiaceae, Rubiaceae and Anacardiaceae dominated the tropical forests of southern Eastern Ghats (Pragasan and Parthasarathy 2010). Sandhyarani et al (2007) also reported Euphorbiaceae as the dominant family followed by Moraceae and Lauraceae in the Eastern Ghats. This trend indicates that across various

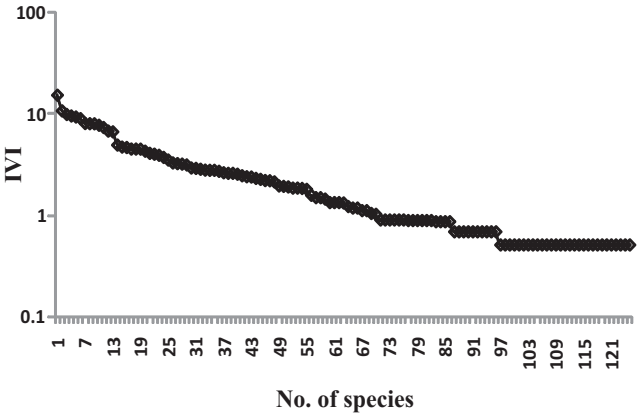

Fig. 2. Dominance-diversity curves of tree species of tropical moist forest of Mizoram, Northeast India

tropical forests a greater similarity is evident at the family level. Eight *Ficus* spp. were found in the present study belong to the Moraceae family, and according to Carauta (1989) and Oliveira-Neto et al (2017), fig trees are key components of many tropical forests, since a wide variety of animals feeds on their fruits, including mammals, birds, and even fish. These species are responsible for the dispersion of seeds, thus helping the regeneration of the forest.

CONCLUSION

The tree species exhibits reverse J-shaped population curve that indicates good regeneration status which is important for the sustainable development of the forest community in future in the absence of any major environmental and or human interference. This suggests proper management plants operated by villagers in selecting mature trees for their uses and effective management of forest community. The most common tree species with highest removal percentage were: *Albizia richardiana*, *Engelhardtia roxburghiana, Ficus religiosa, Neolamarckia cadamba, Pterospermum lanceifolium, Schima wallichii, Terminalia myriocarpa* suggest that these species may be at risk of losing their dominance from the area in the future in the absence of proper regeneration. Therefore, further studies on regeneration potential of tree species from the forest would assist better management plans and conservation of species in the community reserve forest in future. The present analysis would be useful in developing future forest management and conservation plans through long-term monitoring of forests in this region.

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Structural and Floristic Diversity of Different Landscape in Western Ghats of Kodagu, Karnataka, India

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Abstract: The study was under taken to assess the structural and floristic diversity in selected landscape elements of Kodagu district which lies in Western Ghats, Karnataka.In natural forest and sacred grove, random sample plot of 20 X 20 m and for coffee plantations 25X50 m plot was laid out. The data on species richness, composition and number of individuals, height and DBH (≥10 cm DBH) were collected. Differences occurred between the natural forest, sacred grove and coffee plantation landscape in terms of speciesrichness, number of individuals observed, composition and association of species in each landscape elements. In evergreen forest belt coffee plantations had higher Shannon diversity and species richness (3.611 and 7.864, respectively) indicating the species *in situ* and per se *circa situ* conservation plays an important role as compared to natural forest and sacred grove. In transitional belt, Shannon diversity and species richness was more in sacred grove (3.834 and 11.55, respectively) as compared to natural and coffee plantations due more number of sacred grove or devarakaadus in the belt. There was higher species richness and Shannon diversity in coffee plantations of dry deciduous belt (20.96 and 3.853, respectively) as management practices in coffee owners by retaining the remnant native tree species as compared to natural and sacred grove which are highly posed to anthropogenic factors. The IVI values are also differs with respect to climatic and management practices between landscape elements and more of *Mangifera indica, Ficus racemosa, Ficuss bengalensis, Acrocarpus fraxinifolius* and *Garcinia gummi- gutta*. Hence, coffee plantations can help to protect the tree species, sustain smallholder production and offers more scope for conservation of biodiversity.

Keywords: Landscape, Conservation, Circa situ, Anthropogenic factors, Bioclimatic zone, Floristic diversity

Kodagu district in the southern Indian state of Karnataka is located on the leeward side of the Western Ghats. Natural vegetation has been classified into several floristic types ranging from wet evergreen forests through intermediate forms to dry woodlands and thickets (Elouard 2000a). However, landscape studies have revealed a gradual conversion of privately owned forests into coffee plantations, opening of the canopy, and increase of exotic trees during the last few decades (Elouard 2000b and Garcia et al 2010). Despite these changes, the biodiversity harboured in the district remains higher than in most coffee cultivating areas of the world. A recent survey of coffee plantations in central Kodagu recorded almost 280 species of trees. The high density and diversity of native trees in coffee plantations of Kodagu has been attributed to the existence of high indigenous diversity (Elouard et al 2000) as well as the tough forest protection laws in the district (Ambinakudige and Satish 2009). In India there are approximately 4125 sacred groves covering 39 063 ha of forest and has been identified as one of the eight hottest hot spots of biodiversity in the world (Mittermeier et al 2005). It has largest wooded districts in the country with 81.4 per cent of the land area under tree cover. Though sacred groves are seen in many other parts of the world and in India, Kodagu District, Karnataka State in South India is a unique landscape known for sustaining the tradition of sacred groves. The indigenous communities of the district are nature and ancestral worshipers, and sacred groves called “Devakadu” are community-managed informal conservation sites. While covering only 2 per cent of the district, the sacred groves are dispersed throughout the district, representing the diverse topographic, climatic and vegetation conditions. The expansion of coffee plantations in Karnataka increased tremendously during 2010 to 2015 with 2,27,340 ha to 2,30,434 ha and in Kodagu 1,03,580 to 1,04,922 ha. Coffee agroforestry systems (CAFS) exhibit a continuum of structural and biological diversity, from species-rich complex agroforests quite similar to natural secondary forests to simple coffee plantations planted with a few shading trees (Toledo and Moguel 2012).

This paper presents the part of the findings of assessing and evaluation of *circa situm* conservation values of shade coffee landscape elements of Kodagu district. The information gathered in the study will enable us in how the farmers are actually involved in conserving the tree species in the coffee plantations and sacred groves and adds to conservation values. The main objective of the study is to

compare the species richness, species assemblages and dominance between natural forest, sacred grove and coffee plantations in bioclimatic zones. This study was undertaken in Kodagu with a research hypothesis that floristic diversity and structural composition of tree species are expected to vary among three landscape elements with a highest diversity expected in evergreen forest which due to more protection and decrease with increasing land use intensity in semi evergreen and dry deciduous forest belts of natural forest, sacred grove and coffee plantations.

MATERIAL AND METHODS

Study site: The study was conducted in forest-coffee agroforest landscape mosaics of Kodagu district which lies in the Central Western Ghats region covering an area of 4106 km^2 of which about 38 per cent of area is under natural and tree plantation. The study area has a steep West to East climatic gradients especially for temperature and rainfall from the edge of ghatsand an altitudinal range of 700-1200 m above sea level which receives annual rainfall between 1500 to 3500 mm with maximum rainfall during monsoon season. The climatic conditions for mean maximum temperature (32°c) in April and May and lowest mean minimum temperature (15°c) in December and January. In Kodagu, the state forest department's estimates show that there are 1,214 sacredgroves covering an area of 6,375 ha (1.6% of total geographical area of Kodagu).

Data collection and sampling design: Based on temperature and rainfall regimes, entire Kodagu was classified into three bioclimatic zones as Zone-1: Evergreen forest belt (high rainfall: >4000 mm), transition forest belt (intermediate rainfall: 2000-4000 mm) and dry deciduous forest belt (low rainfall: 1400 mm)Three landscape elements such as natural forest (NF), sacred grove (SG) and coffee plantations (CFP) were selected in each bioclimatic zone for the purpose of study. A statistical random sampling design was used to collect vegetation data from 20 x 20 m plots. A minimum of 20 plots were placed within each combination of landscapes of natural forest and sacred grove. For coffee plantations based on species area curve method available three plots of 25 x 50 m were laid out in three bioclimatic zones. A total of 60 sample plots in natural forest and sacred grove and 9 plots in coffee plantations were laid out. In each of 0.1ha plots, all the woody plants were counted and identified as far as possible *in situ* at species level using field key (Pascal and Ramesh 1987). Sample specimens which could not be identified in the field were collected for identification. Height and diameter at breast height (DBH) of all the trees with ≥10 cm DBH in sample plots were measured using Blume Leiss Hypsometer and digital caliper (Haglof, Sweden), respectively.

Data analysis: For vegetation analysis density, abundance, frequency, species richness and basal area per hectare were estimated to measure the structure and heterogeneity of three landscape elements. The relative frequency, relative density, relative dominance (relative basal area), and importance value index (IVI) (Curtis and McIntosh, 1951) were derived for each of the three landscape elements.

Species richness: A measure of the number of species present for a given number of individuals was calculated by using Margalef's Index (Margalef 1958). To measure dominance, Simpson Index derived from probability theory was used (Simpson 1949). It gives relatively less weightage to rare species and more weightage to common species and Equitability Index (Pielou 1969) was calculated. A two-tailed *t*-test (Past 3 software) was usedto compare Shannon Wiener diversity Index and Simpson Dominance Index, Evenness, Margaleef richness and Fisher alpha in the categorized landscape elements. The diversity indices were calculated using Past 3 software and Biodiversity pro and IVI was analyzed in MS- Excel using aggregated data of the sample plots in each land use type of bioclimatic zones of Kodagu

RESULTS AND DISCUSSION

Both natural, climatic and anthropogenic factors influence the structural and functional characteristics of the tropical landscape. The significantly high plant species diversity and richness in evergreen forest belt as compared to other land use practices while semi evergreen and dry deciduous forest were on par with each other. Variation in diversity and composition across the land use types could be explained by the three main interacting factors; the climate, disturbance factors and management systems in coffee plantations. Among the climatic factors, rainfall is the important determinant of floristic diversity and composition and the present study regions has rainfall gradient from West- East comprising evergreen forest on the Western side of the district and towards the East semi evergreen, most dry deciduous forest. Bongers et al (2004) have showed that species richness and composition was highly related to rainfall gradient in African forests.

The analysis of the results showed that there was significant difference in number of stems, species, species richness, fisher alpha, dominance, simpson index of dominance, Shannon index and Shannon evenness expect number of stems to the hectare (Table 1). The number of stems was more in sacred grove (758) followed by natural forest and least was in coffee. However, number of species to the hectare was more in natural forest (61.25) and coffee

plantations (48) than sacred grove which significantly varied. Species richness significantly varied within the landscape elements and found more in coffee plantations (7.86) followed by natural forest and least was in sacred grove with significant differences. Similarly Fisher alpha values were more in coffee plantations (14.33) followed by natural forest and least in sacred grove. The species dominance was more in natural forest (0.038) followed by coffee plantations and sacred grove. Simpson index of diversity was more in sacred grove (0.967) followed by coffee plantations and the least in natural forest. Shannon diversity was more in coffee plantations (3.611) followed by natural forest and sacred grove. The Shannon evenness was more in sacred grove (0.9669) followed by coffee plantations and was least in natural forest (Fig. 2). The land use in state owned evergreen and semi evergreen forest types was protection and limited to wildlife grazing and browsing and equate to moderate levels of disturbances. Conversely, dry deciduous forest belt, the land use systems were highly subjected to higher levels of human related activities such as livestock grazing, illegal felling and collection of non-timber forest products which are of high levels of disturbances. Murthy et al (2016) in Western Ghats of India where the more disturbed dry deciduous had low species diversity when compared to less disturbed forests.

The species richness in coffee plantations were almost on par with the natural forest and sacred grove is due to the management practices where farmers retain native tree species for more ecological and social benefit which they derive from it. In Transition belt of the district species richness and diversity was observed as many of the "kodavas" worship god by creating existing natural forest and

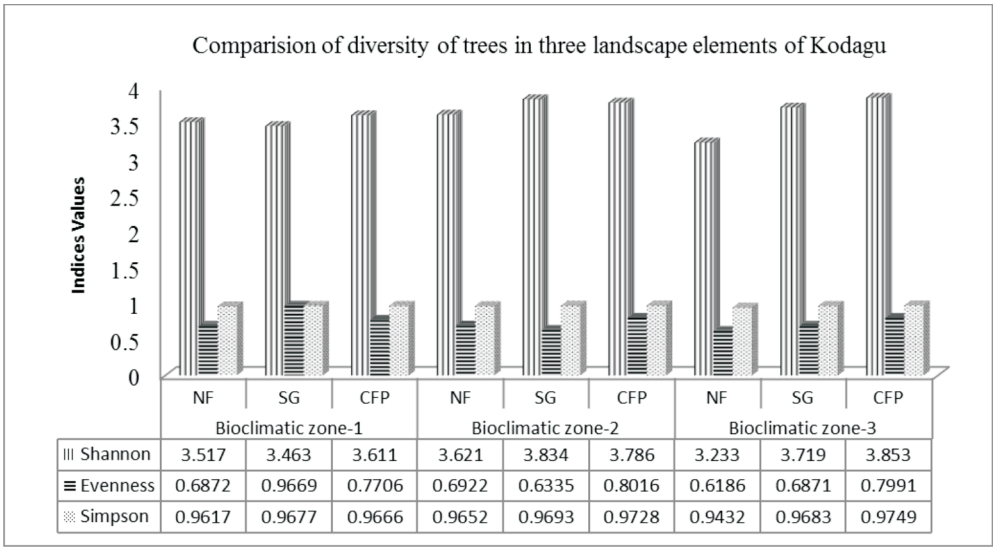

Fig. 1. Diversity parameters for the tree species studied between different landscape elements in bioclimatic zones

Table 1. Vegetation characteristics in natural forest, sacred grove and coffee plantations of bioclimatic zone-1 (evergreen forest belt)

Parameters	Natural forest	Sacred grooves	Coffee plantations	Difference	t-values	p-values
No. of species	49	33	48	43.30	8.37	0.013962
No. of stems	746	758	394	632.67	2.29	0.033812
No. of species ha^{-1}	61.25	41.25	48.00	50.16	8.54	0.013436
No. of stems ha^{-1}	932.50	947.50	394	758	4.16	0.0531*
Species richness (Margaleef Index)	7.25	4.82	7.86	6.64	7.16	0.018936
Fisher alpha (α)	11.76	7.038	14.33	11.04	5.17	0.035419
Dominance D	0.038	0.032	0.033	0.034	20.18	0.002146
Simpson 1-D	0.961	0.967	0.966	0.965	523.44	0.000000
Shannon H	3.51	3.46	3.61	3.53	81.64	0.000142
Shanon eveness H/S	0.687	0.966	0.770	0.808	9.74	0.010359

*Not significant at 0.05 % level and 95% confidence level

demarcating the land as sacred grove which aids in conservation of tree species. In dry deciduous forest belt which receives lesser rainfall has lesser species diversity and species richness in natural and sacred grove due to encroachment, anthropogenic factors and lesser rainfall. However higher species diversity and species richness was due to more protection and management practices (Fig. 2)

In bioclimatic zone-2, which lies in the transition belt of Kodagu, there were significant differences among the observed values for all the characteristics of different landscape elements (Table 2). Out of 182 species observed in all the landscape elements, more number of species were in sacred grove (73) followed by coffee plantations and was least in natural forest. The observed number of individuals in plot were more in coffee plantations (526) followed by natural forest. However, number of species to the hectare was more in sacred grove (91.25) followed by natural forest and the least in coffee plantations. Similarly, species richness also showed the same trend. Shannon evenness for the species in coffee plantation was more (0.801) and was more or less the same in sacred grove and natural forest.

For bioclimatic zone-3, which receives low rainfall of less than 2000 mm, the vegetation characteristics were entirely different from other two zones (Table 3). However, the observed parameters statistically differ from each other except for the number of species to the hectare and dominance of the species. Out of 160 species observed in landscape elements of the zone, more number of species was in sacred grove (60) and coffee plantation (59) and the least in natural forest because of various disturbance factors. The statistically differences were observed with the landscape elements for species richness, fisher alpha, simpson, Shannon diversity and Shannon evenness and more in coffee plantations followed by sacred grove and the least values were observed in natural forest. This study also revealed that considerable number of tree species are being managed and conserved in coffee plantations. However, as compared to coffee farms in other regions the number of tree

Table 2. Vegetation characteristics in natural forest, sacred grove and coffee plantations of bioclimatic zone-2 (semi-evergreen forest)

Observed values	Natural forest	Sacred grooves	Coffee plantations	Difference	t-values	p-values
No. of species	54	73	55	60.67	9.82	0.010197
No. of stems	514	510	526	516.67	107.47	0.000000
No. of species ha^{-1}	67.50	91.25	55.00	71.25	6.70	0.021546
No. of stems ha^{-1}	642.50	637.50	526	602	15.83	0.003966
Species richness (Margaleef Index)	8.49	11.55	8.69	9.57	9.69	0.010476
Fisher Alpha (α)	15.22	23.33	15.47	18.00	6.76	0.021174
Dominance D	0.034	0.030	0.027	0.030	13.85	0.005171
Simpson 1-D	0.965	0.969	0.972	0.969	441.26	0.000000
Shannon H	3.62	3.83	3.78	3.74	58.08	0.000296
Shannon Evenness H/S	0.692	0.633	0.801	0.709	14.39	0.004790

Table 3. Vegetation characteristics in natural forest, sacred grove and coffee plantations of bioclimatic zone-3 (dry deciduous forest)

Observed values	Natural forest	Sacred grooves	Coffee plantations	Difference	t-values	p-values
No. of species	41	60	59	53.33	8.63	0.013135
No. of stems	516	428	341	428.33	8.47	0.013627
No. of species ha^{-1}	51.25	75.00	59	273.42	2.40	0.138382*
No. of stems ha^{-1}	645	535	329	503	5.43	0.032269
Species richness (Margaleef Index)	6.40	9.73	10.01	8.71	7.52	0.017228
Fisher Alpha (α)	10.46	19.00	20.96	16.80	5.21	0.034871
Dominance D	0.056	0.033	0.025	0.038	4.03	0.056212*
Simpson 1-D	0.943	0.968	0.974	0.962	99.63	0.000100
Shannon H	3.233	3.719	3.853	3.601	19.12	0.002723
Shannon evenness H/S	0.618	0.687	0.799	0.701	13.33	0.005575

*Not significant at 0.05 % level and 95% confidence level

species observed in the study area appears to be lower. For example, in Veracruz, Mexico, the species richness of studied coffee farms reach up to 107 (Lopez-Gomez et al 2008). Similarly, ninety four mature tree species (DBH>10cm) were recorded in Geuinean coffee farms (Correia et al 2010). On the other hand, Bandeira et al (2005) reported 45 tree species, which is comparable to the result of the present study. The difference in species richness could probably emanate from the differences in farm management and regional plant species pool variation (Williams-Linera 2002).

Among the species observed in bioclimatic zone-1 of natural forest, Importance Value Index of top ten species range from 8.07 to 17.87 and was highest in *Memecylon umbellatum brum* (17.87) followed by *Mangifera indica, Aporusa lindleyana, Cinnamomum malbatrum* and *Messua ferrea.* Density of *Aporusa lindleyana* was highest (78.75) followed by *Mangifera indica* and *Cinnamomum malbatrum* per hectare. The total basal area of natural forest was 12.17 m^2 ha^{-1} and was highest in *Memecylon umbellatum brum* (2.57 m^2 ha^{-1}) followed by *Baccaurea courtallensis and Mangifera indica* (Table 4). In sacred grove, *Garcinia gummi-gutta* had the highest IVI, density and basal area followed by *Lannea coromandelica.* Similarly, *Mangifera indica* occupied almost in coffee plantations with IVI and basal area followed by *Erythrina suberosa.*

In bioclimatic zone-2, among the top ten tree species, *Artocarpus hirsutus* had the highest IVI and basal area followed by *Mangifera indica* (Table 5). The IVI values ranged from 7.53 to 14.53 in natural forest of Transition belt. Similarly, *Artocarpus hirusutus* had the highest number of trees (63.75 ha^{-1}) followed by *Gliricidia maculata*. In sacred grove, IVI values ranged from 6.23 to 14.07 and highest being *Vitex altissimia* followed by *Artocarpus hirsutus*. Coffee

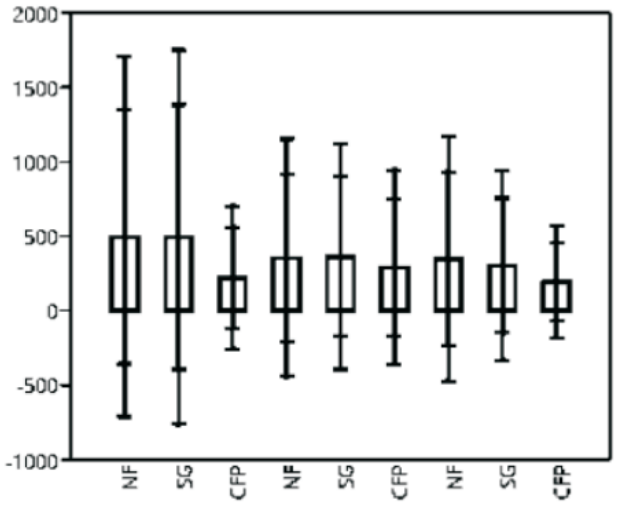

Fig. 2. Whisker plots for number of species and stems per hectare across different landscape elements in bioclimatic zones of Kodagu (at 95% confidence interval)

Table 4. Top ten dominant species found in natural forest, sacred grove and coffee plantations of bioclimatic zone-1 (evergreen forest belt) with density ha^{-1}, basal area (m^2ha^{-1}) and important value index (IVI)

Natural forest				Sacred grooves				Coffee plantations			
Tree species	IVI	Density	Basal area	Tree species	IVI	Density	Basal area	Tree species	IVI	Density	Basal area
Memecylon umbellatum	17.87	3.75	2.57	*Garcinia gummi-gutta*	17.20	41.25	1.14	*Mangifera indica*	18.40	3.00	1.28
Mangifera indica	15.78	68.75	0.90	*Lannea coromandelica*	13.73	33.75	0.83	*Erythrina suberosa.*	15.34	12.00	1.53
Aporusa lindleyana	12.92	78.75	0.27	*Careya arborea*	13.64	17.50	1.02	*Pterocarpus marsupium*	13.69	18.00	0.72
Cinnamomum malbatrum	12.21	65.00	0.50	*Myristica malabarica*	13.57	26.25	0.90	*Dalbergia latifola*	12.53	01.00	0.07
Messua ferrea	11.63	37.50	0.77	*Trema orientalis*	12.43	20.00	0.84	*Sterculia alata*	11.86	10.00	0.22
Garcinia gummi-gutta	9.70	22.50	0.72	*Lophopetalum wightianum*	11.80	22.50	0.74	*Dipterocarpus indicus*	11.08	01.00	0.55
Baccaurea courtallensis	9.43	13.75	0.94	*Erythrina subumbrans*	10.87	33.75	0.49	*Psidium guajava*	9.52	05.00	0.02
Calophyllum polyanthum	8.96	46.25	0.19	*Bauhinia racemosa*	10.43	23.75	0.56	*Myristica malabarica*	8.54	05.00	0.15
Artocarpus hirsutus	8.91	48.75	0.14	*Albizia amara*	9.94	12.50	0.83	*Ficus racemosa*	8.19	08.00	0.55
Syzygium cuminii	8.07	40.00	0.16	*Pterocarpus marsupium*	9.71	38.75	0.29	*Hopea parviflora*	7.13	04.00	0.45

plantations IVI values are less as compared to natural and sacred grove. However, IVI values ranged from 7.27 to 11.76 and highest being in *Holigarna arnottiana* followed by *Santalum album*. The density of *Ficus racemosa* was more in coffee plantations (36 ha^{-1}) followed by *Ficusasperima*. In dry deciduous belt of bioclimatic zone-3, the association of tree

Table 5. Top ten dominant species found in natural forest, sacred grove and coffee plantations of bioclimatic zone- (Semi-evergreen forest) with density ha^{-1}, basal area (m^2ha^{-1}) and importance value index (IVI)

Natural forest				Sacred groves				Coffee plantations			
Tree species	IVI	Density	Basal area	Tree species	IVI	Density	Basal area	Tree species	IVI	Density	Basal area
Artocarpus hirsutus	14.53	63.75	0.36	*Vitex altissima*	14.07	61.25	0.74	*Holigarna arnottiana*	11.76	5.00	1.32
Mangifera indica	13.38	21.25	1.86	*Artocarpus hirsutus*	9.85	32.50	0.86	*Santalum album*	10.96	17.00	0.60
Spathodea companulata	12.76	21.32	1.53	*Olea dioica*	8.67	28.75	0.61	*Ficus racemosa*	10.69	36.00	0.30
Lannea coromandelica	11.98	16.25	1.53	*Hopea parviflora*	8.21	22.50	1.12	*Oroxylum indicum*	10.43	21.00	0.41
Terminalia tomentosa	10.12	30.00	0.56	*Macaranga peltata*	8.03	23.75	0.67	*Leucaenea leucocephala*	9.14	15.00	0.52
Toona ciliata	9.04	27.50	0.40	*Mallotus tetracoccus*	7.87	30.00	0.48	*Ficus asperrima*	8.57	28.00	0.08
Gliricidia maculata	8.59	35.00	0.19	*Canarium strictum*	7.84	22.50	0.07	*Phylanthus emblica*	8.22	12.00	0.47
Miliusa tomentosa	8.13	3.75	1.63	*Tabernaemontana heyneana*	7.14	17.50	1.00	*Careya arborear*	7.83	10.00	0.60
Trema orientalis	8.11	18.75	0.69	*Cinnamomum malbatrum*	6.54	23.75	0.33	*Meopsisemuri*	7.68	15.00	0.18
Chukrasia tabularis	7.52	2.50	1.53	*Careya arborea*	6.23	11.25	1.32	*Kydia calycina*	7.27	18.00	0.30

Table 6. Top ten dominant species found in natural forest, sacred grove and coffee plantations of bioclimatic zone-3 (Dry deciduous forest belt) with density ha^{-1}, basal area (m^2ha^{-1}) and importance value index (IVI)

Natural forest				Sacred grooves				Coffee plantations			
Tree species	IVI	Density	Basal area	Tree species	IVI	Density	Basal area	Tree species	IVI	Density	Basal area
Lagerstroemia microcarpa	22.95	86.75	0.76	*Artocarpus hirsutus*	12.05	38.75	0.59	*Ficus religiosa*	11.49	18.00	0.47
Tectona grandis	20.15	60.00	0.92	*Olea dioica*	10.60	30.00	0.66	*Ficus racemosa*	10.20	06.00	1.20
Terminalia bellirica	16.19	60.17	0.38	*Terminalia bellirica*	10.18	23.75	0.92	*Toona ciliata*	10.06	16.00	0.21
Dalbergia latifola	14.28	36.25	0.76	*Vitex altissima*	9.35	28.75	0.30	*Kydia calycina*	9.87	13.00	0.32
Vitex altissima	11.12	47.50	0.01	*Mallotus philippensis*	9.28	32.50	0.30	*Citrus reticulata*	8.74	08.00	0.66
Pterocarpus marsupium .	10.82	31.25	0.41	*Toddalia asiatica*	8.80	23.75	0.44	*Oroxylum indicum*	8.44	08.00	0.47
Lannea coromandelica	10.15	8.75	0.77	*Xanthophyllum flavescense*	7.80	13.75	0.74	*Artocarpus hirsutus*	8.19	15.00	0.11
Butea monosperma	9.75	11.25	0.67	*Pterocarpus marsupium*	7.67	21.25	0.48	*Miliusa tomentosa*	7.74	12.00	0.18
Radermachera xylocarpa	9.51	16.25	0.42	*Cassia fistula*	7.43	20.00	0.20	*Delonix regia*	7.72	09.00	0.18
Morus alba	8.95	17.50	0.33	*Dimocarpus longan*	7.19	17.50	0.28	*Pongamia pinnata*	7.21	09.00	0.24

species are entirely different from other zone species. The IVI values ranged from 8.95 to 22.95 (Table 6). The IVI and density of *Lagerstroemia microcarpa* was more (22.95 and 86.75, respectively) followed by *Tectona grandis* (20.15 and 60 ha^{-1}). The basal area of *Tectona grandis* was more in natural forest (0.92 m^2 ha^{-1}) followed by *Lagerstroemia microcarpa* and *Dalbergia latifolia*. Similarly, IVI and density of *Artocarpus hirsutus* was more in sacred grove (12.05 and 38.75, respectively). The basal area of species in sacred grove differs and was more in *Terminalia bellirica* (0.92 m^2 ha^{-1}) and least in *Cassia fistula* (0.20 $m^2 ha^{-1}$). Coffee plantations of the zone has the more number of *Ficus* species an IVI and density of *Ficus religiosa* was highest (11.49 and 18 ha^{-1}) and found more basal area in *Ficus racemosa* (1.20 $m^2 ha^{-1}$). IVI of top ten tree species revealed that in almost all the landscape elements *Mangifera indica* occupied being evergreen species. Among the top ten tree species *Artocarpus hirsutus* occupied in almost in all landscape. Coffee plantations of dry deciduous belt have the more number of *Ficus* species with its IVI and density for its ecological and social benefits. These results are in line with the studies conducted by Correia et al (2010) who reported that IVI of native tree species in coffee farms are similar to coffee plantations of Kodagu district.

In well-protected sacred groves, biodiversity is well preserved. At the same time, coffee, which is often considered as a threat to biodiversity, had significant tree diversity. Although diversity was less in coffee plots than sacred groves. This exemplifies how shade grown coffee has the propensity to conserve pockets of biodiversity even though it has less diversity than natural forests with sacred groves. Even though coffee retains some biodiversity, it cannot substitute for natural forest. Existing coffee plantations should be encouraged to preserve endemic species. The encouragement may be in the form of niche market for the shade grown coffee where growers receive premium prices for shade grown coffee. Some conservationists such as Conservation International and National Audubon Society (Conservation International 2001, National Audubon Society 2000, Philpott and Dietsch 2003) already advocating for premium price for shade grown coffee. Shade coffee can conserve tree biodiversity and could help improve the livelihoods of the local people if conservation practices and coffee markets are linked.

CONCLUSION

The species diversity and association of different species varied between landscape elements with highest diversity in evergreen forest belt of natural forest and lowest in dry deciduous forest belt. The diversity pattern among the different landscape elements suggests for conservation of rare, endangered and threatened native species. Next to natural forests, coffee plantations contain high diversity. The coffee plantations are more desirable in conserving biodiversity and acts a circa situ conservation where human interventions required to retain the species. Certain species were unique to particular landscape elements and not in others as *Ficus bengalensis* and *Ficus racemosa* which are considered as key stone species was recorded only in coffee plantations and not in other landscape elements. Therefore promotion of native trees on the farms with specific attention to rare species and species with low population's densities should have higher priority.

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Eucalyptus-based Agroforestry System under Semi-Arid Condition in North-Western India: An economic Analysis

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Abstract: The compact block with smaller spacing currently used for Eucalyptus plantations in the Northern India does not permit economical intercropping from succeeding year. This discourages the small landholders who need regular income from taking up Eucalyptus plantations and benefiting from the expanding market for pulpwood and plywood. Therefore, Eucalyptus planted in three spacing geometry of compact block (3m×3m), wider (6m×1.5m) and paired row (17m×1m×1m) was compared with sole Eucalyptus (3m×3m) and sole agriculture (without tree) cropping system at a constant density of 1111 trees ha^{-1} . In experiment, *Sesbania aculeata* (*kharif)* and *Hordeum vulgare* (*rabi*) were intercropped in three spacing geometry of Eucalyptus (till the harvesting of trees) and also compared with mono cropping up to eight years of plantation. Yield of agricultural crops was significantly reduced in different spacing geometry over control and reduced from 15 percent in second year and more than 60 percent in eighth year of plantation. The results showed that 17m×1m×1m spacing of Eucalyptus registered the highest NPV @ 12 percent discounting of INR 185336 followed by spacing of 6m×1.5m (Rs.140975). The B:C ratio of these agroforestry system was recorded maximum in wider spacing (17m×1m×1m) and ranging from 1:1.57 and followed by 1:1.44 (6m×1.5m), 1:1.25 (sole Eucalyptus) and 1:1.2 (sole agricultural crops). The all the agroforestry system had an IRR ranging from 15 to 32 percent. Therefore, on the basis of economic analysis, the study conclude that the Eucalyptus based agroforestry intercropped with *S. aculeata* and *H. vulgare* cropping system performed most efficient in 17m×1m×1m as compared to other Eucalyptus spacing and sole cropping of Eucalyptus and crops.

Keywords: Economics evaluation, Eucalyptus, *Sesbania aculeata*, *Hordeum vulgare*, Agroforestry system

Demand and supply of industrial wood is elevated at higher pace after the outlawing the harvesting of green timber from the reserved as well as private lands of India through the implementation of National Forest Policy 1988. As per the FSI (2011) reports states that as being 21 per cent of forest area contributes only 3 million cubic meter wood (approximately 6%) and remaining 44 million cubic meter wood comes from agroforestry sector of the country. The demand for furniture, paper and small wood has been rising between 8-12 per cent annually (Shrivastava 2017). This leads towards raising various commercial tree species plantation mainly poplar, eucalyptus, melia, dalbergia, teak, bamboo and casuarina trees outside the forest area through captive industrial plantation as well as agroforestry (Chavan et al 2015, 2016). Among mainly commercial tree species, *Eucalyptus* genus are most extensively planted throughout the world on approximately 20 million hectares and are expanding rapidly. Eucalyptus planting in India started taking shape through extension activities of the state forest departments in the late sixties and early seventies. It gradually gained momentum in all parts of India, especially in Punjab, Haryana, western Uttar Pradesh, Gujarat, Tamil Nadu, North Bengal and Andhra Pradesh (Chaturvedi et al 2017). Eucalyptus is the most popular choice to be planted along the edges, or bunds, of agricultural fields, and appears to be well incorporated and accepted in agroforestry in India. In farm forestry component, eucalyptus comprised 71.6 per cent of the total trees planted. In Haryana, various tree plantation drives and agroforestry farms helped to bring out 45 percent of total outside forest area under eucalyptus (HSAPCC 2011). Eucalypts are the most preferred species under agroforestry plantations in India due to the assured market, highly lucrative returns from trees and supportive government policies, attracting farmers in a big way (Prasad et al 2010).

Presently various factors like heat & cold waves, outbreak of insect and diseases, increase in water table and problematic soils are affecting the productivity and returns of the traditional agriculture, therefore a need for shifting to a potential tree-based cropping system from monocropping system. Tree-based systems have a long gestation period, which allows intercropping at pre-bearing stage in order to utilize interspaces and generate additional income. Intercultural operations in annual crops positively influence the vegetative growth of trees at initial stage (Saroj et al 2003). The change suggested should also essentially address the

income, employment and viability concerns of local stakeholders for larger adoption in the region. Decision of the farmer to shift is affected by several dynamic and interactive factors such as agronomic and environmental characteristics, economic and policy considerations, skills and personal attributes of farm managers and social concerns. The potential tree-based diversification, therefore, must be tested in terms of income, resource conservation and environmental externality, in particular, and system sustainability in general. The eucalypts based agroforestry system favour the growing of various crops due to sparse canopy and interception of light. Keeping these in view, the present study specifically examined the Eucalyptus-based agroforestry systems on the saline soils in semi-arid tract of India.

MATERIAL AND METHODS

Site description: The study was carried out at CCS Haryana Agricultural University, Hisar, Haryana (India) at 29° 10' N latitude and 75° 43' E longitude at an elevation of 215 m above mean sea level. The site is situated in the semi-arid region of North-Western India. The climate is subtropical-monsoonic with an average annual rainfall of 350-400 mm, 70-80 per cent of which occurs during July to September. The summer months are very hot with maximum temperature ranging from 40 to 45°C in May and June whereas, December and January are the coldest months. The soil is sandy-loam type and medium in organic carbon, available nitrogen, phosphorus and potassium.

Experimental details: Eucalyptus was planted in three spacing geometry of compact block (3×3m), wider (6×1.5m) and paired row (17m×1m×1m) at a constant density of 1111 trees ha^{-1} in 2008-09. The present experiment was carried out from 2008-09 to 2015-16 period and trees are harvested at the age of ninth years. The plantation was established during July by digging out pits of 30 cm^3 filled with 3:1 potting mixture of (soil: FYM) and planting of 5 months old clones of *Eucalytpus tereticornis* during 2008-09. The experiments were regularly monitored for replacement planting, irrigation and protective measures. Intercropping of *Sesbania aculeata kharif* and *Hordeum vulgare* (Barley) *rabi* were taken Dhainchya under three spacing geometry of Eucalyptus (till the harvesting of trees) and also compared with mono -cropping up to eight years of plantation. The standard package of practices developed by CCS Haryana Agricultural University, Hisar (India) was followed to cultivate annual crops.

Tree and crop parameters: The tree height and girth at breast height (GBH)/diameter at breast height (DBH) were measured randomly in all the spacings. Multimeter and measuring tape was used to measure tree height (m) and GBH (cm) of trees, respectively. These observations were used to calculate the price on per tree basis by using Haryana Forest Development Corporations price list of Eucalyptus of 2016 (www.hfdc.in) at age of eight years. In case of crop, quadrate basis biomass yield (dry) ton/ha were taken.

Economics: Economic analysis was quantified by comparing different agroforestry systems with sole eucalyptus and sole annual crops covering one harvest cycle of eucalyptus. Cost components for raising the plantation have been divided in to two main categories as given under:

Establishment cost: Consists of the cost of establishment of species incurred in the beginning of the year of planting, which includes three main costs *i.e.*, cost of planting material which includes the transportation cost, preparation and transplanting which includes cost of digging pits and then transplanting the seedling and finally of the cost incurred on plant protection .

Operational cost: Includes the subsequent years for the maintenance of the crop and tree, irrigation, fertilizer application and miscellaneous costs including the interest component.

Miscellaneous cost: Includes cost of hoeing and weeding, cultivation in between the rows to get rid of unwanted vegetation when no crop is raised.

The management cost (10%) and risk cost (10%) with existing land rent year wise has been added for the estimation of financial analysis. The parameters used for comparison of systems were net returns, net present value (NPV) @ 12 per cent discounting rate and benefit/cost ratio. Net present value was computed using 12 per cent discount rates. In order to further examine the plantations along with crops in terms of productivity of capital, the concept of discounting was used. Cost and income from intercrop as well as trees was calculated.

Net present value: PNV was estimated as under:

$$\text{Net Present Value} = \sum_{i=1}^{n} \frac{Bi - Ci}{(1+r)i^2}$$

Benefits cost ratio (BCR):- BCR can be expressed as follows:

$$BCR = \sum_{i=1}^{n} \frac{Bi}{(1+r)\wedge^2} / \frac{Ci}{(1+r)\wedge^2}$$

Internal rate of return (IRR):- Internal rate of return is defined as that rate of discount, which equates the present value of stream of net benefits with the initial investment outlay or IRR is that rate at which the PNV of cash flow is zero.

RESULTS AND DISCUSSION

Yield performance of agricultural commodity: The crop rotation of *Sesbania aculeate* - *Hordeum vulgare* (barley) was continuously taken from second year of plantation till

harvesting of *Eucalyptus tereticornis* trees. The *S. aculeate* was sown in the *kharif* season for the improvement of soil nutrient status and reducing the salinity of the field, whereas *H. vulgare* was sown in every *rabi* season for fodder purposes. The biomass and yield of both the crop was significantly affected due to various spacing geometries of trees. The magnitude of crop yield losses in agroforestry systems increased with age of the trees (Table 1-3). Also, the rainfall fluctuations during the *kharif* season, yield of *Sesbania* influenced badly. The decreasing trend of biomass and yield was found in both the crops with the advancement of the age of trees. Among different spacings, paired row spacing (17×1×1m) has produced more yields of crops over 6×1.5m and 3×3m from second year to harvesting year of plantation. In *S. aculeate,* significant yield reduction was observed in different spacing geometries of *E. tereticornis* agroforestry system (9-60%) and paired row spacing recorded lowest reductions over other spacing. The intercrop biomass of *S. aculeate* increased with increase in tree row spacing (or alley width), but only the paired row arrangement produced 90, 80 and 46 percent in third, fourth and eight year of plantation of the sole *S. aculeate* (control). The same trend was also recorded in *H. vulgare,* where in the beginning years of agroforestry systems, the barley experienced an average loss of 7-40 per cent (compared with sole crop yield) in second year to fourth year of plantation, which further increased to 40-69 per cent (5th-8th year of plantation) in three spacings of agroforestry system. The intercrop yields improved with increase in row spacing. However, only the paired rows at 17 m apart produced Barley yields close to that of sole crop. The difference among the yields of annual crops is due to effect of tree spacing and age of trees of the agroforestry systems. The competition for critical resources (light, moisture and space) hampered growth and yield of the agricultural crops. Increased competition with age was due to the increased size of the trees and their ability to mop up greater resources at the expense of crops (Dhyani and Tripathi 1999, Prasad et al 2010). The yield reduction was

Table 3. Growth performace of Eucalyptus under various spacing after 8 years of planting

Spacing (m)	DBH (cm)	Tree height (m)
Agroforestry		
3m×3m	25.15	22.70
6m×1.5m	22.83	22.90
17m×1m×1m	22.30	19.31
CD (p=0.05)	1.89	0.077

Table 1. Biomass production of *Sesbania aculeata* under various spacings of *Eucalyptus*

Spacing	Yield of *S. aculeata* (t ha^{-1})						
	2nd year	3rd year	4th year	5th year	6th year	7th year	8th year
3m×3m	44.0	62.1	23.1	40.6	27.1	31.4	12.0
6m×1.5m	46.7	64.7	34.7	45.7	33.6	43.7	13.7
17m×1m×1m	51.7	68.8	49.5	57.7	54.7	52.7	29.6
Control (Sole agriculture)	66.9	72.1	61.6	65.6	70.7	66.8	65.7
Mean	52.3	66.9	42.2	52.4	46.5	48.7	30.3
CD (p=0.05)	1.44	2.03	2.59	0.86	0.33	0.33	0.66

Table 2. Grain yield of barley under various spacing of *Eucalyptus tereticornis*-based agroforestry

Spacing	Grain yield of barley (t ha^{-1})						
	2nd Year	3rd year	4th Year	5th Year	6th Year	7th Year	8th Year
3×3	2.83 (3.94)	2.40 (3.21)	2.04 (2.92)	1.87 (2.84)	1.42 (3.15)	1.22 (2.03)	1.19 (2.43)
6×1.2	3.04 (4.83)	1.76 (3.28)	2.63 (2.96)	2.24 (3.14)	1.82 (3.52)	1.66 (2.25)	1.56 (1.75)
17×1×1	3.32 (4.60)	2.92 (4.45)	2.96 (3.54)	2.43 (4.05)	2.30 (4.77)	1.95 (2.44)	1.96 (2.94)
Control	3.60 (4.98)	3.20 (4.78)	3.28 (4.28)	3.58 (4.52)	3.31 (5.04)	3.80 (5.56)	3.56 (5.20)
Mean	3.2 (4.59)	2.55 (3.93)	2.78 (3.43)	2.58 (3.64)	2.21 (4.12)	2.11 (3.02)	2.07 (3.08)
CD (p=0.05)	0.176 (0.07)	0.09 (0.08)	0.099 (0.1)	0.096 (0.082)	0.07 (0.067)	0.122 (0.085)	0.064 (0.08)

Parenthesis is indicating yield of barley straw

higher in *kharif* season as compared to *rabi* season.

Growth of eucalyptus trees: The growth of the trees in various spacings of agroforestry performed significantly differed (Table 3). The presence of saline soil in the experimental area hampered the growth of eucalyptus seedlings in early years of plantation. In the study, the growth of eucalyptus in terms of height and dbh was at par in 6×1.5m and 3×3m. The maximum plant height of 22.90 m (6×1.5m) and 22.75 (3×3m) was recorded, whereas diameter at breast height of 25.15 cm in 3×3 m followed by 6×1.5m and 17×1×1. In agroforestry systems, major impact of tree geometry on eucalyptus growth has been observed in paired row spacings that the lateral growth (dbh) exhibited lowest. It appears that the effect of single and double row arrangements on the growth and size of trees evened out over time. Silva (1999) on Eucalyptus also observed that wider spacing performed better for higher growth and higher yield of agricultural crops over other spacings. Prasad et al (2010) reported the spacing geometry of eucalyptus significantly influence the growth parameter of trees in terms of height, dbh and biomass.

Economic evaluation in agroforestry: During the first year, the total cost of planting was higher as compared to control sole agriculture) and the returns from the various systems also negative (Table 1). In sole eucalyptus, the return up to the final harvesting of crops was negative because of absent of any intermediate yield from the trees. The crop yield data after second year of plantation to harvesting of plantations used to calculate input and output cost per hectare basis from the agroforestry system as well as sole cropping. The discount rate of 12 % was used for the calculation of economical analysis of different criteria. The highest gross returns was obtained from 17×1×1m paired row spacing geometries (Rs 9,89,520) followed by wider spacing (6×1.5m) and compact block (3×3m). The sole cropping of eucalyptus (3×3m) was grown with highest input cost (almost at par with than other agroforestry system. Such situation occurred due to extra manpower required to carry out plantation management activities like ploughing for weeding, irrigation, pruning and manuring over the years, but in case of other agroforestry systems these management activities are carried out as part of intercropping of annual crops. In paired row spacing, the gross returns from crop were highest over other two spacing. It is due to the less competition for light, nutrient and moisture, which reflected in the returns from the system. The returns from agroforestry systems of first years are negative due to higher initial investment cost (Prasad et al 2010, Singh and Mavi 2016). The profitability of various spacings of eucalyptus based agroforestry system ranges from Rs 54808 ha^{-1} yr^{-1} for sole eucalyptus to Rs 72690 ha^{-1} yr^{-1} for paired row spacings of eucalyptus based agroforestry system in Southern India (Prasad et al 2010). In the present study, highest net present value (NPV) was obtained from paired agroforestry system (Rs. 1,85,336) as more space permits higher yield and more accommodation of trees. The wider spacing and compact block equally benefited, whereas the control (sole cropping) provides very negligible net present value (Rs. 39,706) over agroforestry models. But the NPV of sole eucalyptus (Rs. 34180) was further less than control cropping. Internal rate of returns determines the maximum interest rate that a system can replay on loans while it recovers all investment and establishment as well as operational cost. The viability of agroforestry system can be judged on the basis of internal rate of returns. The paired row system of eucalyptus-based agroforestry system of 8 year old had an IRR of 32 %, higher than that of other spacing geometries of wider row at 28 and compact block at 27 per cent. The results of IRR are comparatively higher as compared to results of Dube et al (2002). They analyzed the economic aspects of Eucalyptus-based agroforestry

Table 4. Details of financial analysis of eucalyptus based agroforestry system and control

Particulars	Spacing (m)			Tree control (3×3)	Crop control
	3×3	6×1.5	17×1×1		
Input (Rs.) cost for trees	407812	407812	407812	549655	-
Input cost for crops	179687	182761	182761	-	301348
Total costs	587499	590573	590573	549655	301348
Return from trees	933000	933000	989520	1000000	-
Return from crops	197244	223854	266729	-	345119
Total returns	1130244	1156854	1256249	1000000	345119
Net returns from the rotation	542745	566281	665676	450345	43771
Net present value	128300	140975	185336	34180	39706
B:C ratio (discounted at 12%)	1.40	1.43	1.57	1.12	1.22
Internal rate of return (%)	27	28	32	15	-

systems in the savanna region of Brazil and observed that IRR of 13.49 per cent discounted at 12 per cent. Higher IRR rates reported by Prasad et al (2010) in modified tree geometries ranges from 56-88 per cent, where as sole eucalyptus woodlot (28%) for Eucalyptus based agroforestry system in Andhra Pradesh (India). The highest IRR than discounting rate accepted and provides enumerative returns on the investment.

Higher value of benefit-cost ratio in paired row (1.57) as compared to wider spacing (1.43), compact block (1.40) and control sole agriculture (1.22) indicates that 17 ×1×1m is more appropriate spacing of Eucalyptus based agroforestry system from efficiency and profitability point of view. In Andhra Pradesh for short rotation of four years, eucalypts based agroforestry is providing benefit cost ratio of 1:2 for 17×1×1m paired row system (Prasad et al 2010). Dwivedi et al (2007) observed that wide planted and bund planted poplar and eucalyptus gives higher return over traditional rice-wheat system.

CONCLUSIONS

Economic evaluation of various agroforestry systems for adoptability is crucial in need due to increasing land pressure and diversification of traditional cropping system. Agroforestry systems in north-western India is performing pivotal role in farmer livelihood for getting higher income. Among various commercial fast growing trees, Eucalypts has wide acceptance due to its versatility of providing huge income and stability of market prices. The large spacing between rows favours the higher yield of annual crops till harvesting of trees. The paired row spacing of 17×1×1m and wider spacing of 6×1m performed better. Maintaining wide spacing in agroforestry system considered important strategies for integration various annual crops and reducing the possibility of declining crop reduction and farmers curiosity.

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Morphometric Analysis and Prioritization of Sub-Watersheds in Bino Watershed, Uttarakhand: A Remote Sensing and GIS Perspective

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Abstract: In this study, morphometric analysis and prioritization of the nine sub-watersheds of Bino watershed, located in the North-Eastern part of the Ramganga river catchment in Almora and Pauri Garhwal districts of Uttarakhand State of India, was carried out using remote sensing and geographical information system (GIS). The morphometric parameters considered for analysis are stream length, bifurcation ratio, drainage density, stream frequency, texture ratio, form factor, circularity ratio, elongation ratio and compactness ratio. The Bino watershed has a dendritic drainage pattern. The highest bifurcation ratio among all the sub-watersheds is 3.476 which indicates a strong structural control on the drainage. The maximum value of circularity ratio and elongation ratio are 0.534 and 0.817, respectively for the SW7. The form factor values are in range of 0.164 to 0.524, which indicates that the Bino watershed has moderately high peak flow of shorter duration. The compound parameter values were calculated and prioritization rating of nine mini-watersheds in Bino watershed was carried out. The mini-watershed with the lowest compound parameter value is given the highest priority. The SW1 has a minimum compound parameter value of 4.22 is likely to be subjected to the maximum soil erosion; hence, it should be provided with immediate soil conservation measures.

Keywords: Watershed, GIS, Remote sensing, Morphometric analysis, Water shed

Watershed is a natural hydrological entity which allows surface run-off to a defined channel, drain, stream or river at a particular point and size varies from fractions of hectares to thousands of km^2. The national remote sensing agency (1995) has classified the watershed into sub-watershed (30-50 km^2), mini-watershed (10-30 km^2) and micro-watershed (5-10 km^2). Morphometric analysis is significant for prioritization of micro-watersheds even without considering the soil map and this requires measurement of the linear features, gradient of channel network, and contributing ground slopes of the drainage basin. Many works have been reported on morphometric analysis using remote sensing and G1S techniques (Srinivasa et al 2004, Chopra et al 2005, Khan et al 2011, Kandpal et al 20l7). Chopra el al (2005) completed morphometric analysis of Bhagra-Phungotri and Hara Maja sub-watersheds of Gurdaspur region, Panjab. Nookaratnam et al (2005) considered sediment yield index (SYI) and morphometric analysis utilizing remote sensing and GIS for locating check dam by prioritization of small scale watersheds. In the present study, an effort has been made with the following objectives: (1) to determine morphological parameters of individual sub-watersheds of Bino watershed using RS and GIS techniques; and (2) to prioritize sub-watersheds based on morphological parameters and fixed their priority rank for soil and water conservation measures.

MATERIAL AND METHODS

Study area: The Bino sub-catchment lies between 29° 47'06" and 30° 02' 906" N latitude and 79° 6'14.4" and 79° 17'16.8" E longitude in the North-Eastern part of the Ramganga river catchment in Almora and Pauri Garhwal districts of Uttarakhand. The climate of the watershed differs from Himalayan sub-tropical to sub-temperate. The everyday mean temperature stays highest during May and June and least in December and January. The frost occurs in nights during December-February. The region encounters three particular seasons viz. winter (October to March), summer (April to mid-June) and monsoon (mid-June to September). Recording and non-recording type rain-gauges are setup at Jaurasi, Tamadhan and Bungidhar for the measurement of daily rainfall. The mean annual rainfall in the area is 931.3 mm, most of which occurs from South-West monsoon commencing in the mid-June and ending in September.

Geo-referencing and delineation of watersheds: The boundary of Bino sub-catchment was marked by utilizing Topo-sheet Nos. 53-N/4, 53-N/8, 53-O/1 and 53-O/5 of Survey of India (SOI) on a scale of 1:50,000 for delineation. Topo-sheets were scanned (tiff format) and geo-referenced

to frame complete image of the region utilizing mosaic operation with the assistance of ENVI 4.7 software. The mosaicked image was imported in Quantum GIS 2.6.1 software and the Bino sub-catchment boundary was digitized by monitoring the ridge points from the contours. The outlet position was set at the confluence point of Bino with the Ramganga River. The Bino sub-catchment was divided into 9 sub-watersheds. The codification of these sub-watersheds was done in increasing order from the outlet at Bino up to the most distant watershed as SW1, SW2, SW3, SW4, SW5, SW6, SW7, SW8, and SW9 (Fig. 1).

Geomorphologic parameters of watershed: Geomorphologic characterization is an efficient depiction of the geometry and stream channel arrangement in the watershed. Geometry and stream channel system of the watershed require the estimation of: (i) linear aspect; (ii) areal aspect; and (iii) relief aspect of channel system and contributing ground slopes. The initial two aspects (i and ii) are planimetric and the third aspect looks at the vertical imbalances in the drainage basin. The g geomorphological parameters of stream network in a watershed are required to understand the hydrologic conduct of the watershed so that planning and management of its assets could be done sequentially. The parameters computed in the present study using ArcGIS10.2 include area, perimeter, stream order, stream length and stream number, which were obtained from the digitized coverage of the drainage network map. However, linear/areal parameters of the sub-watersheds such as bifurcation ratio (R_b), drainage density (D_d), stream frequency (F_s), texture ratio (R_t), mean length of overland flow (L_{om}), and the shape parameters such as form factor (F_f), circularity ratio (R_c), compactness coefficient (C_c) and elongation ratio (R_e) were calculated by the standard formula (Table 1). Prioritization of sub-watersheds was done on the basis of morphometric parameters were assessed according to the linear/aerial and shape parameters, because linear/areal parameters are directly related to the gross soil erosion from the sub-watersheds, the highest value of each parameter was given the highest priority rank starting from one and so on with decreasing value of the parameters. The shape parameters have inverse relationship to the gross soil erosion from the sub-watersheds, hence the parameters with the lowest value was given the highest priority of one and so on with increasing value of the parameter (Nookaratnam et al 2005). Final priority ranking was made on the basis of the compound (average) rank of each sub- watersheds such that the lowest value of compound rank for a sub-watershed was given the highest priority rank one and so on for all the sub-watersheds of Bino watershed.

RESULTS AND DISCUSSION

The study area was divided into nine sub-watersheds (Fig. 1). The stream order analysis and drainage network map of the Bino watershed was prepared using the spatial analyst tools of ArcGIS 10.2 software (Fig. 2). Bino watershed shows a dendritic drainage pattern. The highest bifurcation ratio is 3.476 for sub-watershed SW1; highest circularity ratio is 0.534 for sub-watershed SW7; and highest elongation ratio of 0.817 is for sub-watershed SW7, which indicates a possibility of less soil erosion form these sub-watersheds. The form factor

Table 1. Various morphological parameters and formula used for computation

Geomorphologic parameters	Formula	References
Stream order (u)	Hierarchical rank	Strahler (1964)
Mean stream length (L_{sm})	$L_{sm}=L_u/N_u$ where, L_u = total length of streams of order u, N_u = total number of stream segments of order u	Strahler (1964)
Basin length (L_b)	$L_b = 1.312\ A^{0.568}$	Nookaratnam et al (2005)
Bifurcation ratio (R_b)	$R_b=N_u/N_{u+1}$	Schumn (1956)
Drainage density (D_d)	$D_d=L_u/A$	Horton (1945)
Mean length of overland flow (L_{om})	$L_{om}=$ 1/ 2 x drainage density	
Stream frequency (F_s)	$F_s=N_u/A$	Horton (1945)
Texture ratio (R_t)	$R_t=N_u/P$ where, P = watershed perimeter (km)	Horton (1945)
Form factor (F_f)	$F_f=A/L_b^2$ where, L_b = length of basin (km)	Horton (1945)
Elongation ratio (R_e)	$R_e=1.128\ A^{0.5}/L_b$	Schumn (1956)
Circularity ratio (R_c)	$R_c=12.57\ A/P^2$	Miller (1953)
Compactness coefficient (C_c)	$C_c=0.2821\ P/A^{0.5}\ P$	Horton (1945)

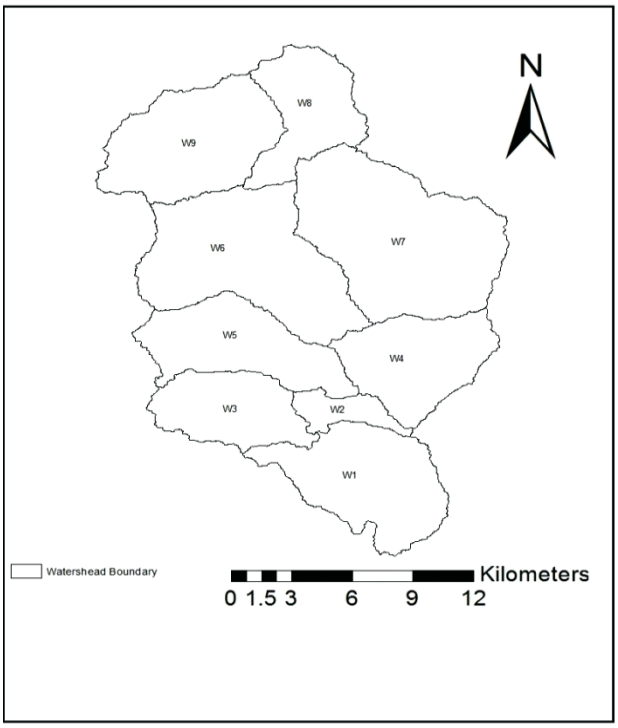

Fig. 1. Sub-watersheds of Bino watershed

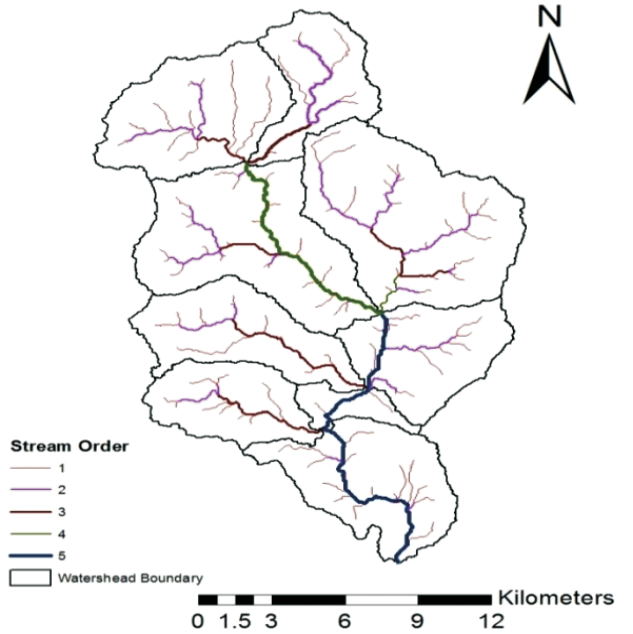

Fig. 2. Drainage network map of sub-watersheds of Bino watershed

Table 2. Sub-watershed wise morphometric parameters of Bino watershed

Subwatershed (SW) name	Number of streams for the order (u)					Total number of streams	Total length of streams (km)	Drainage area (km^2)	Basin length (km)	Perimeter of basin (km)
	1	2	3	4	5					
SW1	14	3	0	0	1	18	31.593	34.85	11.42	32.84
SW2	2	0	0	0	1	3	12.527	7.11	6.58	16.95
SW3	9	2	1	0	0	12	17.654	22.55	7.60	24.34
SW4	13	3	0	0	1	17	23.024	28.09	8.22	25.94
SW5	9	2	1	0	1	13	21.156	29.71	11.60	31.83
SW6	24	6	1	1	0	32	37.660	51.86	13.81	39.91
SW7	23	6	2	1	0	32	41.441	59.62	10.66	37.46
SW8	9	2	1	0	0	12	20.980	23.37	11.58	28.88
SW9	12	2	1	0	0	15	28.798	37.65	8.94	30.36

Table 3. Linear/areal and shape parameters of various sub-watersheds of Bino watershed

SW name	Linear/ areal parameters					Shape parameters			
	R_b	D_d	F_s	R_r	L_{om}	F_f	R_c	C_c	R_e
SW1	3.476	0.906	0.516	0.548	0.551	0.267	0.406	1.557	0.583
SW2	2.000	1.759	0.421	0.176	0.284	0.164	0.311	1.778	0.457
SW3	2.621	0.782	0.532	0.493	0.638	0.390	0.478	1.435	0.704
SW4	3.391	0.819	0.605	0.655	0.610	0.415	0.524	1.370	0.727
SW5	1.619	0.712	0.437	0.408	0.702	0.220	0.368	1.635	0.530
SW6	2.289	0.726	0.617	0.801	0.688	0.271	0.409	1.551	0.588
SW7	2.552	0.695	0.536	0.854	0.719	0.524	0.534	1.358	0.817
SW8	2.621	0.897	0.513	0.4155	0.556	0.174	0.352	1.672	0.470
SW9	2.884	0.764	0.398	0.494	0.653	0.471	0.513	1.385	0.774

Table 4. Ranking of sub-watersheds on the basis of linear/areal and shape parameters

SW name	Linear/areal parameters					Shape parameters				Compound rank	Priority ranking	Priority category
	R_b	D_d	F_s	R_r	L_{om}	F_f	R_c	C_c	R_e			
SW1	1	2	5	4	8	4	4	6	4	4.22	1	Very high
SW2	8	1	8	9	9	1	1	9	1	5.22	5	Medium
SW3	4.5	5	4	6	5	6	6	6	6	5.39	7	Low
SW4	2	4	2	3	6	7	8	4	7	4.78	4	High
SW5	9	8	7	8	2	3	3	7	3	5.56	8	Very low
SW6	7	7	1	2	3	5	5	5	5	4.44	2	Very high
SW7	6	9	3	1	1	9	9	1	9	5.33	6	Low
SW8	4.5	3	6	7	7	2	2	8	2	4.61	3	High
SW9	3	6	9	5	4	8	7	3	8	5.89	9	Very low

values for all sub- watersheds are in the range of 0.164 to 0.524 (Table 3). All the sub-watersheds were given ranks on the basis of their linear/areal and shape parameter values (Table 4). Finally, the compound rank of all the sub-watersheds was evaluated on the basis of these parameters and prioritization ranking was done (Table 4). Sub-watershed SW1 with the minimum compound rank of 4.22 is assigned the highest priority rank one, followed by sub-watershed W6 with compound rank value of 4.44, and so on. The highest priority indicates greater risk of soil erosion from the watershed which requires better and earliest soil and water conservation measures for better development and management.

CONCLUSION

Present study makes use of remote sensing and GIS techniques for morphometric analysis and prioritization of the sub-watersheds in Bino watershed of Ramganga River basin in Uttarakhand state of India. The morphometric attributes of various sub-watersheds demonstrate their relative qualities for hydrologic reaction of the Bino watershed. The consequences of morphometric investigation demonstrate that sub-watersheds SW1 and SW6 were highly prone to soil erosion and should be taken up first followed by others as per their ranks for the execution of proper soil and water conservation and management techniques for soil erosion control and safeguard the land from further erosion in the study region.

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Carbon Sequestration by Trees-A Study in the Western Ghats, Wayanad Region

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Abstract: The carbon sequestration of 610 trees belonging to 45 species was estimated. Diameter at breast height (DBH) and the approximate age of trees were documented to measure the rate of carbon sequestration. The average carbon content of these trees was 50.391t/tree. The total carbon sequestered by these trees was 138.367t/year. Highest (33709 kg/year) sequestration was observed in *Artocarpus heterophyllus* and the lowest (52.69 kg/year) in *Spondias pinnata*. *Melia azedarach* showed the highest average DBH and more carbon sequestration potential, whereas *Azadirachta indica* showed the minimum carbon sequestration potential. The regression analyses indicated that both DBH and number of trees have a positive relation with carbon sequestration rate of tree species.

Keywords: Carbon, Sequestration, Trees, Wayanad, Western Ghats

Carbon sequestration is a natural method for the removal of carbon from the atmosphere by storing it in the biosphere (Chavan and Rasal 2010). A carbon sink absorbs CO_2 from the atmosphere, and stores it as carbon. Trees serve as a sink for CO_2 by fixing carbon during photosynthesis and storing excess carbon as biomass. As more photosynthesis occurs, more CO_2 is converted into biomass, reducing carbon in the atmosphere and sequestering it in plant tissues above and below ground (IPCC 2003, Gorte 2009) resulting in the growth of different parts (Chavan and Rasal 2010). The concept of CO_2 sinks has become more widely known after the Kyoto Protocol emphasized the significance of Co_2 sinks as a form of carbon offset. In the present study the carbon sequestration rate of selected trees in the Wayanad region of the Western Ghats, one of the hottest biodiversity hotspots, was estimated. Although quite a large area of the district is covered by forest, the continued and indiscriminate exploitation of the natural resources resulted in an imminent environmental crisis.

MATERIAL AND METHODS

Wayanad district of Kerala, a part of the Western Ghats, stands on the southern tip of the Deccan plateau. It is bounded on the east by Nilgiris and Mysore districts of Tamil Nadu and Karnataka respectively, on the north by Coorg district of Karnataka, on the south by Malappuram district and on the west by Kozhikode and Kannur districts of Kerala. The present study was carried out in the Kakkavayal ward of the Meenangadi Panchayath of Wayanad district (11 °39'23" North Latitude and 76°10'11" East Longitude). Data on the DBH of 610 trees were documented using measuring tapes and their age was documented from the data provided by the farmers. The trees were selected randomly. The Above Ground Biomass (AGB) was calculated using the allometric equation developed by Udayakumar et al (2016) for the tropical dry forests:

AGBdry = exp (2.2014 LN (DBH) - 1.0615)

Where, AGBdry = Above ground dry biomass of tree (kg); DBH = diameter at breast height (cm); 2.2014 and -1.0615 are constants.

Below ground biomass (BGB) was calculated using the following formula (MacDicken 1997, Hangarge et al 2012):

BGB (Kg/tree) = AGB (Kg tree^{-1}) x 0.26

Total biomass (TB) is the sum of the AGB and BGB (Sheikh et al 2011):

TB = AGB+ BGB (kg tree^{-1})

Generally, 50 per cent of biomass of any plant species is considered as carbon (Pearson et al 2005). Therefore, the weight of carbon in the tree was estimated by multiplying the biomass of the tree by 50 per cent (Birdsey 1992).

Carbon storage = Biomass x 50% or Biomass/2 (kg tree^{-1}).

To determine the weight of CO_2 sequestered in the tree, multiply the weight of carbon in the tree by 3.6663 (Vishnu and Patil 2016). The weight of CO_2 sequestered in the tree per year was determined by dividing the weight of carbon dioxide sequestered in the tree by its age. Statistical analyses were made following IBM SPSS Statistics version 21. The relationship between CO_2 sequestration, DBH and the number of individuals of tree species were investigated using the curve estimation procedure. The rate of CO_2

sequestration and the distribution of tree species were log transformed as they were not distributed uniformly. To estimate the closeness and relationship of various parameters a regression analysis was performed.

RESULTS AND DISCUSSION

The present study estimated the carbon sequestration in randomly selected 610 trees belonging to 45 species (Table 1). The estimated total AGB of the trees was 79.985 t and the total BGB was 20.796 t. The total biomass was 100.781 and total carbon storage by the trees was 50.391 t. The annual total carbon sequestration of the trees under study was 138.367 t/year. Among the trees studied, *Artocarpus heterophyllus,* the most prevalent species in the study area, sequestered 33709 kg CO_2/year which was the tallest among the species studied. In the present study the annual CO_2 sequestration of *Melia azedarach* was 3168.25 kg/year which had the highest average DBH (300 cm) among the trees. *M. azedarach* had the highest AGB (27433.51 kg/tree) and total biomass (34566.22 kg/tree). The rate of CO_2 sequestration was also high (63365.07 kg/tree) in *M. azedarach.*

In the present study *Dalbergia latifolia* sequestered 8312.86 kg/tree and had the second highest average DBH as well as average total biomass. Higher level of biomass storage in *D. latifolia* may be attributed to its maximum energy conversion potential and photosynthetic rate as described by Srivastava and Ram (2009). *D. latifolia* has the highest average age (27.75) and its annual CO_2 sequestration was 11083.86 kg/year. The carbon content of *A. indica* in the present study was 79.32 kg/tree. This species had the lowest average DBH and sequestered 145.41 kg/year, this may be due to its smaller DBH. Earlier study (Chavan and Rasal 2010) showed that the below ground carbon and mean organic carbon of *A. indica* were 0.26 and 2.08 t/tree respectively. The present study also showed that *M. azedarach* had the maximum whereas *A. indica* had the minimum carbon sequestration potential. *Syzygium caryophyllatum, Cinnamomum verum, Terminalia arjuna, Aporosa mahagani, Lagerstroemia microcarpa, Hydnocarpus kurze, Pterocarpus marsupium* and *Terminalia bellerica* have the DBH greater than 77 cm and more carbon content than other studied tree species.

Regression analyses: The linear regression (Table 2) showed that there was a significant positive relation between the tree DBH and CO_2 sequestration. The DBH explained 23% of the CO_2 sequestration. Hence the DBH can be used to predict the CO_2 sequestration rate of the tropical tree species.

The CO_2 sequestration rates and the number of tree species were transformed into natural log before performing the regression analysis as they were skewed in the distribution. The results of multiple regression (Table 2) showed that both DBH and number of tree species explained 69 per cent of the CO_2 sequestration rate of the tree species. The number of tree species is the primary contributor for CO_2 sequestration rate followed by size of the tree species. The predicted value indicated that the DBH has linear relationship (Fig. 1 and 2) with the sequestration rate and CO_2 sequestration logarithmically increased with number of trees (Fig. 3). Hence CO_2 sequestration rate initially increased rapidly with increase in number of individuals of a species then it stabilizes. According to Vishnu and Patil (2016) the trees with maximum DBH have higher carbon stock. The results obtained in the regression analyses are in agreement with these findings.

CONCLUSION

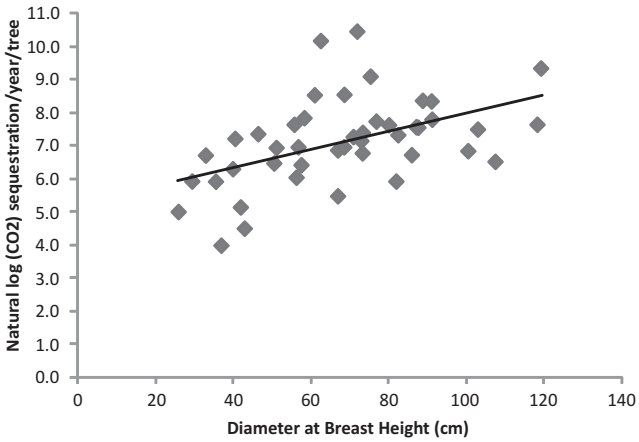

Fig. 1. Relation between the tree DBH and CO_2 sequestration

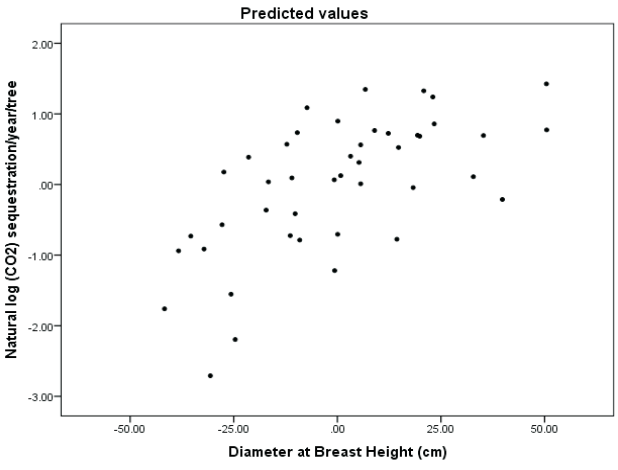

Fig. 2. Linear relation between DBH and CO_2 sequestration

Table 1. Summary of carbon sequestration by 45 tree species

Tree species	Average DBH in cm	Average age	Above ground biomass (kg tree^{-1})	Below ground biomass (kg tree^{-1})	Total biomass (kg tree^{-1})	Carbon (kg tree^{-1})	CO_2 sequestered (kg tree^{-1})	Tree count	CO_2 sequestered of all trees in kg	CO_2 sequestered/ year in kg
Cinnamomum verum	80.14	12.14	1500.65	390.17	1890.82	945.412	3466.16	7	24263.15	1998.61
Melia azedarach	300.0	20.0	27433.1	7132.71	34566.22	17283.11	63365	1	63365.08	3168.25
Artocarpus heterophyllus	71.96	10.79	1183.99	307.83	1491.82	745.912	2734.74	133	363720.13	33709
Bauhinia variegata	40.0	8.5	325.03	84.51	409.54	204.77	750.741	6	4504.45	529.934
Cassia fistula	50.6	10.0	545.34	141.79	687.12	343.56	1259.59	5	6297.99	629.79
Mangifera indica	62.6	10.06	871.22	226.51	1097.73	548.87	2012.30	127	255562.83	25403.86
Tamarindus indica	76.89	12.78	1369.94	356.18	1726.12	863.06	3164.24	9	28478.14	2228.34
Dalbergia latifolia	119.24	27.75	3599	935.74	4534.74	2267.37	8312.87	37	307575.89	11083.82
Cocos nucifera	68.66	14.31	1067.74	277.61	1345.36	672.68	2466.24	29	71520.91	4997.97
Artocarpus hirstus	91.08	14.58	1988.93	517.12	2506.05	1253.03	4593.98	13	59721.74	4096.14
Aporosa mahagani	88.82	11.45	1881.91	489.29	2371.20	1185.61	4346.78	11	47814.49	4175.94
Areca catechu	33.0	14.13	212.82	55.33	268.15	134.07	491.55	23	11305.75	800.12
Tectona grandis	75.4	11.2	1312.18	341.17	1653.34	826.67	3030.82	32	96986.32	8659.49
Ficus exasperata	73.0	11.4	1221.98	317.71	1539.7	769.85	2822.5	5	14112.5	1237.94
Ficus bengalensis	67.0	10.0	1011.74	263.1	1274.79	637.39	2336.88	1	2336.88	233.69
Erythrina indica	55.8	9.25	676.37	175.86	852.23	426.11	1562.27	12	18747.22	2026.73
Citrus aurantifolia	42.0	5.0	361.88	94.09	455.97	227.99	835.87	1	835.87	167.173
Grevillea robusta	61.04	8.87	824.14	214.28	1038.41	519.21	1903.56	23	43781.93	4935.95
Persea americana	46.5	6.17	452.77	117.72	570.49	285.25	1045.79	9	9412.15	1525.47
Abrus precatorius	73.33	10.0	1234.17	320.89	1555.06	777.53	2850.67	3	8551.99	855.19
Annona reticulata	51.2	9.0	559.67	145.51	705.19	352.59	1292.71	7	9048.991	1005.44
Psidium guajava	35.6	8.0	251.48	65.39	316.87	158.43	580.867	5	2904.34	363.042
Terminalia bellerica	87.67	13.67	1828.68	475.46	2304.14	1152.07	4223.84	6	25343.03	1853.91
Garcinia cambogia	71.0	11.4	1149.49	298.87	1448.36	724.18	2655.07	6	15930.39	1397.40
Cinnamomum malabatrum	58.38	9.07	747.14	194.26	941.39	470.69	1725.71	13	22434.29	2473.46
Spondias pinnata	37.0	12.0	273.77	71.18	344.95	172.48	632.35	1	632.35	52.695
Syzygium cumini var. cumini	67.0	10.0	1011.73	263.05	1274.79	637.39	2336.88	4	9347.51	934.75
Michelia champaca	40.58	6.44	335.49	87.23	422.72	211.36	774.91	11	8524.05	1323.61
Pterocarpus marsupium	91.25	15.62	1997.12	519.25	2516.37	1258.18	4612.88	8	36903.02	2362.55
Saraca asoca	57.6	14.0	725.34	188.59	913.93	456.96	1675.36	5	8376.82	598.34
Phyllanthus emblica	68.6	12.0	1065.68	277.07	1342.77	671.38	2461.49	5	12307.48	1025.62
Myristica fragrans	29.5	6.3	166.26	43.23	209.499	104.75	384.04	6	2304.27	365.76
Delonix regia	100.5	12.5	2470.10	642.23	3112.33	1556.16	5705.37	2	11410.73	912.86
Hydnocarpus kurze	107.5	20.0	2864.77	744.84	3609.61	1804.8	6616.95	2	13233.89	661.69
Adenanthera pavonina	82.0	10.0	1578.39	410.38	1988.78	994.39	3645.73	1	3645.73	364.57
Terminalia arjuna	82.5	10.0	1599.66	415.91	2015.57	1007.79	3694.85	4	14779.4	1477.94
Azadirachta indica	26.0	6.0	125.91	32.74	158.65	79.325	290.83	3	872.49	145.41
Syzigium jambos	56.33	11.67	690.598	179.56	870.15	435.08	1595.12	3	4785.36	410.06
Syzygium caryophyllatum	86.0	15.0	1752.88	455.75	2208.63	1104.31	4048.74	3	12146.23	809.75
Vitex bicolour	43.0	10.0	381.12	99.092	480.214	240.11	880.30	1	880.304	88.03
Anacardium occidentale	103.0	13.75	2607.39	677.92	3285.32	1642.66	6022.48	4	24089.91	1751.99
Mimusops elengi	73.4	9.0	1236.77	321.56	1558.33	779.17	2856.66	5	14283.29	1587.03
Lagerstroemia micfrocarpa	118.3	24.17	3536.83	919.58	4456.42	2228.21	8169.28	6	49015.69	2027.96
Ceiba pentandra	87.17	13.3	1805.80	469.51	2275.314	1137.66	4170.99	6	25025.95	1881.65
Hevea brasiliensis	56.83	9.5	704.16	183.08	887.25	443.624	1626.46	6	9758.74	1027.24

Table 2. Linear and multiple regression that explains the factors influencing CO_2 sequestration of tree species

Independent variable	Predictor	Unstandardized coefficients		Standardized coefficients	t	p	Model (r^2)	ANOVA
		B	SE	Beta				
Linear regression								
CO_2 sequestration (log)	Constant	5.24	0.548		9.558	0.000	0.235	F=12.89; df=1 P<0.00
	DBH	0.027	0.008	0.485	3.590	0.001		
Multiple regression								
CO_2 sequestration (log)	Constant	4.88	0.358		13.627	0.00	0.687	F=44.93; df=2 P<0.00
	DBH	0.026	0.005	0.460	5.25	0.00		
	Number of trees (log)	0.033	0.004	0.673	7.69	0.00		

t: t value, p: p value

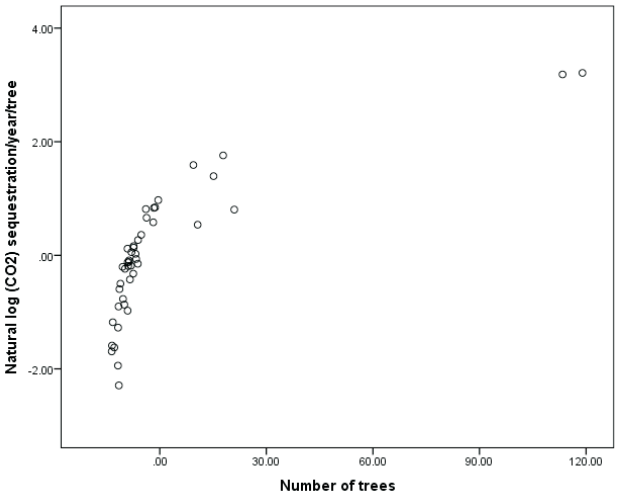

Fig. 3. Logarithmic increase in CO_2 sequestration with number of trees

The trees with higher biomass have more sequestration potential and the rate of CO_2 sequestration was high in *Melia azedarach* which had the highest average DBH, AGB and as total biomass. The woody plants have more carbon sequestration potential than others as. they store more carbon in their woody biomass. There was a significant positive relation between the tree DBH and CO_2 sequestration. The DBH has linear relationship with the sequestration rate and the CO_2 sequestration logarithmically increased with number of trees.

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Mapping of Natural Hazards and Expected Incidences in Great Himalayan National Park Conservation Area, Himachal Pradesh

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***Abstract*:** The Great Himalayan National Park Conservation Area (GHNPCA) has been declared as world heritage site by UNESCO in June, 2014 which depicts its faunal and floral diversity. One of the main threats to the conservation area includes habitat alteration. So the major cause; landslide is equally responsible for disturbed ecosystem. The objectives were to assess the impact of landslides on habitat of avi-faunal species and biodiversity. Landslides were identified through multispectral data of IRS IB (LISS-II), 1993 and LANDSAT 8**(OLI),** 2013 of October, on 1:50,000 scales, correlated with temporal NDVI difference, while slope information was used to further confirm land cover change caused by a landslide and validated with high resolution imagery of Google Earth. The extracted incidences increase from year 1993 (14 landslides) to 2013 (30 landslides), indicating alarming damage by the landslides. Most of the landslides took place in the north western part of the study area. Majority of the landslide polygons lies within the areas of negative change in NDVI values and at the areas where there are conjunction cliffs, and escarpments. The increasing frequencies of landslides correlated with the increased frequencies of earthquake data from 1885 to 2005 and witnessed that the area is also pressurized by tectonics. A continuous monitoring on temporal changes and alterations of habitat is imperative for better planning and implementation of wildlife and forest management plan.

Keywords GHNPCA, NDVI, Conservation Area, RS and GIS, Landslide, Earthquake

The Great Himalayan National Park Conservation Area (GHNPCA) has rich biodiversity as compared to the other areas at similar altitude in Western Himalayas supports several endangered mammals and pheasants and is one of the two National Parks in the world which support a population of the endangered Western Tragopan (*Tragopan melanocephalus) and* Himalayan Musk Deer (*Moschus chrysogaster)*. Apart from these faunal and avifaunal species, GHNPCA is also major site for the habitat of *Cheer, Pheasant, Kokalash, Khalij* and *Monal* species. As far as the floral diversity is concerned within GHNP, a total of 832 plant species belonging to 427 genera and 128 families of higher plants were recorded in which more than 60 species of plants including those already listed in the IUCN Red Data Book are collected for commercial purpose from the park (Singh and Rawat 2000). The flora includes dense forests of moist Himalayan temperate forests between 1500m to 3600m a.s.l. characterized by both coniferous and broad leaved species. Most of the natural hazards in the form of landslides/ mass flow were observed within the contact zone of the GHNP, Sainj Wildlife Sanctuary and Eco-development zone and is responsible for the transformation of the landforms. Landslides are particularly common and cause massive damage in tectonically active Himalaya. It is estimated that about 200 landslides exist in the protected area and at least 50 landslides need immediate treatment for stabilization to overcome disruption of path and communication by these landslides (Negi 1996). Landslides frequently result in sharp changes in land cover types, which can easily be detected by airborne or satellite-based remote sensing techniques (Zhang et al 2010). Remote sensing (RS) provide efficiently and quickly a large facilitation for landslide detection and evaluation in recent decades (Pradhan et al 2006, Tralli et al 2005). Therefore, the techniques of GIS and RS can be integrated to explore the potential landslides (Naithani et al 2013).

The objective of this study is to contribute to understanding the impact of hazards emphasizing on incremental landslide incidences on species habitat destruction and related landform changes in conservation area. The research also investigates some preliminary inference for estimation and mapping of loss of biodiversity and its impacts on animal's habit-habitat in Great Himalayan National Park Conservation Area.

MATERIAL AND METHODS

Study area: The Great Himalayan National Park and its entities collectively known as Great Himalayan National Park Conservation Area (GHNPCA) located in Kullu district, Himachal Pradesh encompass nearly 1171 km^2 area and lies

between 31°38' 28" N to 31°51' 58" N latitude and 77°20' 11" E to 77°45' 52" E longitude. The park area comprises the watersheds of Jiwa, Sainj, Parvati and Tirthan rivers which are tributaries of Beas River.

Land use/cover (LULC) extraction: The multispectral satellite data of IRS IB (LISS-II), 1993 and LANDSAT 8(OLI), 2013 of October (Path 147 Row 38) and the Survey of India (SOI) toposheets (1:50,000 scale) were used for geo-referencing the satellite images as well as for ground information. The radiometric calibration is done using the conversion of digital values into the absolute reflectance as prescribed by (Finn et al 2012). The spatial database of GHNPCA was prepared and it includes the cliffs, escarpment, topographic data (DEM, Slope, and Aspect), drainage network, road network, landuse/cover classification along with the various vegetation type classes, lineaments, habitation areas and most importantly the species sighting data which indicates about the habitat area of a particular species. The species sighting data is recorded by local ground survey (Ramesh et al 1999, Vinod et al 1999) and imported into GIS environment for analysis. Landuse/Land-cover (LULC) was prepared using IRS IB (LISS-II), 1993 satellite data, familiarization of ground features, drainage parameters, reconnaissance survey and elevation information (Naithani and Mathur 2014, Minakshi and Verma 2014, Naithani and Mathur 2016). The distribution of different LULC types is given in Table 1.

The various factors mentioned above are also evaluated and correlated with the landslide areas. A digital elevation model (DEM) was created by interpolating the contour lines delineated from SOI toposheet at 1:50,000 scale at 20 m interval. The digital elevation model made it possible to explore the area in three dimensions and greatly facilitated the visual interpretation process (Jensen 1996).

Landslide extraction: This analysis is carried out on the basis of local survey and collected data of different species such as Cheer, Khalij, Monal, Kokal, Tragopogan and cross overlay analysis with extracted landslide sites within the study area. Satellite images with different colour composites draped over the DEM were used to facilitate the identification of landslides and interpretation of their properties (Fig. 1). Digitization of the boundaries of each element of the landslides i.e. main scarp and accumulation body, was carried out using the visual image interpretation techniques and verified using high resolution data available on platforms like Google Earth. Since landslides geo-hazards usually occur on higher slopes and thus destroy the vegetation-cover and cause distinct vegetation fraction variation, therefore any negative changes in vegetation-cover between the year 1993 and 2013 images could be considered as landslide indicators. The extracted source and accumulation regions constituted the whole landslide distribution to be detected with multi-temporal NDVI imagery (Zhang et al 2010). The Normalized Difference Vegetation Index (NDVI) which shows the limits of easy saturation and atmospheric sensitivity (Rouse et al 1974) is calculated for both the years and difference in NDVI value is hence calculated and used for landslide recognition:

$$\text{Difference NDVI value } (Diff_{NDVI}) = NDVI_{1993} - NDVI_{2013}$$

Where $NDVI_{1993}$ is the NDVI of 1993 IRS IB (LISS-II) image, and $NDVI_{2013}$ is the NDVI of 2003 Landsat 8 (OLI) image. The average values of $Diff_{NDVI}$ values are extracted for the individual landslide location areas. The detailed methodology adopted for this study is represented by a flowchart (Fig. 2) which includes field/ ground observations as well as extraction of information from satellite data and its representation over a DEM.

RESULTS AND DISCUSSION

Landslide statistics: The extracted incidences increase from year 1993 to 2013, indicating alarming damage by the

Table 1. Landuse/ land cover classification scheme for the study area

Type	Area in Km^2
Conifer (Pinus roxburghii)	2.08
Mixed conifer	127.98
Conifer and broad leaved mixed	33.16
Broad leaved	66.62
Broad leaved and conifer mixed	83.36
Riperian	0.14
Slope grasses	25.92
Grasslands/ blanks (Temp. sub Alpine and Alpine)	221.80
Secondary scrub	22.28
Alpine scrub	117.62
Plantation	0.16
Habitation/Agrculture/Orchards	25.55
Exposed rocks with slope grasses	27.60
Alpine exposed rocks with slope grasses	149.73
River	4.35
Lakes	0.87
Escarpments	33.82
Landslide	0.41
Snow	184.01
Morian	24.24
Morainic islands	0.48
Glaciers	18.82
Total	1171.00

Source: Naithani and Mathur 1988

landslides (Table 2). The increasing frequencies of landslides can also be correlated with the increased frequencies of earthquake data of the region, which also depicts the increasing pattern of release of energy in the recent past in comparison to the last few decades (Table 3**)**. It is also witnessed that the area is not only pressurized by human intervention but tectonically sensitive as well.

Landslide interrelation with controlling factors: The various topographical and other factors mentioned are correlated with the landslide areas. Most of the landslides took place in the north western part of the study area with some smaller ones in the north eastern section while only a few occurred in the southern part and in central part. Majority of the landslide polygons lies within the areas of negative change in NDVI values and at the areas where there are conjunction cliffs, and escarpments (Fig. 3 and 4).

Slope is one important factor influencing landslides and the relationship between landslide occurrence and slope shows that steeper slopes have large number of landslides. As the slope angle increases, then the shear stress in the soil or other unconsolidated material generally increases. Although the slope of the landslide regions ranges from 0 to 60 degree, the slope of about 70 per cent of the landslide regions is larger than 25 degree (Fig. 5)**.** The investigation on the inter-relationship between landslides and aspect, depicts that south and northeast-facing steeper slopes have greater landslide probabilities, which may be because of solar illumination, precipitation, drying nature of land and maximum human interventions on these aspects. The distribution of study area in different slope categories and the area estimation is given in the Table 4.

A number of lineaments were observed and traced, which may be the probable cause of landslide incidences and biodiversity loss in the year 1993. A total of 14 landslides intersected with the drainage, whereas 23 such intersections were observed in the year 2013, causing damming on the drainage sites. Likewise for the same years, the intersection between road network and landslides have also been observed and increased intersections were observed, which may act as a hurdle for approaches towards the major park routes and sighting areas **(**Fig. 6)**.** Increasing frequencies of landslide were observed near or above escarpments and cliffs.

Majority of landslides in 1993 and 2013 lie within the areas of conifers mixed with broadleaved, broadleaved mix with conifers, exposed rock slopes, grasslands, temperate broadleaved, subalpine broadleaved, temperate grassland, subtropical grassland, temperate mixed conifer and sub alpine mixed conifer vegetation classes indicating the loss of habitat of Monal and Cheer pheasants (Fig. 7). Proximity analysis has been done for eco-zone in relation to landslides,

Table 2. Total number of landslides and their area during the year 1993 and 2013

Landslide area (m^2)	Landslide number	
	1993	2013
0-10000	1	9
10000-20000	1	7
20000-30000	6	8
30000-40000	2	2
40000-50000	1	0
50000-60000	2	0
60000-70000	0	1
70000-80000	0	1
80000-90000	0	1
90000-100000	0	0
> 100000	1	1
Total	14	30

Table 3. Large earthquakes in the GHNP region

Period	Intensity (Richter scale)	Epicenter
May 1885	7	J and K
April 1905	8	Kangra (H.P.)
February 1906	6.4	Kullu (H.P.)
January 1975	6.2	Kinnor (H.P.)
April 1986	5.5	Dharmshala (H.P.)
October 1991	6.6	Uttarkashi (U.K.)
March 1995	4.9	Chamba (H.P.)
July 1997	5	Sundarnagar (H.P.)
March 1999	6.8	Chamoli (U.K.)
March 2005	5.1	Kangra (H.P.)

6 villages come under the 500m proximity from the landslide occurrence points in 2013.

According to the results drawn, there was in total about 0.66 Km^2 in 1993 and 0.74 Km^2 in 2013 of park area destroyed by landslides which may be considered as the habitat loss of species within the park.

CONCLUSION

Landslides cause social, economic and environmental damage, often resulting in substantial loss of life also. Infrastructure and heritage sites are damaged or destroyed. As per the results drawn, there was in total about 0.66 km^2 in 1993 and 0.74 km^2 in 2013 of park area destroyed by landslides. Majority of landslides in 1993 and 2013 lie within the areas of dense forest classes followed by other classes also indicating the loss of habitat of Monal and Cheer pheasants**.** Proximity analysis depicts that eco-zone in relation to landslides, 6 villages come under the 500m proximity from the landslide

Table 4. Slope estimation in GHNPCA

Slope angle	Slope categories	Area in km^2	Percentage
0-20	Low	221	19
21-50	Moderate	623	53
51-70	High	187	16
71-90	Very high	140	12

Source: Naithani and Mathur 1998

occurrence points in 2013. Most of the landslides took place in the north western part of the study area. Although the slope of the landslide regions ranges from 0 to 60 degree, the slope of about 70% of the landslide regions is larger than 25 degree. Fourteen landslides intersected with the drainage and lineaments were observed and traced in the year 1993. Whereas 23 such intersections were observed in the year 2013. The use of RS and GIS greatly facilitates the estimation of impacts of the disaster with knowhow of the controlling factors like slope, aspect and elevations analysis upon these landslides suggests that region with high landslide risk should be taken into account for GHNPCA for preparation of a comprehensive management action plan.

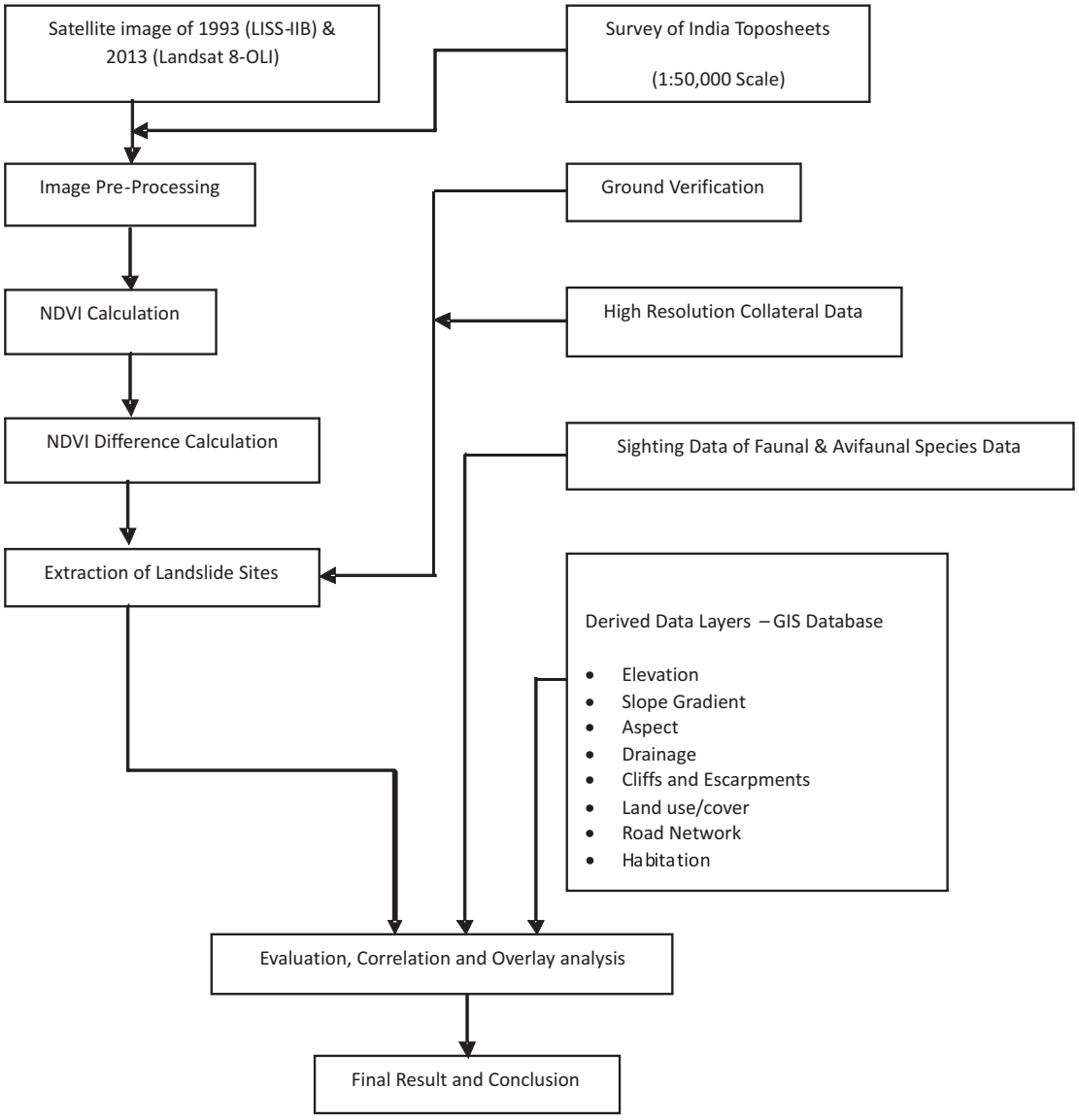

Fig. 2. Flowchart of overall methodology adopted for this study

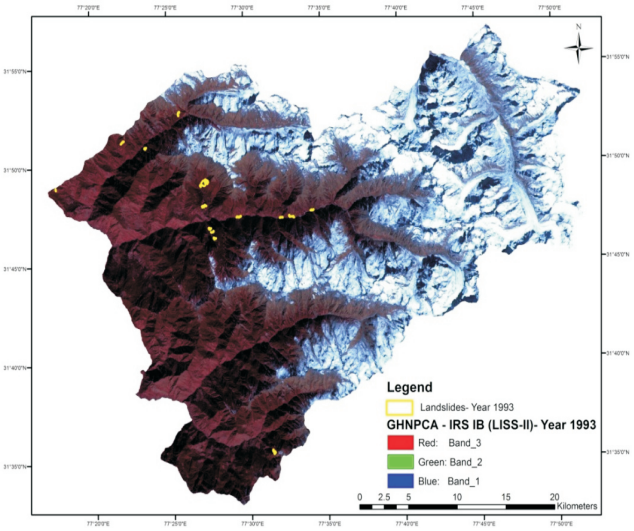

Fig. 1. Extracted landslides overlaid on the post-event image of year 1993

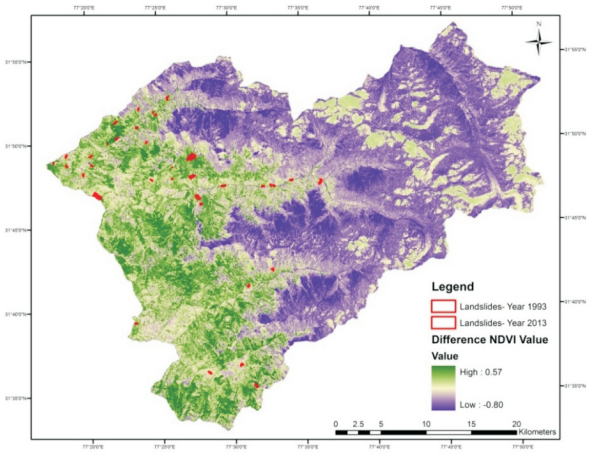

Fig. 3. Extracted landslides overlaid on the $Diff_{NDVI}$ image between year 1993 and2013

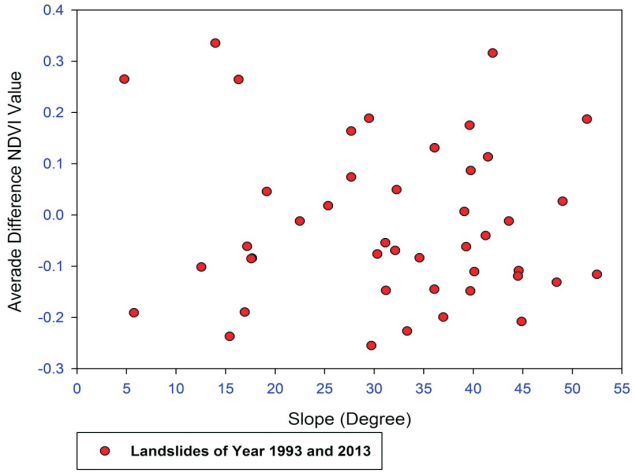

Fig. 4. Relationships between landslides and average $Diff_{NDVI}$ values

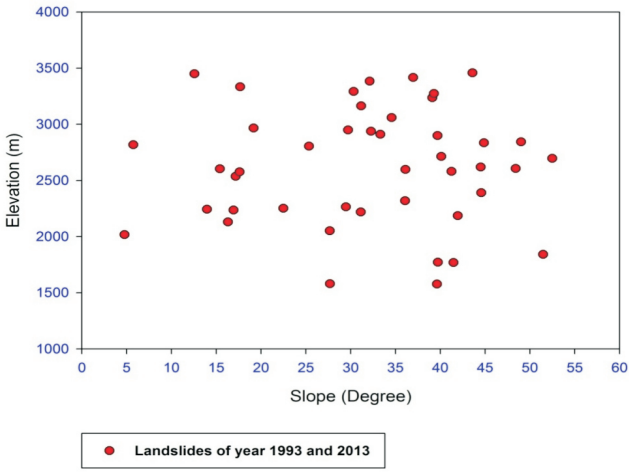

Fig.5. Relationships between landslides and elevation

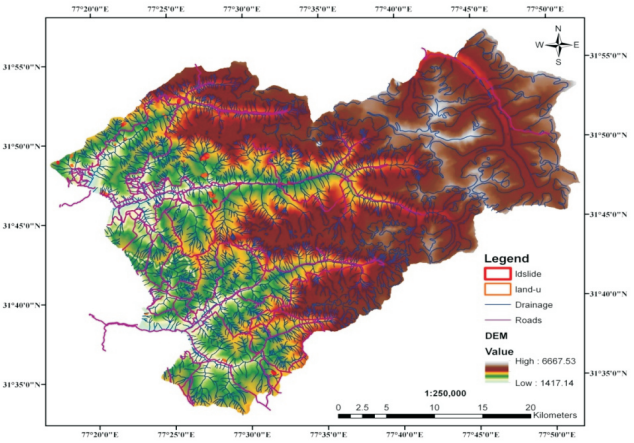

Fig. 6. Extracted landslides, drainage and roads overlaid on the DEM

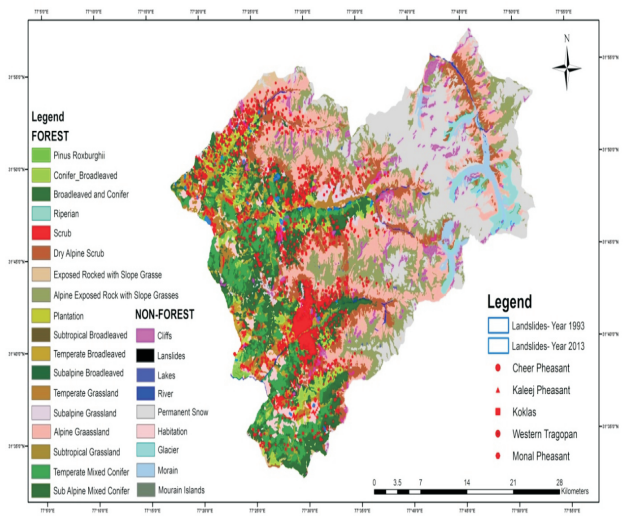

Fig. 7. Distribution of Avi-Faunal species and landslides in different vegetation classes

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Human-Panther Conflicts in the Aravalli Hills of Southern Rajasthan-A Case Study

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***Abstract*:** Many recent scientific studies suggests that anthropogenic activities are increasing consistently especially due to mining and setting up of more number of associated industries in the Aravalli region of Southern Rajasthan.As a result,there is continuous loss of natural habitat and prey base for the carnivores. This is resulting into increased number of cases of human-panther conflicts, thereby adversely affecting both human-beings and panthers of this area. The present study is categorized broadly into two time periods before study period (2006 to 2013) and within study period (2014 to 2018). There is a peak in attacks on livestock during the 2015-2016 which strongly suggests that prolonged steady mining activity from 2006 to 2015 resulted into panthers targeting livestock which are maintained in human populated areas thereby increasing human-panther conflicts. The loss of panther's natural habitat and prey is enforcing their migration towards nearby villages and cropland areas targeting for easier prey. Loss of vegetation has created undesired situations of wildlife migration and simultaneously making them more vulnerable to the killing hands of poachers.All these collective anthropogenic activities have created ecological imbalance in the region of Aravallis. Being apex carnivore, protecting and conserving Indian panthers of this region will certainly assure the future existence of remaining forest and its floral and faunal biodiversity and wildlife in particular.

***Keywords*:** Aravalli hills, Indian Panther (*Panthera pardus fusca*),Human-Panther Conflict, Mining, Conservation

The Aravallis lies in the Western part of India running approximately 692 km with coordinates $24^0 35' 33''$ N and $74^0 42' 30''$ E and is one of the oldest mountain ranges of the World dating back to the collision of pre-Indian subcontinent with Eurasian plates. Numerous rivers arise and flow through the Aravalli hills, which include *Luni, Banas, and Vakal* of Rajasthan. The Aravalli hills of Sothern Rajasthan are natural habitat of rich floral and faunal biodiversity which includes the top carnivore from family Felidae, the Indian Panther (*Panthera pardus fusca*). Due to excessive mining, heavy industrialization and other anthropogenic activities like construction of more and more houses and commercial buildings, natural habitat and natural wild prey base of Indian panthers is continuously declining at a very faster rate. Due to which panthers are moving to nearby or sometimes far away to human dominated areas, villages and croplands located adjacent or at the periphery of forests. Due decreasing natural wild prey base, feral and domestic cattle's becomes easily approachable sources of food for panthers (WWF-India 1997, Chauhan and Goyal 2000, Vijayan and Pati 2001). All these situations are human generated, which are continuously increasing and raising the chances of human-panther conflicts. In India forests are generally surrounded by villages due to which panthers for certain reasons prefer to live on the edges of villages and forests (Gee 1964, Santipillai et al 1982, Tikader 1983, Johnsingh 1992, Daniel 1996 and WWF-India 1997). Among the big cats, panthers are highly adaptable carnivore species in the wild and utilize wide ranges of prey species from very small rodents to large *Nilgai* (Bertram 1982, Daniel 1996, Edgaonkar and Ravi 1997, Stander et al 1997, Mukherjee and Mishra 2001 and Kulkarni et al 2004).

MATERIAL AND METHODS

Study area: Geographically the study area is located in Southern Rajasthan (Fig. 1) which lies in between $23^0 48' 6.974''$ to $25^0 6' 23.225''$ North Latitude and $73^0 0' 1.088''$ to $74^0 25' 57.830''$ East Longitude. It consists of diverse wild flora and fauna with many seasonal and perennial major water bodies. There are many mining areas and associated processing units situated in Udaipur region which have been clustered into 17 mining blocks namely *Badgaon, Bhinder, Girwa, Gogunda, Jhadol, Jhallara, Kherwara, Kotda, Kurabad, Lasadiya, Mavli, Phalasiya, Rishabhdeo, Salumber, Sarada, Sayara* and *Semari* (Fig. 2). Main water bodies of Udaipur are*Ayad River, Bada Madar, Badi Talab, Chhota Madar, Fateh Sagar, Goverdhan Sagar, Nandeshwar Talab, Pichhola Lake, Swaroop Sagar* and *Udai Sagar*. To assess the impacts of mining (Table 1) on decreasing vegetation, forests and human-panther conflicts, data were collected from various sources likefield visits at the sites of human-panther conflicts, field surveys, on spot interview of

villagers and victims and annual reports of forest and mining departments. GPS 72-H has been utilized for keeping records of tracks and spots of human-panther conflicts (Table 2) and probable presence of panthers in and outside the mining area. Data for panther casualty and rescue operations were also collected.

RESULTS AND DISCUSSION

The mining area (in hectares) remained almost constant during 2008-15, followed by a minor reduction afterwards. The major mining includes lead, zinc, asbestos, cadmium, dolomite, limestone, quartz, rock-phosphate, fluorspar, soapstone while minor mining includes granite, marble. The present day situation is the result of mixture of both major and minor mining. The major mining has shrunk considerably and minor mining is on rise (Table 1) which has severe impact on ecology appears to be drastic. Most importantly, it is also the total number of mining leases which matters and this has significantly increased since 2006.

A year wise analyses of data for the study area have also been done for number of mining leases, area of mining leases (Table 1) and number of human-panther conflicts with their types (Table 2) showing immense increment in human-panther conflicts in the past years mainly due to anthropogenic damages and disturbances in their natural habitats and wild prey which led to shifting movements of

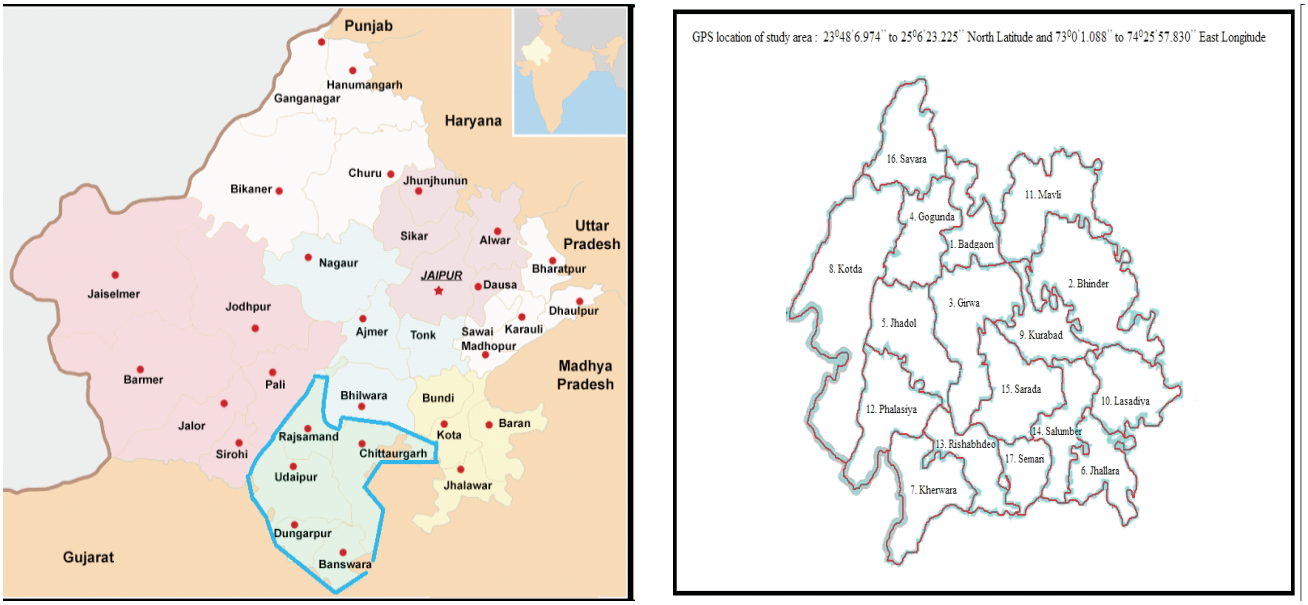

Fig. 1. Southern Rajasthan showing location of study area

Table 1. Number and area of leased mines in the study area (2006-2018) (Source: DMG, GOR)

Year	Number of mining leases			Area of mining (in hectare)		
	Major	Minor	Total	Major	Minor	Total
2006-07	171	441	612	13793.79	475.10	14268.891
2007-08	158	478	636	13240.36	529.61	13769.969
2008-09	155	455	610	11852.83	522.350	12375.185
2009-10	161	463	624	11882.94	547.713	12430.658
2010-11	160	472	632	12341.62	585.285	12926.906
2011-12	169	480	649	12351.07	585.723	12936.795
2012-13	171	488	659	12154.06	603.540	12757.602
2013-14	189	543	732	12327.52	597.25	12924.77
2014-15	237	522	759	12635.58	618.25	13253.83
2015-16	11	715	726	6283.680	6151.85	12435.53
2016-17	10	698	708	6284.580	3677.998	9962.578
2017-18	19	701	720	7084.580	4677.998	11762.578

panthers towards human habituated areas in search of food and shelter. The present study is categorized broadly into two time periods before study period (2006 to 2013) and within study period (2014 to 2018). There is a peak in attacks on livestock during the 2015-2016. This strongly suggests that prolonged steady mining activity (2006-15) resulted into panthers targeting livestock which are maintained in human populated areas thereby increasing human-panther conflicts. As the mining activities are accelerated, the attacks on humans witnessed a sharp increase. This however, declined mainly in the subsequent period due to important measures taken by government to curtail down such conflicts some of which are like availability of water to panther, restoration of broken food chains in relation to panthers, providing compensation to victims and public awareness regarding their safety.

The panther population was the worst affected of all the stakeholders (whether human, livestock or panther) in the conflict. The trend is observed to increase in nature after year 2015-2016 (Table 3). The number of panther casualties would have been more if rescue missions were not there. This helped to reduce the losses to a greater extent. This is the outcome of initiatives taken by authorities in the wake of these conflicts by Government of Rajasthan through '*Project Leopard*'. The formation of special task force for the prevention and mitigation of such incidences has certainly resulted into a major drop in livestock and human casualties, increased number of panther rescue missions and lesser

Table 2. Livestock lifting and human casualty in the different forest division (2006-2018)

Year	Livestock lifting (injury/death)			Total	Human casualty (injury/death)			Total
	Udaipur	Udaipur	Udaipur		Udaipur	Udaipur	Udaipur	
2006 - 2007	0	0	0	0	0	0	0	0
2007 - 2008	0	0	0	0	0	0	0	0
2008 - 2009	0	0	0	0	0	0	0	0
2009 - 2010	0	0	0	0	0	0	0	0
2010 - 2011	0	5	0	5	0	3	1	4
2011 - 2012	1	4	2	7	0	1	3	4
2012 - 2013	6	18	21	45	1	2	15	18
2013 - 2014	6	13	31	50	0	2	0	2
2014 - 2015	19	17	56	92	1	2	0	3
2015 - 2016	32	41	44	117	1	7	0	8
2016 - 2017	54	29	15	98	1	4	0	5
2017 - 2018	5	2	0	7	0	1	0	1

Table 3. Panther casualty and operations in the different forest division (2006-2018)

Year	Panther casualty (injury/death)			Total	Panther rescue operation			Total
	Udaipur	Udaipur	Udaipur		Udaipur	Udaipur	Udaipur	
2006 - 2007	0	0	0	0	0	0	0	0
2007 - 2008	0	0	0	0	0	0	0	0
2008 - 2009	0	0	0	0	0	0	0	0
2009 - 2010	1	0	0	1	0	0	0	0
2010 - 2011	3	0	0	3	0	0	0	0
2011 - 2012	3	0	3	6	0	0	0	0
2012 - 2013	0	2	1	3	0	1	0	1
2013 - 2014	4	5	5	14	0	1	0	1
2014 - 2015	0	7	4	11	1	1	0	2
2015 - 2016	6	4	14	24	4	1	0	5
2016 - 2017	9	7	4	20	0	0	0	0
2017 - 2018	5	1	0	6	2	2	0	4

Fig. 3. Degraded natural terrain, vegetation and source of water (encircled) after extensive mining in the study area

number of panther casualties.

The present study shows that probably the human-panther conflicts which include livestock lifting, human casualties and panther casualties were comparatively increased within the study period from 2014 to 2018 as less number of records or absence of records is found and reported for human-panther conflicts during the time period 2006 to 2013. Reason for the same may be co-related to increase in mining especially in terms of area, nearby forest divisions and human settlements. Mining area sometimes gives added advantage to panthers in terms of availability of water in mining pits, waste blocks providing suitable habitat for panther with various favourable conditions (like hiding, temperature, breeding etc.) and availability of easy prey like dogs raised by people working in mining areas which brings panther more close to human and their settlements thereby increasing the chances of human-panther conflicts.

The panthers prefer to stay in or utilize those habitats which have a proper balance between hiding and easy prey approach to both natural wild and domesticated animals. The water source lays importance in their distribution but not very significantly. There was moderate influence on distribution of Indian panthers even if they are disturbed due to mining since they have excellent ability in adapting to their changing environments. However, it impacts adversely on the human community in the nearby vicinity. The occupancy of panthers in mining regions somehow depends on altered vegetation and terrains if mining creates steep slopes and rugged terrains (used by panthers as escape terrains) or reduce vegetation density or height (for improved visibility). Whether increased occupancy reflects a benefit for panthers, is depends on the demographic responses of the panthers to the resources and conditions available in mining area, such as easy and affordable approach of panthers to the nearby human habituated areas preferably for hunting domestic animals as easy targets of food. Simultaneously, it is also observed that extensive mining has significantly reduced the natural habitats and natural prey base for Indian panthers (*Panthera pardus fusca*) thus creating vulnerable and fragile situations in between human and panther with increased human-panther conflicts. The present study show that certainly there are negative impacts of extensive mining and related establishments as also demonstrated in other research studies for other faunal species (Dyer et al 2001).

Indian Panthers are very sensitive to sudden and continuously changing surroundings adversely of their natural habitat and natural prey. Absence of congenial conditions enforces them to turn towards nearby villages targeting easy domesticated prey commonly calves of cows and buffaloes, goats, sometimes adult cows, buffaloes and even dogs. This whole scenario maximizes the chances of encounter of panthers with humans and thereby leads to increased human-panther conflicts affecting adversely both panthers and humans.

CONCLUSIONS

It is observed that the impact of ecological disturbance may take longer time to appear and harder to mitigate. Hence timely detection and early prevention of any such ecological disturbances is very important. It is also observed that proper implementation of rules and regulations by agencies may result into improvement in situation.

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Joint Forest Management for Conservation and Auxiliary Income in Himachal Pradesh

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***Abstract*:** The study was conducted to oberve the effect of Joint Forest Management activities on socio-economic status and income generation. A total of 206 respondents from 18 Joint Forest Management Committees (JFMCs) of the selected 6 Forest Development Agencies (FDAs) using multistage random sampling technique were selected. The households were extracting 14.31 quintals of fuelwood, 16.65 quintals of fodder/ grasses about 1.80 quintals of leaf litter/ animal bedding and 0.70 quintals of humus per annum from the forests. There were some farmers who also earned about 242.72 rupees per annum on an average from the sale of Non-Timber Forest Products (NTFPs) like Morchella (*guchhi)*/ wild vegetables. The level of inequality for the non-farm income was found to be highest (0.45), followed by inequality in farm income (0.39) and inequality in forest income (0.23). The overall inequality index value was found to be 0.31 for the total level of income. The poor and underprivileged households were benefitting the most from community based forest management under JFM than well-off households, as they are more dependent upon forest to meet their livelihood requirements. The reduction in fund allocation of JFMCs is a threat to the conservation efforts of the government and local people who are losing employment opportunities.

***Keywords*:** JFM, Income inequality, Employment, Gini coefficient

The state of Himachal Pradesh exhibits a unique relationship between its people and the forests. About 89.97 per cent of the total population of the state lives in the rural areas and supports livestock population of more than 48.50 lakhs. Around 66 per cent of the geographical area of the state is under forests of which 39.64 per cent is under tree cover (FSI 2013). Forests are important to protect environment from pollution and maintain ecological balance. The contribution of forests to the state net revenue was 215.46 lakh in 2011-12 (Anonymous 2012). The Joint Forest Management is one such programme that seeks to develop partnerships between local community institutions and state forest department for sustainable management and joint benefit sharing of public forestlands. The primary objective of JFM is to ensure sustainable use of forests to meet local needs equitably, while ensuring environmental sustainability. The central premise is that local women and men who are dependent on forests have the greatest stake in sustainable forest management. In response to the National Forest Policy and to ensure equity and social justice, the state governments, which are responsible for forest management under Indian constitution, have started encouraging the communities living nearby the state forests for formation of FPCs under JFM. The provision of a steady income from forest derived products will give individuals the incentive to manage their forests sustainably as well as contribute to the goals of development and poverty alleviation (Howie 2007, Sherry et al 2005). The state of Himachal Pradesh has about two decades of experience with JFM approach as it was started in 1993. As more than two decades have passed since the inception of participatory forest management programme it is commendable to evaluate its impact on the socio economic status of rural people in providing employment, poverty alleviation, sustainable forest development and their interaction with the forests.

MATERIAL AND METHODS

A multistage random sampling technique was used to select the final sample for the present study. In the first stage, 15 per cent FDAs viz. 6 out of 36 FDAs were selected for the present study after consultation with forest department and National Afforestation and Eco development Board officials. In the second stage, from each selected FDA, list of Joint Forest Management Committees (JFMC) was taken and three functional JFMCs from each FDA were chosen randomly. Further, from the each selected JFMC, minimum of 10 respondents were selected randomly, thus, making a total of 206 respondents from 18 selected JFMCs. In addition to this nearly 20 per cent of the total office bearers of FDAs and JFMCs were also selected to carry out the survey work.

Primary data for the present study was collected through personal survey method on a specially structured and pretested survey schedule. Secondary data pertaining to various aspects of JFM and other technical parameters was collected from various government offices. Tabular analyses along with econometric analyses have been adopted to fulfil the specific objectives of the study.

Gini coefficient:

$$Y = \frac{N+1}{N-1} - \frac{2}{N(N-1)\,\mu} \sum_{i=1}^{n} p_i x_i$$

Where,

γ is the Gini coefficient, μ is the population's mean income and ρ_i is the income rank ρ of person i with income x.

In this model the household with the highest income is accounted for rank 1 and the poorest household receives a rank of N.

Lorenz curve: The Lorenz curve is a graphical representation of the proportionality of a distribution. It represents a probability distribution of statistical values, and is often associated with income distribution calculations and commonly used in the analysis of inequality. In the present study, the population in the Lorenz curve is represented as households and plotted on the x-axis from 0 to 100 per cent and the income is plotted on the y- axis and is also from 0 to 100 per cent. Larger the gap between Lorenz curve and the line of equality indicates the more unequal distribution of income among the sample households.

Compound growth rate:

$Y_n = Y_0 (1 + r)^t$

Where, Y_n= area at time, t_n, Y_0= area at time, t_0, r = rate of growth, t = time period

Log linear equation model:

Log Y= Log_a+ b_1LogX_1 + b_2LogX_2 + b_3LogX_3 + b_4LogX_4 + b_5LogX_5+ b_6LogX_6

Y= Household level returns from forests (Rupees)

X_1 = Involvement of male members in JFM activities (Number)

X_2= Age of the decision maker (Year)

X_3= Size of the land holding (Hectare)

X_4= Livestock holding size (Number)

X_5= Income from non-farm activities (Rupees)

X_6= Distance to the forest (Kilometer)

RESULTS AND DISCUSSION

Socio-personal characteristics: The socio personal characteristics are given in Figure 1. The average size of the family for selected households was 6.45 having a sex ratio of 946 females per thousand males which was less than the

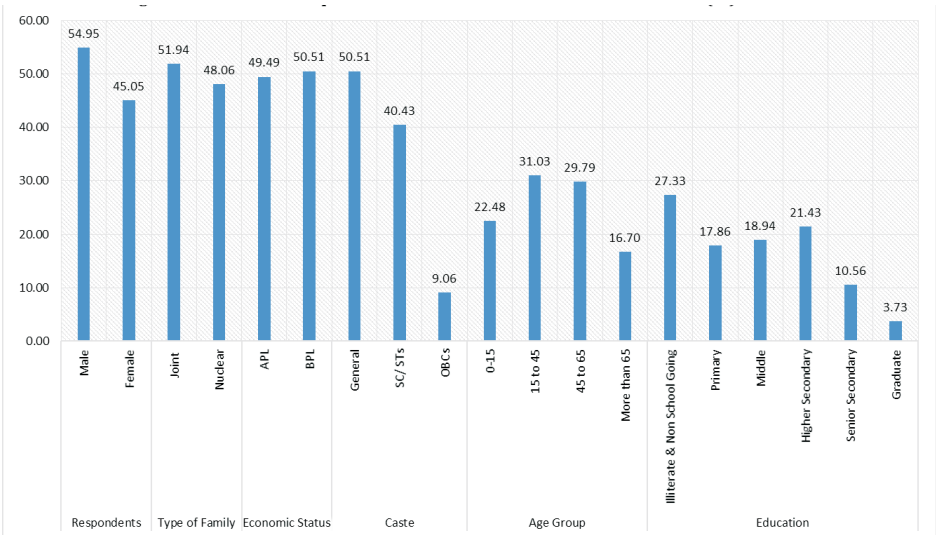

Fig. 1. Distribution of respondents on basis of socio-personal characters (%)

Table 1. Land use pattern of households (Area in ha)

Cultivated land						Non-Cultivated land		Total
Cereals		Vegetables		Pulses	Orchards	Fallow/ Barren land	Ghasnis/ pasture	
IR	UIR	IR	UIR					
0.039	0.221	0.042	0.066	0.011	0.097	0.051	0.234	0.761
(5.07)	(29.05)	(5.58)	(8.68)	(1.43)	(12.76)	(6.71)	(30.72)	(100)

Figures in parentheses indicate percentages to the total in each case. IR-irrigated; UIR= Not irrigated

state average of 972 females per thousand males. Dependency ratio estimated with respect to family size was 0.40 indicated dependence up to 40 per cent per household in the study area.

Land use pattern: The average land holding size was 0.76 ha which was less than the states average operational land holding size of 0.99 ha. The cereal crops irrigated and unirrigated accounted for about 34.12 per cent of the total farm land holding, followed by pasture, vegetables and orchards (Table 1).

Production: The share of vegetables production is highest in both *kharif* and *rabi* season followed by the cereal crops (Table 2).

Dependence on forests: Fire wood, fodder and NTFPs collected from the forest were sold at their market selling price. Leaf litters and humus were valued based on the opportunity costs of time spent in collecting and transporting a head load of leaf litter/ humus from forests. On an average the households extracts 14.31 quintals of fuelwood, 16.65 quintals of fodder/grasses about 1.80 quintals of leaf litter/ animal bedding and 0.70 quintals of humus per annum from the forests. The farmers also earn about 242.72 rupees per annum from the sale of NTFPs like *guchhi*/ wild vegetables etc. in which only limited families were engaged.

Income structure: The farm income contributed the most (56.43%) to the gross income of the households followed by non-farm income i.e. from services, business and wages (39.34%) and income from forests (4.23%) (Table 3). The share of farm income was mainly comprised of income from orchards followed by agriculture and livestock.

Factors affecting the dependency on forests: The log linear model was run to observe the relationship between the household returns from the forest and the independent variables. The fit was significant and value of R^2 and adjusted R^2 was 0.500 and 0.485 respectively (Table 4). The relationship of male members and total cattle unit were found positively and significantly related with income earned from forests, contradicting the results of Das and Sarker (2011) in study conducted in West Bengal. The other independent variables like age, size of land holding, total non-farm income and distance to the forest area were negatively and significantly related with income from forest. This notion can be explained by the observation that the poor households with less landholding, engage themselves in the JFM activities because they do not have private land or assets to depend upon to meet their livelihood requirements. The large proportion of their income is also derived from the livestock which can be reared easily due to availability of fodder from the forests. In addition the households having high non-farm income had less opportunity cost than the households with higher farm income thus they spend less time and derive less benefits from the forests being managed. The regression result shows an inverse relationship between age of the household head and income from forests. It simply explains that households headed by aged person benefit less from the forests than those with younger ones.

The regression analysis reveals that poor and underprivileged households with less landholding were benefiting more from community based forest management under JFM than rich households. The annual income from community forest is higher for smaller households than that of large households. Similar results were found in studies conducted in Orissa (Sahu 2008, Sahu and Rath 2010) and in western Nepal (Sapkota and Oden 2008).

Table 2. Average household production of crops in study area

(Qtl)

Kharif season		*Rabi* season	
Maize	2.77 (15.08)	Wheat	5.87 (33.58)
Paddy	0.64 (3.45)	--	--
Vegetables	14.90 (80.99)	Vegetables	11.5 (65.82)
Pulses	0.09 (0.48)	Pulses	0.10 (0.60)
Sub total	18.40 (100.00)	Sub Total	17.47 (100.00)

Figures in parentheses indicate percentages to the total in each case

Table 4. Determinants of heterogeneity in log linear model

Parameter	β	Standard error	t ratio	Significance level
Constant	22462.70	1755.40	12.80	0.000
Gender (Male)	2386.44	692.92	3.44	0.001
Age	-109.50	29.01	-3.78	0.000
Land holding	-218.99	32.49	-6.74	0.000
Total cattle unit	1213.49	267.91	4.53	0.000
Non-farm income	-0.01	0.00	-3.97	0.000
Distance from forest	-3222.00	439.10	-7.34	0.000

R Square= 0.500, Adjusted R Square= 0.485, Standard error=4513.91

Table 3. Income distribution of sample household (₹ '000)

Farm income			Total farm income	Non -farm income			Total non- farm income	Income from forest	Total
Agriculture	Orchard	Livestock		Service	Wages	Business			
66.11 (24.15)	73.47 (26.84)	14.87 (5.43)	154.45 (56.43)	77.06 (28.15)	15.25 (5.57)	15.38 (5.62)	107.68 (39.34)	11.58 (4.23)	273.70 (100)

Figures in parentheses indicate percentages to the total in each case

The specified variables in the model explain 50 percent of the variation in the total income derived from the forests. The lower value of R^2 indicated the scope for further research of some of additional relevant variables to be included in the regression equation.

Income inequality: The degree of inequality in the distribution of income from different sources was estimated using Gini Coefficient Ratio (GCR) and the Lorenz curve as shown in Figure 2. The GCR was to be highest in the non-farm income (0.45), followed by farm income (0.39) and income from forests (0.23) (Fig. 2). The level of inequality was 0.31 for the total level of income and thus it can be concluded that the income derived from the households from the forest reduced the income inequality at an overall level. The earlier works also conclude that participatory forest management had impact on socio-economic development of rural people by creation of alternative job opportunities and improved agricultural production, thereby financially

Table 5. Status of expenditure incurred and employment generated in selected JFMCs in last 10 years

Year	Expenditure incurred (₹ in lakhs)	Employment generated (mandays)
2005-2006	1.03	925
2006-2007	1.17	400
2007-2008	2.01	1240
2008-2009	3.85	2490
2009-2010	2.60	1372
2010-2011	5.48	3933
2011-2012	5.37	2649
2012-2013	13.9	6601
2013-2014	3.32	1970
2014-2015	2.88	1651
2015-2016	0.34	232
Total expenditure	41.95	23463
Growth rate (%)	2.63	2.53

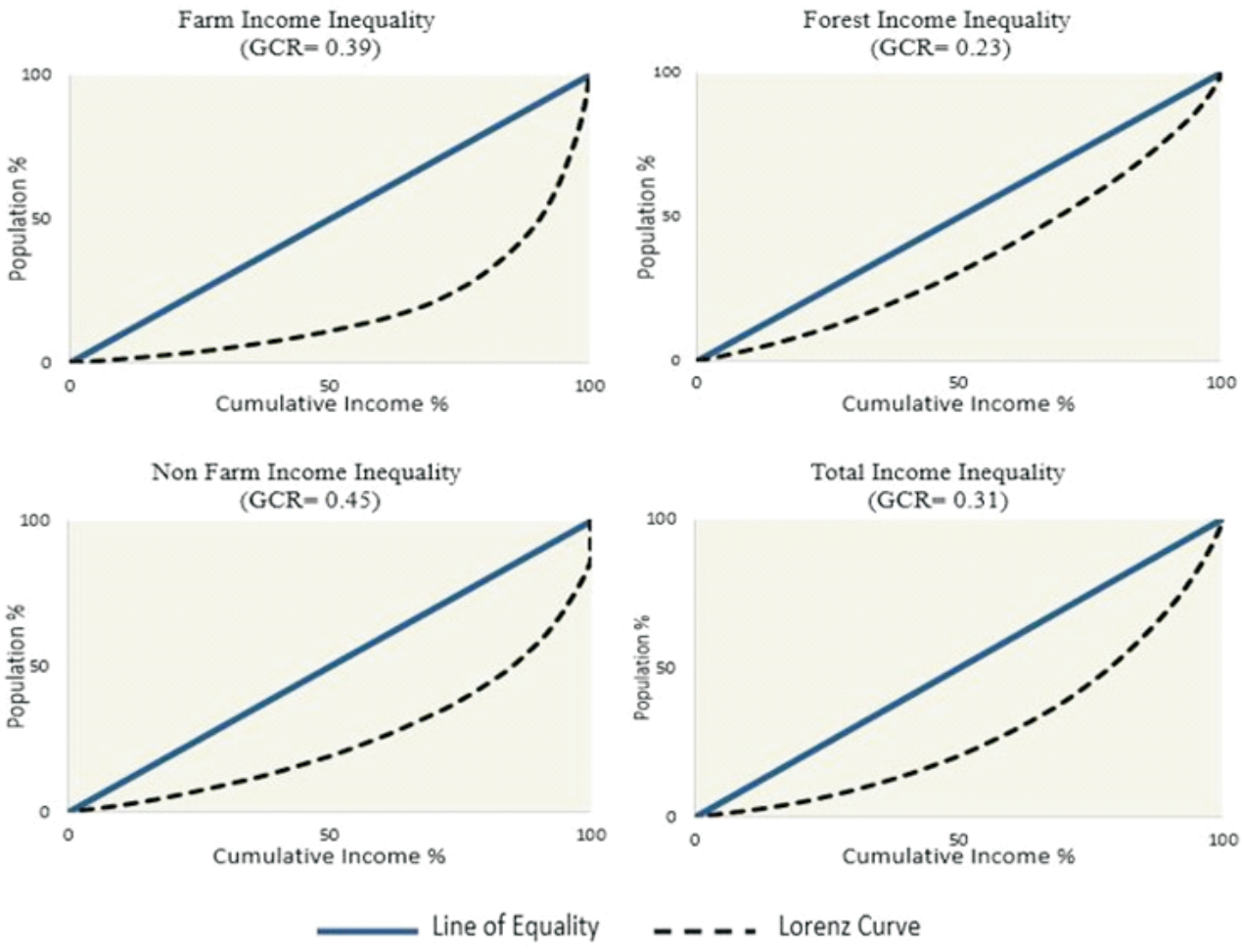

Fig. 2. Lorenz curve showing level of income inequality from different sources

empowering them and alleviating poverty through empowerment, accountability and capacity building of the rural poo (Kumar 2002, Gupta et al 2004, Danwar et al 2007, Mir et al 2014)

Expenditure incurred and employment generated in the selected JFMCs in the last ten years: Expenditure of 41.95 lakh rupees incurred in the selected JFMCs during 2005-06 to 2015-16 maximum during 2012-13. The funding to the JFMCs was meagre and irregular (Table 5). Employment of 23463 man-days was generated in the selected JFMCs during the period. The JFMCs had huge potential to generate the employment in the rural areas if proper need based work like plantation activities, nursery preparation, construction of check dams, retaining wall, water pond, tank, road/ paths, *kuhl*, vermi composting pits etc. is undertaken. There is a need to strengthen JFM programme with ample financial support which can ultimately help empowering the rural poor and also develop the villages along with the major objectives of forest management. The highest number of man-days were generated during the financial year 2012-13, when most funds were received by these JFMCs. After 2012-13 there was a sharp decline in the employment generation. The uneven funding to JFMC had damaging impact on its employment objective eclipsing its holistic role as a participatory rural development program. The compound annual growth rate in the selected JFMC's for expenditure incurred and employment generated for the period was 2.63 and 2.53 per cent, respectively. Many earlier studies mentioned similar types of constraints in feasibility and longevity of JFMC activities in their respective study areas of Himachal Pradesh (Brahmi et al 2008, Guleria and Vaidya 2015, Lal et al 2016).

CONCLUSION

The joint forest management activities had helped in the sustainable use of the forest resources by the common people along with their conservation and creation of the alternative income sources for the forest dwellers by providing them with jobs and access to forest resources like fire wood, fodder and NTFPs. The regression analysis revealed that poor and underprivileged households were benefiting from community based forest management under JFM than well-off households. The inadequate fund allocation is a threat to the conservation efforts involving the local people as it is reducing the employment opportunities.

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Diversity of Endophytic Fungi in Few Lianas of West Medinipur, South-West, India

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Abstract: Four woody lianas were selected for isolation and study of endophytic fungiand its diversity from three forest areas of West Medinipur district. Aerial tissues (leaf, petiole and bark) were assessed for isolation of endophytes. A total of 173 plant segmentsout of 225 were inhabited by fungi and 229 endophytic fungi were isolated. The isolated fungi belong to 31 genera, with few sterile mycelia. Among all isolated endophytes-*Fusarium* sp., *Penicillium* sp., *Pestalotiopsis* sp., *Aspergillus* sp., *Nigrospora* sp. were most common. In *Bauhinia* sp., maximal endophytic fungi (36.68%) were observed. Five fungal species were identified by molecular method using ITS-rDNA sequence by NFCCI, Pune. Isolated endophytic fungi were *Lasiodiplodia* sp. *Acrocylindrium* sp., *Arthrinium* sp. and *Aspergillus* sp. Simpson's diversity was maximum in *Bauhinia* sp. (0.8926). Diverse group of endophytic fungi were in *Bauhinia* sp. and *Celastrus* sp.

Keywords: Endophytes, Diversity, Lianas, Fungi

Endophytes are found in all groups of plant community. The term endophyte is most commonly used for those micro organisms which infect and colonize internally and here the tainted tissues in host plant will not show any instant symptoms, and will be evenly applied for prokaryotic bacteria as well as eukaryotic fungi (Banerjee 2011). Fungal endophytes in aerial tissues of host are culturable on synthetic media. *Muscodorvitigenus, M. equiseti M. heveae* were isolated from *Hevea brasiliensis* in Thailand (Siri-Udom et al 2016). Endophytic organisms have been exhibited as the key components in symbiotic relationships of plant hosts, influencing tolerance power of host to stressful condition. Endophytic fungi are very important in the biodiversity since they have an effect on structure and defence mechanism of plants and ultimately in the ecosystem (Wilson 2000). Arnold et al (2000) isolated extremely abundant and very diverse group of endophytic fungi from plant tissues. Endophytic fungi are ubiquitous in distribution found within the tissues of plants.

Lianas are a group of plants which are woody climbers in the forest and climb up tall tree. Knowledge of lianas and their ecology has lagged well behind other plant groups. Studies on endophytic diversity of lianas are also lacking. So, present research was focused on a relative study of endophytic diversity of some lianas plants in some regions of West Medinipur district of West Bengal in South-East India.

MATERIAL AND METHODS

Sampling: The study was conducted in West Medinipur district of West Bengal, India. (latitude 22°25' to 22°57' North, longitude 87°11' East, altitude 2 meters from the sea level). The climate is tropical, warmer and humid with a mean temperature of 30°C and an annual average precipitation of 130cm. Four lianas plants-*Bauhinia vahlii* (Caesalpiniaceae), *Celastrus paniculata* (Celastraceae) *Combretum roxburghii* (Combretaceae) and *Ventilago denticulata* (Rhamnaceae) were selected from Chilkigarh for endophytic fungal screening. Stem and leaf samples from healthy, disease free mature plants were collected in winter. The samples after collection immediately transferred into zipper-lock plastic packets, brought to the laboratory and preserved at 4°C within 3-4 hours of collection. Samples were processed within a few hours after sampling to reduce the chances of contamination.

Surface sterilization: Samples were thoroughly washed under tap water before processing starts, then were immersed in 70% ethanol for 1 minute, immersed in sodium hypochlorite (NaOCl) solution (3% available chlorine) for 3 minutes (5 minutes for bark segment), again immersed in 70% ethanol solution for 1 minute, finally rinsed with sterile distilled water for 3 times and allowed to surface dry.

Placement of samples: Samples were cut into pieces of 1 square cm size and placed into water agar (WA), 5 pieces in each, equidistant from each other separately from leaf, petiole and stem. Fungal hyphae appeared in almost every sample of water agar plate.

Isolation of fungi: Each hypha was isolated and transferred to a plate of potato dextrose agar (PDA) media. New plates with hyphae were incubated in light chamber of incubator at

23°C. Huge mycelial growth was observed after 7/8 days of incubation. Slants of culture were prepared and stored at 4°C in refrigerator for identification and further work in future.

Identification: Fungi were isolated and then identified on the basis of its morphological and reproductive and few on molecular characteristics using standards manuals (Gilman 1971, Barnett and Hunter 1996, Ellis and Ellis 1997, Nagamoni et al 2006). Few endophytic isolates could not be identified by those manuals. Five of those unknown fungal species were identified by molecular method using ITS-rDNA (Internal Transcribed Spacer-Ribosomal DNA) sequence by National Fungal Culture Collection of india (NFCCI), Pune and their phylogenetic trees were shown in Figure 1, 2, 3, 4 and 5.

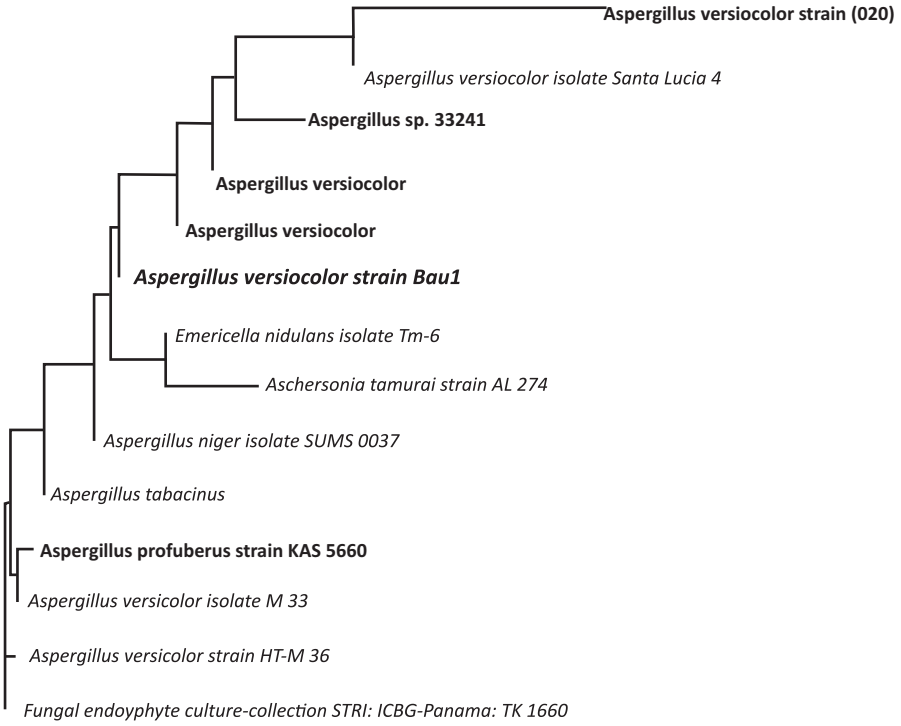

Fig. 1. Phylogenetic tree of isolatedfungus-1 from Bau.-1 based on ITS-rDNA sequence

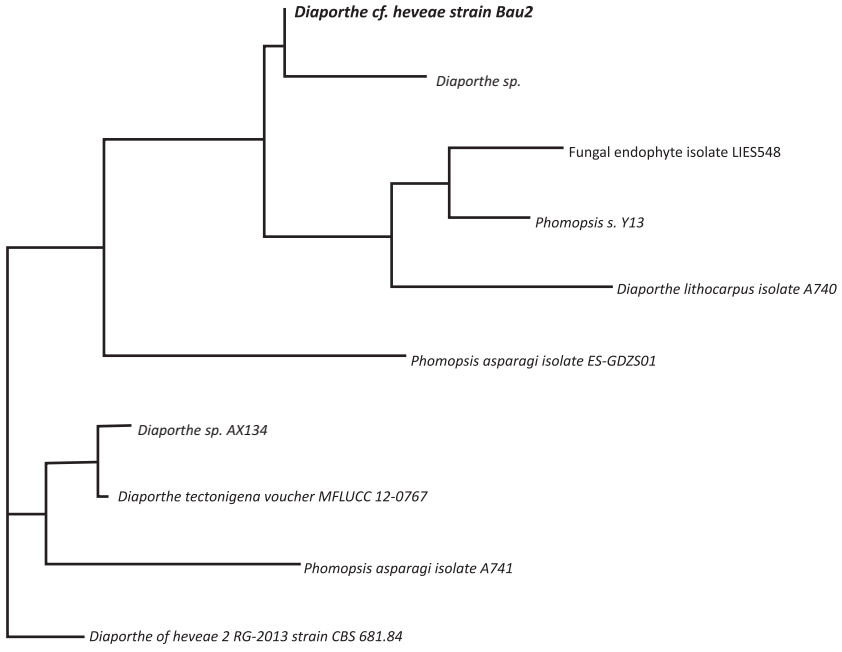

Fig. 2. Phylogenetic tree of isolated fungus-2 from Bau.-2 based on ITS-rDNA sequence

Statistical calculation: The relative colonization frequency (CF%) was calculated as the number of sample segments colonized by at least a fungus divided by total number of segments plated ×100 using the formula outlined by Hata and Futai (1996)

CF = (N_{col}/N_t ×100, where N_{col}= number of segments colonized by at least a fungus, N_t = total number of segments plated.

Dominant endophyte percentage (D)=N_i/N_s×100, where N_i=percentage of colony frequency of individual endophytes, N_s=percentage of colony frequency of all endophytes. Using palaeontological statistics software package (PAST) (Hammer et al 2001), following diversity indices were calculated-(a)

Simpson's diversity index (1-Dominance) was calculated using the formula 1-D, where D = $\Sigma n(n-1)/N(N-1)$. Here, n = the total number of organisms of a particular species, N = the total number of organisms of all species.

Shannon-Wiener index (H') = $-\Sigma s(P_i)(\ln P_i)$, where H' = Symbol for the diversity in a sample of species or kinds, s = the number of species in the sample, P_i = relative abundance of i^{th} species or kinds and measured by = n/N, N = total number of individuals of all kinds, n_i = number of individuals of i^{th} species, In = log to the base 2.(c)

Evenness (E) = H'/H'max, where H'max is the maximum value of diversity for the number of species.

RESULTS AND DISCUSSION

All the four woody lianas were infested with huge number of endophytic fungi forming an symbiotic association. Altogether 245 fungal endophytes were isolated from 375 segments of leaf, petiole and stem from four lianas. The endophytes belong to 31 genera, few unknown and few sterile mycelia. Previous studies also showed that different number of endophytic fungi were isolated from woody lianas of different locations (Banerjee 2011).

The highest number of fungal endophytes was isolated from *Combretum* sp. (CF=73.33%) and *Bauhinia* sp. (CF=67.2%). Most of the endophytic fungi were colonized in petioles (CF=68.75%). In *Combretum* sp. leaf shows maximum colonization frequency (88%). Colonization frequency (%) of endophytic fungi in four lianas plants are-*Bauhunia* sp.-36.38, *Celastrus* sp.-20.52, *Combretum* sp.-25.76 and *Ventilago* sp.-17.03. It is an evidence for the tissue specificity of endophytes. Previous researchers also observed tissue specificity of endophytes in their studies (Raviraja 2005). Bauhinia showed the highest Simpson's diversity (0.8926) with maximum Shannon-Weiner index (2.494) and highest Fisher Alfa index (7.652). All these indices indicate great species specificity of endophytes. Similarity coefficient was calculated to determine the

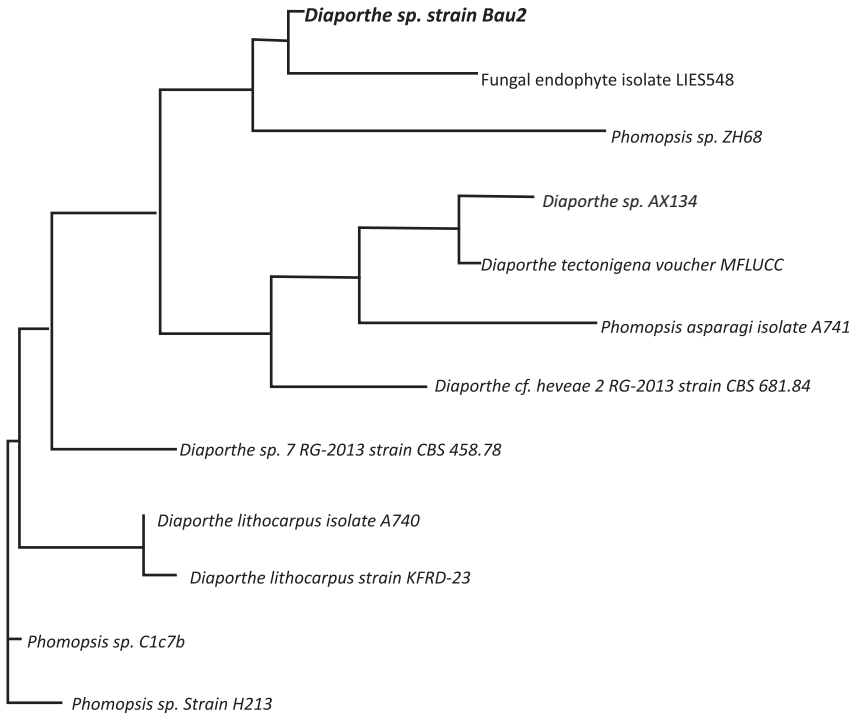

Fig. 3. Phylogenetic tree of isolated fungus-3 from Bau.-3 based on ITS-rDNA sequence

Table 1. Colonization frequency of endophytes from different aerial segments of four woody lianas

Endophytic fungi	*Bauhinia* sp.			*Celastrus* sp.			*Combretum* sp.			*Ventilago* sp.			Total
	S	P	S	L	P	S	L	P	S	L	P	S	
Acrocylindrium sp.	0	0	1	0	0	0	0	0	0	0	0	0	1
Apophysomyces sp.	0	0	0	0	0	1	0	0	0	0	0	0	1
Arthrinium sp.	0	0	0	2	2	0	0	0	0	0	0	0	4
Aspergillus sp.	0	0	4	2	2	1	3	1	3	0	0	0	16
Bispora sp.	0	1	0	0	0	0	0	0	0	0	0	0	1
Botryotrichum sp.	0	0	0	0	1	1	0	0	0	0	0	0	2
Chaetomium sp.	0	0	0	0	0	0	8	0	0	0	0	0	8
Chrysosporium sp.	0	0	0	0	1	2	0	0	0	0	0	0	3
Cladosporium sp.	0	0	1	0	0	0	0	0	0	0	0	0	1
Curvularia sp.	0	0	0	0	0	0	0	0	0	0	2	1	3
Cylindrocladium sp	7	4	0	0	0	0	0	0	0	0	0	0	11
Dicoccum sp.	0	0	1	0	0	0	0	0	0	0	0	0	1
Diplodia sp.	0	0	0	0	1	0	0	0	0	0	0	0	1
Fusarium sp.	0	0	0	0	0	1	0	0	0	4	7	21	33
Fusidium sp.	0	1	0	0	0	0	0	0	0	0	0	0	1
Geotrichum sp.	0	0	2	0	0	0	0	0	0	0	0	0	2
Humicola sp.	0	0	2	0	0	0	0	0	0	0	0	0	2
Hymenella sp.	1	0	0	0	0	0	0	0	0	0	0	0	1
Lasiodiplodia sp.	0	0	0	0	0	2	0	0	0	1	0	0	3
Mucor sp.	0	1	3	0	0	4	0	2	0	0	0	0	10
Murogenella sp.	0	0	0	0	0	0	0	0	0	0	0	1	1
Nigrospora sp.	0	0	0	0	3	1	0	0	0	0	0	0	4
Papulospora sp.	2	3	1	0	0	0	0	0	0	0	0	0	6
Penicillium sp.	0	0	10	1	0	0	0	1	0	0	0	0	12
Perisporium sp.	0	1	0	0	0	0	0	0	0	0	0	0	1
Pestalotiopsis sp.	2	2	10	0	0	0	0	0	0	0	0	0	14
Philophora sp.	0	0	1	0	0	0	0	0	0	0	0	0	1
Podospora sp.	0	0	0	0	0	0	4	0	0	0	0	0	4
Scopulariopsis sp.	0	0	0	0	0	0	0	2	0	0	0	0	2
Sterile mycelia	2	1	1	0	0	5	5	4	0	0	0	0	18
Torula sp.	1	1	2	0	0	0	0	0	0	0	0	1	5
Unidentified	4	6	5	5	2	7	5	14	1	0	0	0	49
Verticillium sp.	0	0	0	0	0	0	0	0	6	0	1	0	7
Total	19	21	44	10	12	25	25	24	10	5	10	24	229
Grand total		84			47			59			39		229

L=Leaf, P=Petiole, S=Stem

Table 2. Diversity indices, evenness and species richness of endophytic fungi isolated from the lianas

Parameter	*Bauhinia* sp.	*Celastrus* sp.	*Combretum* sp.	*Ventilago* sp.
Taxa_S	19	13	9	6
Individuals	84	47	59	39
Dominance_D	0.1074	0.1426	0.1882	0.6818
Simpson_1-D	0.8926	0.8574	0.8118	0.3182
Shannon_H	2.494	2.239	1.891	0.7354
Evenness_e^H/S	0.6375	0.7215	0.7361	0.3477
Fisher_alpha	7.652	5.945	2.959	1.98

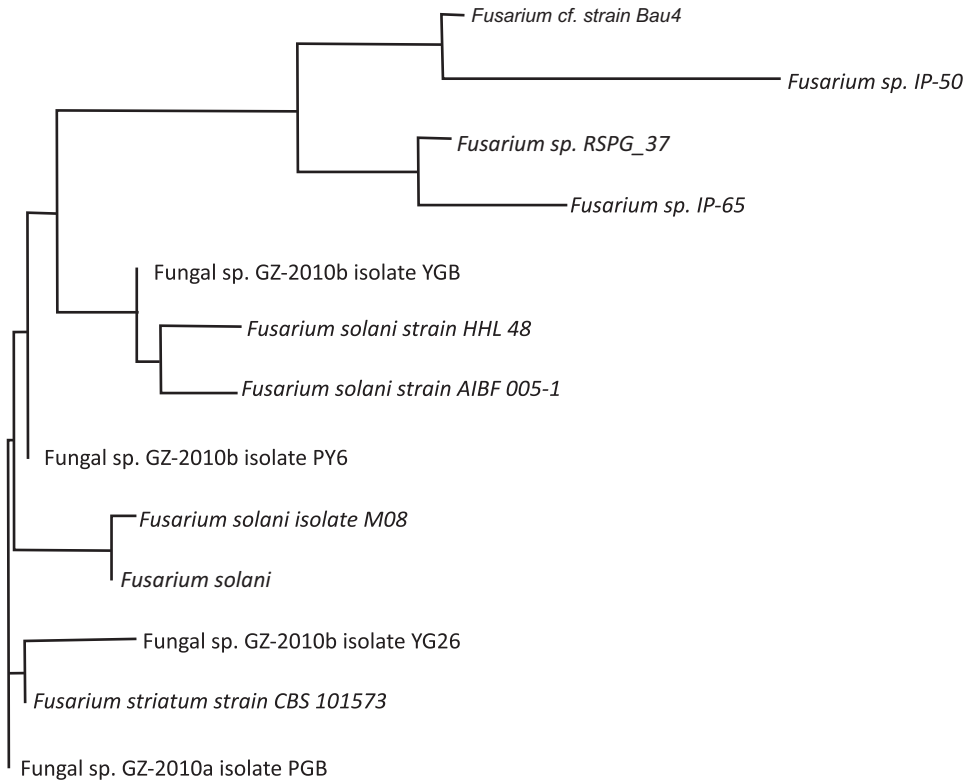

Fig. 4. Phylogenetic tree of isolated fungus-4 from Bau.-4 based on ITS-rDNA sequence

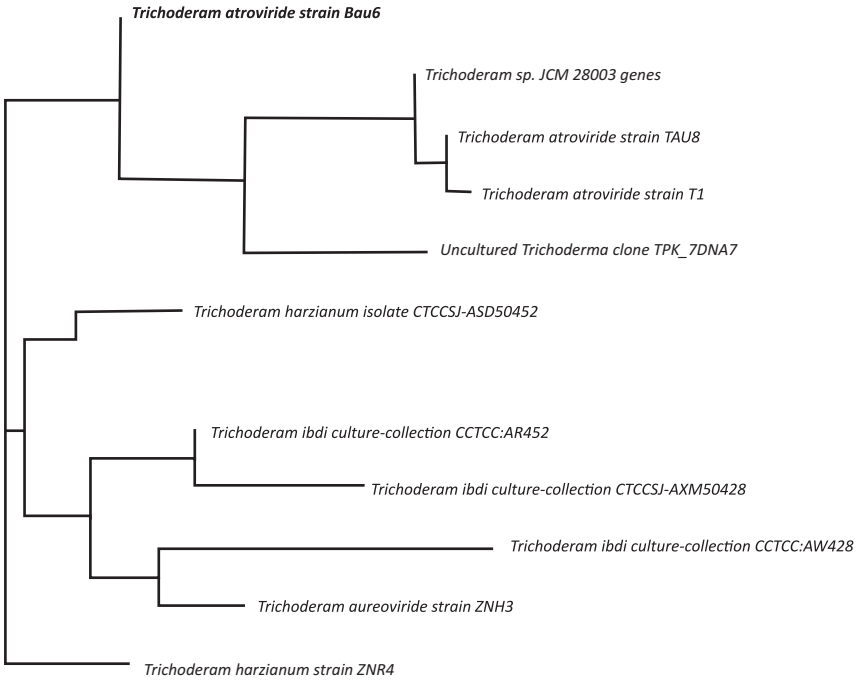

Fig. 5. Phylogenetic tree of isolated fungus-5 from Bau.-6 based on ITS-rDNA sequence

Table 3. Similarity coefficient of four woody lianas (%)

	Bauhinia sp.	*Celastrus* sp.	*Combretum* sp.	*Ventilago* sp.
Bauhinia sp.	100	23.14	22.76	4.59
Celastrus sp.		100	25.64	34.95
Combretum sp.			100	9.21
Ventilago sp.				100

colonization similarity of fungal endophytes in four different host plants. In all plants similarity coefficient ranges between 4.59-34.95 percent . *Celastrus* sp. and *Ventilago* sp. showed the highest similarity coefficient (34.95%). In the present study *Cylindrocladium* sp., *Pestalotiopsis* sp., *Aspergillus* sp., *Penicillium* sp.,

Verticillium sp., *Chaetomium* sp. are the dominant endophytes in all four lianas plants.

CONCLUSION

There is a diverse groups of endophytes in lianas plants documented from the study. Majority has been identified with some unknown genera and some mycelia sterilia. There is host specificity by endophytes and also they have organ and tissue specificity. The plant of *Bauhinia vahlii* shows maximum number of endophytes and *Ventilago denticulata* has minimum numbers. *Celastrus paniculata* and *Ventilago denticulata* show maximum similarity coefficient.

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Biodiversity of Arbuscular Mycorrhizal (AM) Fungi in Agroecosystems of Semi-Arid Region Jaipur, India

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Abstract: The microorganisms are the most abundant member of the soil biota and in agro-ecosystems. Arbuscular mycorrhizal (AM) fungus show a symbiotic relationship with more than 70% plants occurring worldwide in almost all type soil, forming the dominant type of mycorrhiza. The helpful effects of Arbuscular mycorrhizal (AM) fungi on plant growth and soil health are vital for the sustainable management of agricultural ecosystems. In this present study collected rhizosphere soil samples to find out the diversity and abundance of specific species of AM fungi. A total of four genera with 14 species of AM fungi were reported from Jaipur region. Among them, 7 species belonged to *Glomus*, 4 species belonged to *Gigaspora*, 2 species *Acaulospora* and one species belonged to *Scutellospora* genera and out of them four AM fungal sps. first time reported in Jaipur district. Also, a total number of spore density was carried out in 50g soil samples showed a variable range from 29 to 113 AM fungal spores. The aspects of AM fungal ecology emphasizing past and present importance of the global ecosystem function.

Keywords: Arbuscular Mycorrhizal (AM) Fungi, Agroecosystems, Biodiversity, Ecosystem

The microorganisms are the most abundant member of the soil biota and in agro-ecosystems. The wide range of organisms that inhabit soil play important roles in driving many of the key terrestrial bio-geochemical cycles that underwrite primary production, via the provision of mineral nutrients to plants and their characteristics properties that they impact in nature (Ritz and Young 2004). Mycorrhizal symbionts occur in most biomass on earth and are a fundamental reason for plant growth and development on the planet. The common mycorrhizal association in the majority of the plants is the Arbuscular vesicular mycorrhizal type occurring in the majority of agricultural crops, most shrubs and most tropical tree species (Bagyaraj 2014). Arbuscular mycorrhizal (AM) fungus demonstrate a commonly beneficial symbiotic relationship with more than 150 species of 70-80 per cent earth plants occurring worldwide in almost all type soil, forming the dominant type of mycorrhiza. Arbuscular mycorrhiza is a mutually beneficial biological association between species in the fungal phylum Glomeromycota and plants roots (Ramesh and Reddy 2014).

AM fungi benefit their host plant by improving the uptake of water, minerals and particularly the poorly mobile ion phosphorus in the soil. The fungus has shown to improve the tolerance of the plant to drought stress (Berruti et al 2015) and play a critical role in vegetation succession of the ecosystem, plant diversification and productivity, restoration and re-establishment of degraded ecosystems. The present survey aims at improving the understanding of the broad-scale distribution of AM fungi in the agricultural ecosystem of the semi-arid region of Jaipur, India.

MATERIAL AND METHODS

The study area is located in the Jaipur, situated on the eastern border of Thar Desert, a semi-arid land (coordinates 26.9124° N, 75.7873° E). The climate is the Mediterranean hot semi-arid with an average annual rainfall of 650 mm. The elevation above sea level is 431 m and average maximum and minimum temperatures in range of 25-45°C in summer and 5-22°C in winter respectively during the experimental period.

Sample collection: Soil samples were collected randomly from the 10 different sites (Table 1). A random selection of cultivated farmlands was done on each site. The selected each farmland was divided into four zones and from each zone selected plant with their rhizosphere soil was dug out with a trowel to a depth of 0-15 cm after scraping away the top 1 cm layer of soil.

The collected soil samples were sieved (< 2mm mesh size) to remove stones, coarse roots and other litter and then was stored in the sterile polythene bags in the laboratory at 4°C. The soil samples were used for isolation and identification of spores of AM fungi (Colombo et al 2014).

Isolation and identification of AM fungal species: Spores of AM fungi were isolated from the soil samples by using the 'Wet-sieving and decanting method' (Gerdemann and Nicolson 1963). The collected AM fungi spores were

identified with the help of 'Identification Manual of Schenck and Perez' (1990) and spores of common species of AM fungi were identified using 'synoptic keys' of the genera and species of Zygomycetous mycorrhizal fungi by Trappe (1982), on the basis of spore morphological characters i.e. color, size, shape, cell wall structure and type of hyphal attachment.

Diversity of AM fungi species: The arbuscular mycorrhizal fungal diversity was calculated on different parameters using the following formulas:

Species Richness **=** Number of AM fungal species in 50 g air-dried soil.

$$\text{Frequency (\%)} = \frac{\text{Number of site in which AM fungal species was observed}}{\text{Total number of sites}} \times 100$$

$$\text{Relative abundance (\%)} = \frac{\text{Number of spores AM fungal species at one site}}{\text{Total number of spores at that site}} \times 100$$

RESULTS AND DISCUSSION

Isolation and identification of AM fungi: A diverse group of AM fungal spores were collected from the rhizospheric soil from 10 different sites. A total of four genera with 14 species of AM fungi were collected from Jaipur region (Table 2). Among them, seven species belonged to *Glomus* (*G. ambisporum*, *G. etunicatum*, *G. fasciculatum*, *G. intraradices*, *G. macrocarpum*, *G. maculosum*, *G. mosseae*), four species belonged to *Gigaspora* (*G. albida*, *G. decipiens*, *G. gigantea*, *G. margarita*), two species *Acaulospora* (*A. laevis*, *A. rehmii*) and one species belonged to *Scutellospora* (*S. calospora*).

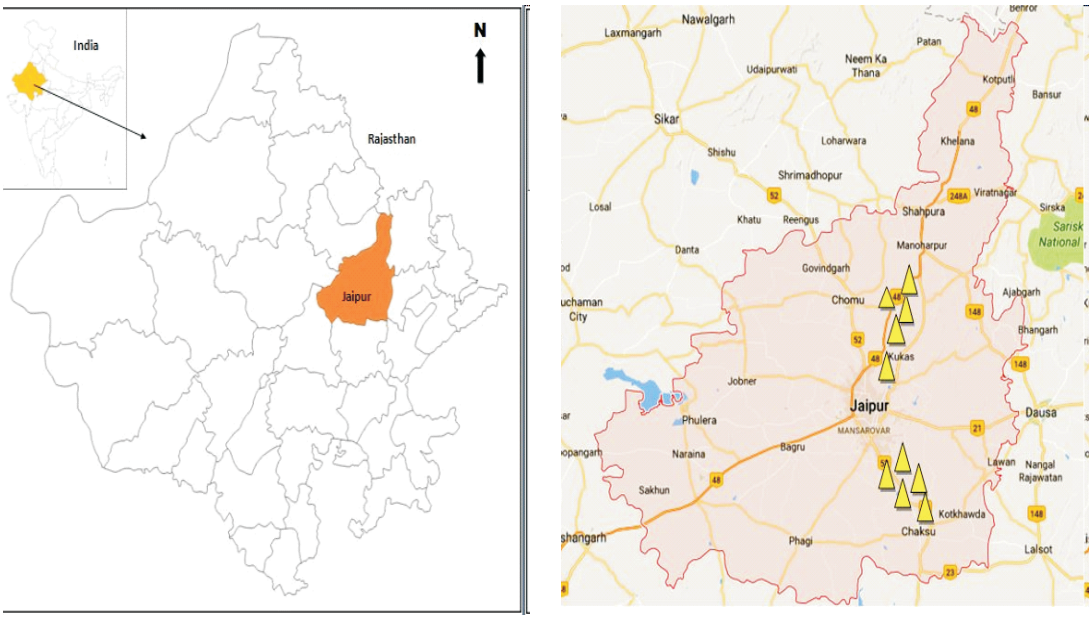
Table 1. Plant rhizosphere soil samples collected from different sites of Jaipur region

Sampling Sites	Crop
Beelwa Kalan	Pearl millet (Bajra)
Goner	Sorghum (Jowar)
Prahladpura	Sorghum (Jowar)
Shivdaspura	Pearl millet (Bajra)
Chaksu	Pearl millet (Bajra)
Amer	Sorghum (Jowar)
Kookas	Pearl millet (Bajra)
Dhand	Pearl millet (Bajra)
Bhanpur Kalan	Pearl millet (Bajra)
Achrol	Pearl millet (Bajra)

The AM fungal spores were identified on the basis of morphological characteristics such as spore wall, colour, size and type of hyphal attachment with the help of identification manual of Schenck and Perez (1990) and synaptic key of genera and species of Zygomycetous AM fungi (Trappe 1982).

Acaulospora laevis *(*Gerdemann and Trappe 1974*)***-** Spores smooth, globose to subglobose shape and size ranging from 120-280µm mostly. Orange-brown, most pale orange-brown colour and consist of a three-layered spore wall with hypha, yellow-brown outer wall, 2-4µm thick and inner two hyaline membranes.

Acaulospora rehmii (Sieverding and Toro 1987)- Spores mostly yellow-brown to dark yellowish orange-brown colour,



(Source: www.google.com/maps)

Fig. 1. Sample collection Sites marked in Jaipur district map

globose to subglobose and occasionally irregular shapes, size ranging from 100 to 160 µm and spore consist of a three-layered spore walls.

Glomus ambisporum (Smith and Schenck 1985)- Spore shape predominantly globose to occasionally subglobose, Spore diameter ranging from 85-193 µm, spore colour dark brown to black and spore wall composed of two-three layers.

Glomus etunicatum (Becker and Gerdemann 1977)– Single spore globose-sub globose shapes, orange-red-brown colour and diameter ranging 75-150 µm, spore layered with two walls, spore contents separated from attached hyphae by a thinly curved septum.

Glomus fasciculatum (Walker and Koske 1987)**-** *Spore* globose, ellipsoid or irregular *shapes* and spore size ranging from 75-149 µm, surface smooth to dull roughened, double walled; wall colour yellow with sporogenous hypha.

Glomus intraradices (Schenck and Smith 1982)- Spore globose- subglobose and sometimes irregular shapes with many elliptical shapes, diameter 98-119 µm, Spore colour yellow to light –brown; spores with one or two, occasionally up to three laminated walls on larger spores and also inner walls darker than outer walls.

Glomus maculosum (Miller and Walker 1986)- Spore globose or sub-globose shape, spore size ranging 130- 190 µm. Spore wall structure with two layers with inside growths of third spore wall with hypha attachment, Subtending hyphae straight to sharply recurved parallel sided or funnel-shaped constricted at the spore base, 5-25µm wide proximally 5-7µm.

Glomus macrocarpum (Tulasne and Tulasne 1845)- Spore subglobose or globose shapes, yellow-brown to dark orange-brown color, spore size ranging from 120 to 240 µm, spores consists of a three-layered spore wall.

Glomus mosseae (Gerdemann and Trappe 1974)**-** Spores pale yellow to brown in colour, circular, sometimes ellipsoid to irregular shape; spore size ranging from 120-300 µm with a hypha attachment. Spore surface smooth to dull roughened without ornaments and with consist of one wall with three layers.

Gigaspora albida (Schenck and Smith 1982)**-** Spore shape globose-subglobose, cream-yellowish colour, spore size ranging from 200-280 µm, smooth surface of the outer wall with subtending hypha. Spore walls three layers, the first two adherents and of equal thickness and third wall differentiates as an introduction to germ tube formation.

Gigaspora decipiens (Hall and Abbott 1984)**-** Spore shape globose to rarely irregular, colour pale yellow to light brown, spore size ranging from 300-460 µm, Spore wall with two-three-layered, Bulbous suspensor cells.

Gigaspora gigantea (Gerdemann and Trappe 1974)**-** Spore shape globose to subglobose, rarely irregular, greenish yellow colour, with a thin, outer wall tightly covering an inner

Table 2. Spore density, species frequency and abundance of AM fungal species from different sampling sites of Jaipur region

AMF species	Spore density (per 50g soil)										Species frequency (%)	Abundance (%)
	Beelwa Kalan	Prahladpura	Goner	Shivdaspura	Chaksu	Amer	Kukas	Dhand	Bhanpur Kalan	Achrol		
Glomus ambisporum	7	0	0	9	0	0	2	0	0	0	30	2.27
Glomus etunicatum	0	8	0	0	7	0	11	0	0	9	40	4.41
Glomus fasciculatum	13	14	9	11	12	6	13	13	12	18	100	15.24
Glomus intraradices	7	0	0	7	0	0	0	0	10	10	40	4.28
Glomus macrocarpum	12	7	11	0	12	0	4	0	0	5	60	6.42
Glomus maculosum	6	0	0	7	0	0	0	0	4	0	30	2.14
Glomus mosseae	17	14	11	19	12	9	6	16	13	12	100	16.25
Gigaspora albida	12	0	0	8	0	5	0	0	0	0	30	3.15
Gigaspora decipiens	0	13	12	13	15	9	13	12	14	11	90	14.11
Gigaspora gigantea	13	0	0	7	0	0	5	0	9	7	50	5.16
Gigaspora margarita	0	7	0	8	10	0	9	0	0	0	40	4.28
Acaulospora laevis	17	9	0	14	12	0	11	10	11	12	80	12.09
Acaulospora rehmii	0	6	0	3	0	0	0	0	0	0	20	1.13
Scutellospora calospora	0	10	10	7	15	0	9	0	13	8	70	9.07
Total spore density (per 50g soil)	104	88	53	113	95	29	83	51	86	92	-	100

* AMF= Arbuscular mycorrhizal fungi, %= Percent

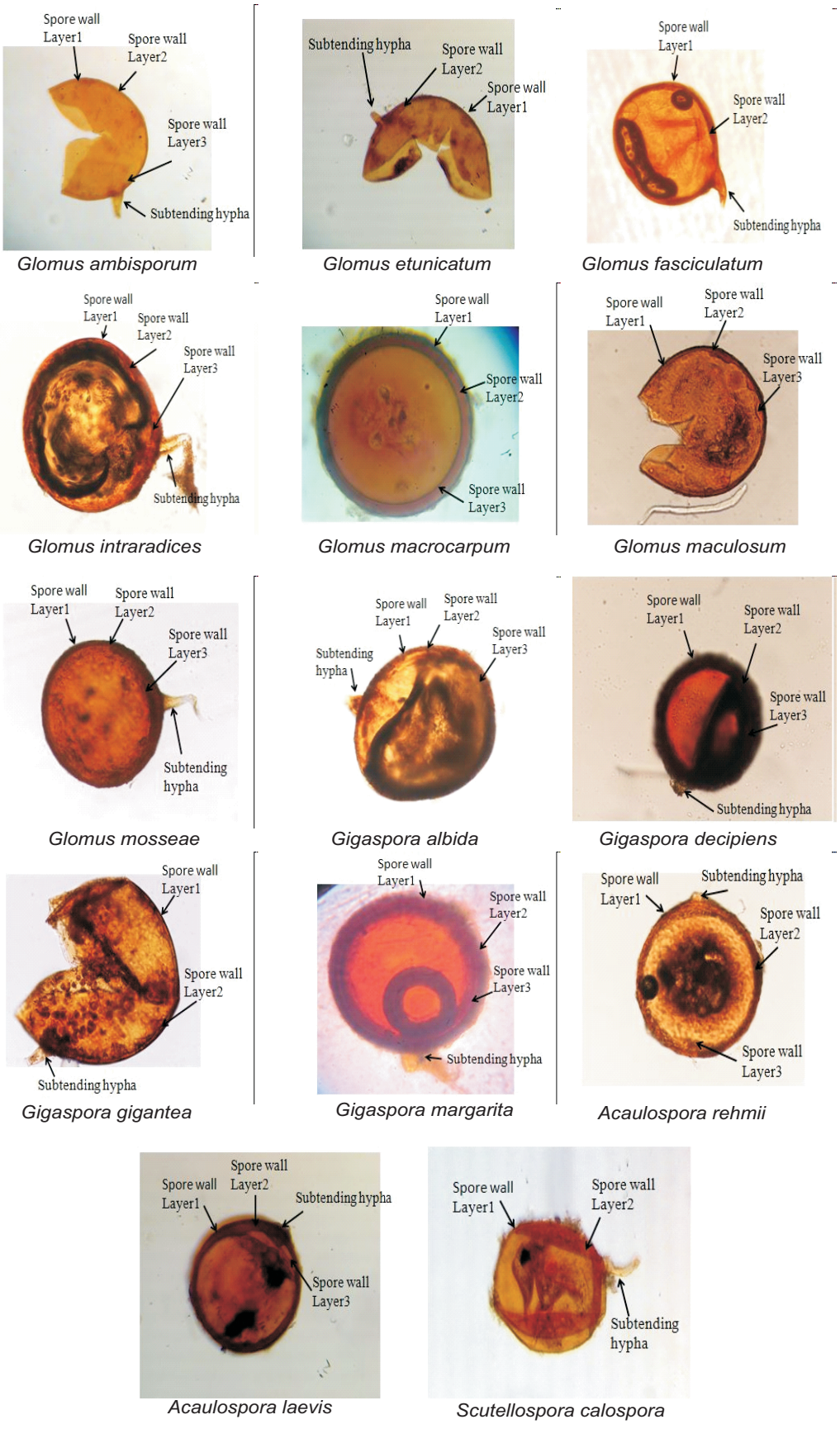


Fig. 2. Spores of different AM fungal species collected from soil samples. 100x

wall. Spore size ranging from 345-398 µm and Suspensor like cells bulbous.

Gigaspora margarita (Becker and Hall 1976)- Spore mostly globose shape, white-yellowish colour, spore size ranging from 240 to 400 µm, surface ornamentation at maturity smooth to dull roughened.

Scutellospora calospora (Koske and Walker 1986)**-** Spores produced singly on the apex of bulbous suspensor cell, Wide range, from subglobose to ellipsoid to oblong, sometimes irregular, pale yellow to greenish yellow colour, spore ranging size 285-360 µm. Spore wall consists of two bi-layered hyaline flexible inner walls.

Biodiversity of AM fungi: The highest species frequency of *Glomus mosseae* and *G. fasciculatum* (100%) and least frequency were reported of (20%) *Acaulospora rehmii* species (Fig. 3). The AM fungal spore density showed a variable range from 29 to 113 AM fungal spore, the highest spore in Shivdaspura sampling site (113 spores) while the lowest from Amer site (Fig. 4). The percentage of AM fungi spore abundance study showed a highest abundance of *Glomus mosseae* (16.25%) and *Glomus fasciculatum* (15.24%) with the lowest one as *Acaulospora rehmii* (1.13%) AM species (Fig. 5).

The diversity of Arbuscular mycorrhizal fungi in Jaipur region was also reported in a previous study (Pande and Tarafdar 2004, Gupta et al 2014). There are about 34 different species were reported from 11 wheat growing agro-climatic regions of India (Singh and Adholeya 2013). In this present study, few new AM fungal species (*Glomus ambisporum*, *Glomus maculosum, Acaulospora rehmii* and S*cutellospora calospora*) have also been isolated and identified for the first time from Jaipur region.

The species frequency of AM fungi in all sampling sites was analyzed and showed the highest frequency of *Glomus mosseae* and *G. fasciculatum* (100%) followed by *Gigaspora decipiens* and *Acaulospora laevis* and least species frequency was of *Acaulospora rehmii* (20%). The highest number of species frequency of AM fungi was reported at Shivdaspura sampling site and twelve species of AM fungi were recorded from this site. These include 5 species of *Glomus,* four species of *Gigaspora,* two species of *Acaulospora and one* species of *Scutellospora.* Lowest number of species of AM fungi was at Amer locality; these include two species each of *Glomus and Gigaspora.*

In general, among the observed species, *Glomus mosseae, Glomus fasciculatum* and *Gigaspora decipiens* are dominant species. These findings were similar to Damodaran et al (2010) where spores of all these species present in the rhizospheric soil of cotton cultivars. Sarkar et al (2016) identified and recorded close relationship of different

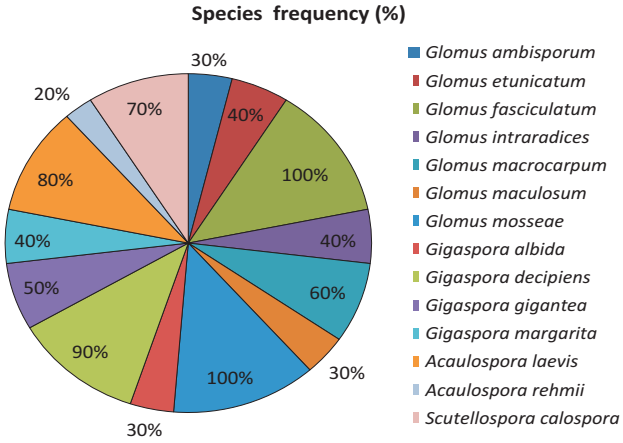


Fig. 3. Species frequency (%) of arbuscular mycorrhizal fungi

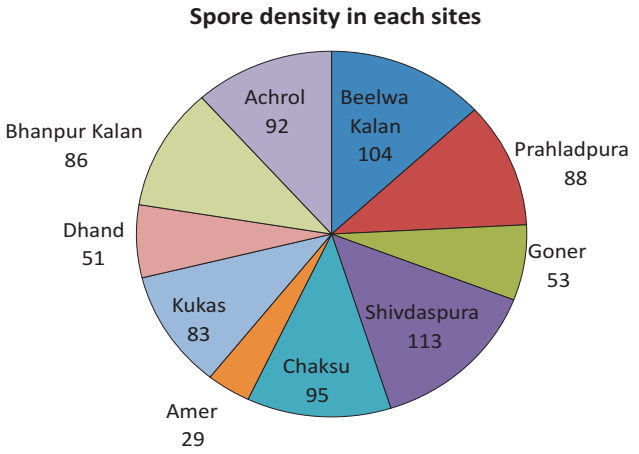


Fig. 4. Arbuscular mycorrhizal fungal spore density (total number of spores)

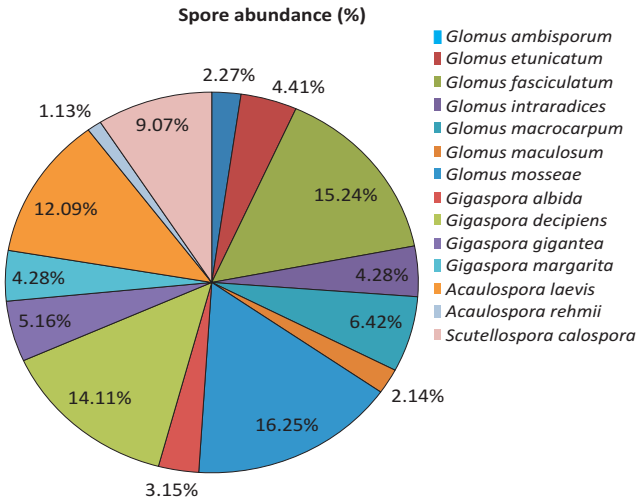


Fig. 5. Spore abundance (%) of Arbuscular mycorrhizal fungal species

species of *Glomus*, *Acaulospora*, *Gigaspora* and *Scutellospora* with the roots of *Citrus* plant.

CONCLUSION

The present survey study has demonstrated that the abundance and natural diversity of AM fungi in pearl millet and sorghum plants roots rhizospheric soil in semi-arid region. A total of four genera with 14 species of AM fungi were reported from Jaipur region. Among them, 7 species belonged to *Glomus*, 4 species belonged to *Gigaspora*, 2 species *Acaulospora* and one species belonged to *Scutellospora* genera and out of them four AM fungal sps. first time reported in Jaipur district (Rajasthan). The aspects of AM fungal ecology emphasizing past and present significance of the worldwide ecosystem function. AM fungi are acknowledged for their ability to improve soil and plant performances in antagonistic environments and under different stresses, especially drought and poor soil quality.

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Aquatic Insects as Indicator of Water Quality: A Study on a Small Stream of Shillong, Meghalaya, North-east India

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Abstract: Aquatic insects are widely used as indicator of water quality for many freshwater ecosystems. The present study was conducted seasonally in four different stretches of Umrisa Stream, Shillong, Meghalaya North-east India during 2015. Insects were collected using kick net method and all out search method. Analyses were done using Past software. A total of 9 orders, 25 families and 45 genera were recorded during the study. The diversity of aquatic insects was highest during pre-monsoon. Family Biotic Index (FBI) revealed good to excellent water quality across seasons and sites. Biological Monitoring Working Party Thailand ($BMWP^{THAI}$) Score and Average Score Per Taxon Thailand ($ASPT^{THAI}$) showed moderate and doubtful to good and clean water quality respectively. SingScore inferred Umrisa stream to have excellent water quality in all the seasons and sites. SIGNAL Score revealed the stream as mildly polluted to healthy habitat. This study revealed that different biological monitoring scores though differed with their results, overall reflected good water quality with signs of initiation of disturbance in the stream.

Keywords: Aquatic insects, Bioindicators, Water quality

Insects are group of organisms that are characterized by three pairs of legs and sometimes wings and are one of the largest groups of living beings on earth. They are categorized into aquatic and terrestrial insects. Aquatic insects are a group of insects that spend a part of their life in water and require aquatic ecosystems to complete their life cycle (Arimoro and Ikomi 2008, Pennak 1978). Their role in aquatic ecosystems are innumerable such as food for fishes and other invertebrates, predate on smaller insects, act as biocontrol agent and help in decomposition process (Yargal et al 2017). In forest streams, aquatic insects break down leaf litter supplying nutrients, carbon and energy to the stream and associated ecosystems (Balachandran et al 2012). Health and habitat quality of a stream can be determined by their relatively stable position and can express long-term changes about its quality than instantaneous conditions (Johnson et al 1993). Further they are very good indicators of water quality since they have various environmental disturbance tolerance level (Arimoro and Ikomi 2008). Any changes in their number and composition in the population at a given time and space can indicate a change in the water quality (Chauhan and Verma 2016). While some are vulnerable and sensitive to pollution, others can survive and proliferate in most disturbed and extremely polluted waters (Hepp et al 2013). Ephemeroptera, Plecoptera, Trichoptera, Coleoptera and Diptera are among the aquatic insects that are found abundantly in stream ecosystems (Subramanian and Sivaramkrishnan 2005). Anthropogenic activities such as domestic sewage, run-off from agricultural lands, laundering into streams and mining alters the structure and functions of the ecosystem and leads to reduction in biodiversity at different levels of biological organization (Medona et al 2015).

The northeastern biogeography zone of India represents the transition zone between the Indian, Indo-Malay and Indo-Chinese biogeographic regions and a meeting place of Himalayan Mountains with those of Peninsular India. Shillong, Meghalaya is located in the Indo-Burma biodiversity hotspot (Myers et al 2000). Hence fauna and flora of the area is unique. Shillong belongs to one of the north-eastern states of India and is a tourist place with aesthetic values of biodiversity. Thereby, there is a much needed conservation strategies of the unique faunal and floral diversity of such place. Although there are studies on hill stream fishes of streams of Meghalaya (Dey et al 2014), aquatic insects are not explored except a few (Gupta and Michael 1992, Gupta 1993 and Muranyi and Li 2013). The stream Umrisa originating from Shillong peak passes through a forest and continues its journey through urban area of Shillong. Since no study on fauna of this stream has been documented so far we tried to explore the aquatic insect community of this stream in different stretches in different seasons and attempted to confirm their role as bio indicator of

pollution. Such study is of immense importance as eastern Himalayan region is data deficient (Allen et al 2010).

MATERIAL AND METHODS

Study area: Shillong (25.5667° N, 91.8833° E) is the capital of Meghalaya, India and is the headquarters of the East Khasi Hills district, Northeastern region. It is situated at an average altitude of 4,908 feet (1,496 m) above sea level, with the highest point being Shillong Peak at 6,449 feet (1,966 m). It lies in the centre of the Shillong plateau surrounded by three hills-Lum Sohpetbneng, Lum Diengiei and Lum Shillong. The study was carried out at a small stream of Shillong locally known as Umrisa (altitude-1611m) and has rocky substratum. It flows through the forests of Lumparing that connects with other channels to join the Umshirpi stream. Shillong peak is the interfluves for many headwater streams flowing through the forests (Fig. 1). Four sites were selected for this study (U1- Upstream, U2 – Upper midstream, U3 – Lower midstream and U4 –downstream). Aquatic insect **s**amples were collected seasonally, that is, pre- monsoon (PRM) (March-May), monsoon (MON) (June-Aug), post-monsoon (PSM) (Sept-Nov) and winter (WIN) (Dec-Feb) in three replicates from each site during 2015.

In upstream, an 'all out search' method was followed for collection of aquatic insects due to the high turbulence terrain where aquatic insects were searched and collected from substrata such as bed rocks, boulders, cobbles, leaf litter and dead wood. In midstream, aquatic insects were sampled by using a hand net (mesh size 40µm) by 'Kick' method (Macan and Maudsley 1968, Brittain 1974). Aquatic insects on water surface of the downstream were collected with a nylon pond net (mesh size: 500 µm; diameter: 30 cm; depth: 15 cm). An 'all out search' method was further employed in all the targeted habitats for better collection of those aquatic insects (Subramanian and Sivaramakrishnan 2007). Insects were fixed at the field with 4 per cent formalin and later preserved at 70 per cent ethyl alcohol. They were identified upto genus level using standard identification keys (Bal and Basu 1994a, b, Pennak 1978, Pescador et al 1995,Thirumalai 2002, Sivec and Yule 2004, ZSI 2004, Zwick 2004, Webb and Maccafferty 2008, Bouchard 2009, Epler 2010, Madden 2010, Webb and Suter 2011) using an imported Motic Stereoscopic Zoom Trinocular Microscope (SMZ – 168TL0).

Biological indices: Five biological indices were used to monitor the impact of disturbance on the stream during the four seasons at different sites. The indices used for the study included Family Biotic Index (FBI) (Armitage et al 1983), Biological Monitoring Work Party Thailand ($BMWP^{THAI}$) Score and Average Score Per Taxon Thailand ($ASPT^{THAI}$) (Mustow 2002), SingScore (Blakely et al 2014) and Stream Invertebrate Grade Number – Average Level (SIGNAL) (Chessman 1995). Relative abundance of the collected aquatic insects was also determined using MS excel spreadsheets. Dominance status was computed using Engelmann's Scale (1978). Diversity Indices such as Shannon Diversity index (H'), Shannon Evenness index (e^H/S), Margalef index and Berger-Parker index of dominance were also computed using Past software.

RESULTS AND DISCUSSION

This study recorded 9 orders, 25 families and 45 genera of aquatic insects. The highest number of orders was during PRM (U1), PSM (U3 and U4) and lowest during WIN (U3). The highest number of families was during WIN (U2) and PRM (U3) and the lowest during WIN (U3). The highest number of genera was recorded during PRM (U1) and lowest during WIN (U3) (Fig. 2). The orders and families are Ephemeroptera (Heptageniidae, Leptophlebiidae, Baetidae), Plecoptera (Perlidae, Nemouridae, Leuctridae), Trichoptera (Hydropsychidae, Lepidostomatidae, Polycentropodidae, Rhyacophilidae, Hydrobiosidae, Ecnomidae), Diptera (Simuliidae, Chironomidae, Tipulidae), Coleoptera (Gyrinidae, Dytiscidae, Hydrophilidae, Elmidae), Odonata (Euphaeidae, Synlestidae, Coenogrionidae), Hemiptera (Gerridae, Hebridae), Blattodea (Blaberidae) and Megaloptera (Corydalidae). Prommi and Payakka (2015) recorded 9 orders and 59 families at Mae Tao and Mae Ku watersheds, Thailand. Wahizatul et al (2011) studied aquatic insect community composition and distribution in relation to water quality in two freshwater streams of Hulu Terengganu, Thailand and documented 9 orders and 42 families during the study period.

The density of aquatic insect community of stream Umrisa was highest during PRM at U4 (Fig. 3). MON was the season with low density of insects in almost all the sites. Ephemeroptera was the most dominant order among the 9 orders during WIN (U3) followed by Trichoptera during WIN (U1) and Diptera during PRM (U2). Plecoptera was abundant during PRM (U3) but not eudominant. The least dominant order was Blattodea (Fig. 4). The presence of Ephemeroptera, Plecoptera and Trichoptera (EPT) at the stream during PRM (all sites), MON (U3 and U4), PSM (U1, U2 and U3) and WIN (U1, U2 and U4) can indicate good and clean water quality condition. These groups are considered as sensitive to changes in environmental stress and their presence and abundance at the sites during the seasons mentioned above signified a relatively clean ecosystem. The taxa *Notacanthurus baei*, *Thalerosphyrus sinuosus*, (Heptageniidae, Ephemeroptera) *Offadens* sp., (Baetidae, Ephemeroptera) *Indonemoura* sp., (Nemouridae,

Plecoptera), *Diplectrona modesta* (Hydropsychidae, Trichoptera) and *Lepidostoma* sp. (Lepidostomatidae, Trichoptera) were recorded in all the four seasons in different sites of the stream (Fig. 5). All the above taxa except *Diplectrona modesta* and *Indonemoura* sp. were eudominant in the 3 sites (U2, U3, and U4) at least in any one of the 4 seasons based on the Engelmann's Scale (1978). No eudominant taxa was recorded in U1, indicating that the

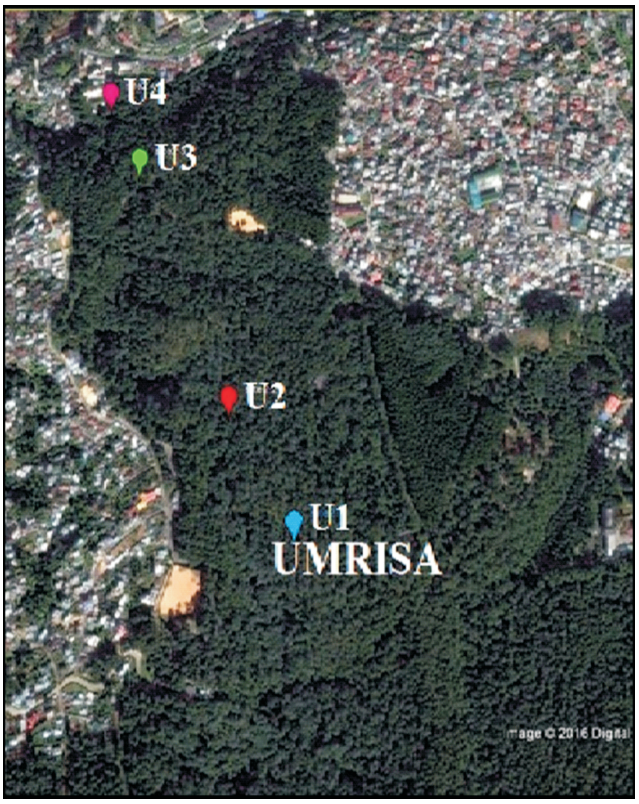

Fig. 1. Google earth map showing stream Umrisa

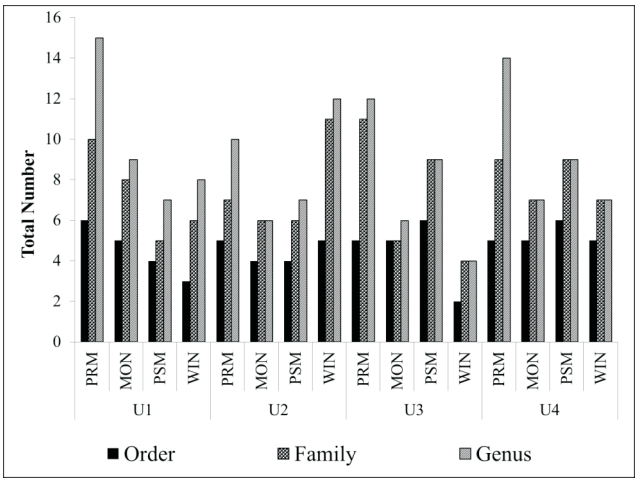

Fig. 2. Temporal and spatial variations in number of orders, families and genera of aquatic insects in the stream Umrisa

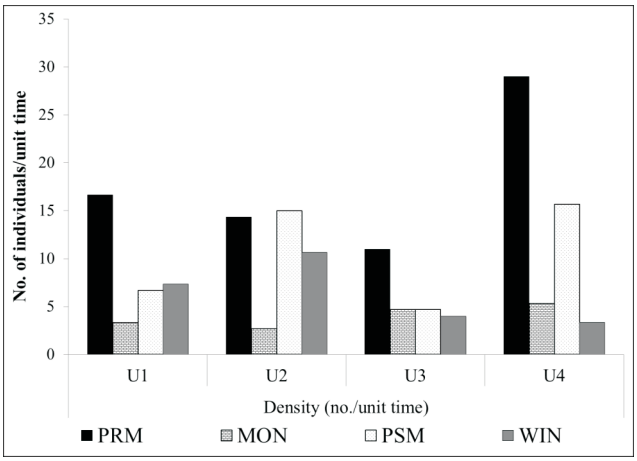

Fig. 3. Temporal and spatial variations in the density (number of individuals/ unit time) of aquatic insects in the stream Umrisa

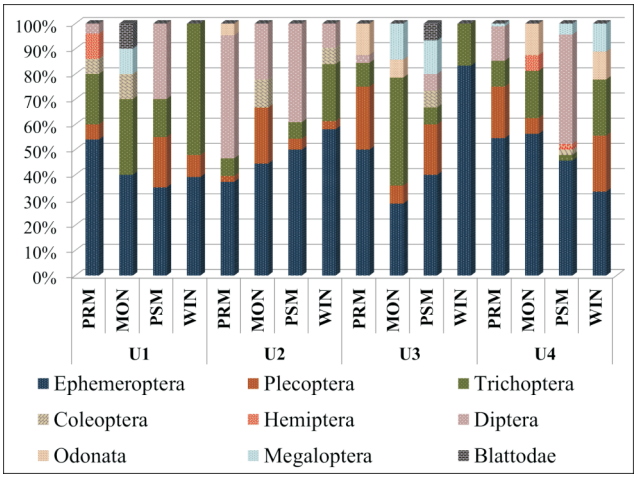

Fig. 4. Temporal and spatial variations in relative abundance of aquatic insect orders of stream Umrisa

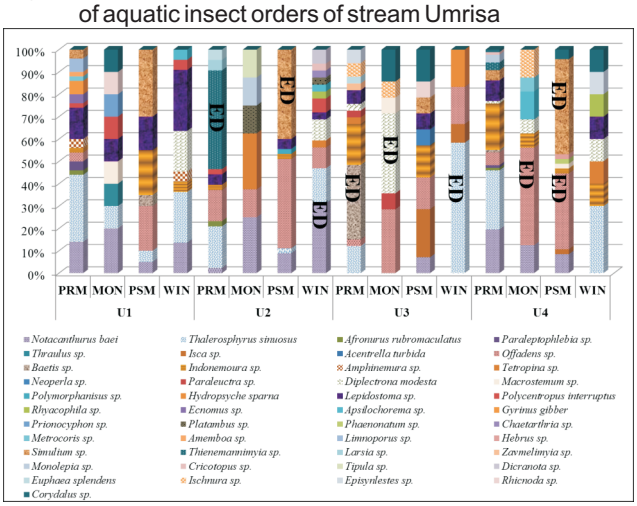

Fig. 5. Temperol and spatial variations in relative abundance and dominance status of aquatic insects of the stream Umrisa using Engelmann's Scale. [<1% - Sub-Recedent (SR), 1% - 3.1% - Recedent (R), 3.2% - 10% - Sub-Dominant(SD), 10.1% - 31.6% - Dominant (D), > 31.7% - EuDominant (ED)].

stream insects present at the site has plenty of food resource and refuge in the form of microhabitat, hence causing less intrusion among interspecies. In rest of the sites altogether seven eudominant taxa were recorded in different seasons. *Thienemannimyia* sp. (Chironomidae, Diptera), *Baetis* sp. (Baetidae, Ephemeroptera), *Notacanthurus baei* and *Thalerosphyrus sinuosus* (Heptageniidae, Ephemroptera) were eudominant during the dry season while *Simulium* sp.(Simuliidae, Diptera), *Offadens* sp. (Baetidae, Ephemeroptera) and *Diplectrona modesta* (Hydropsychidae, Trichoptera) were recorded as eudominant during the wet seasons. The occurrence of the two genera belonging to the same family (*Baetis* sp. and *Offadens* sp: Baetidae) as eudominant in contrasting seasons is noteworthy. Suhaila et al (2011) inferred that Baetidae family in particular and Ephemeroptera order in general was present during dry as well as wet seasons in Teroi River although the abundance of these aquatic insects increased tremendously in wet season. The 7 eudominant taxa recorded in the present study are known to flourish either in polluted or moderately polluted water. Although Ephemeroptera and Trichoptera are known to be sensitive groups (Resh and Rosenberg 1984) and Trichopterans immature larvae survive and flourish in running waters greater than any in other freshwater body (Wiggins 1996, Daly et al 1998) studies have shown that the families Baetidae and Hydropsychidae are common and abundant families in mildly polluted waters in some regions (Ratia et al 2012, Xu et al 2013). *Diplectrona modesta* (Hydropsychidae), a Trichoptera was eudominant at U3 during monsoon (MON). It is also one of the tolerant taxa to organic pollution (Sivaramakrishanan et al 1996).

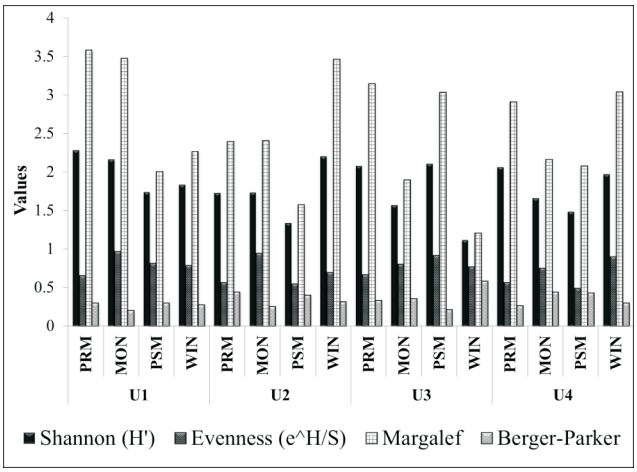

Fig. 6. Temperol and spatial variations in the Shannon diversity index (H'), Shannon evenness index (e^H/S), Margal of index and Berger-Parker index of dominance values of aquatic insects in the stream Umrisa

Table 1. Temperol and spatial variations in BMWP^{THAI}, APST^{THAI}, FBI, SingScore and Signal Score of Umrisa stream

Biological indices	Seasons	U1	U2	U3	U4
FBI	PRM	3.38 (E)	4.88 (G)	3.38 (E)	3.56 (VG)
	MON	3.13 (E)	3.38 (E)	3.5 (E)	4.62 (G)
	PSM	3.75 (VG)	4.57(G)	2.31(E)	4.68 (G)
	WIN	3 (E)	3.93 (VG)	3.83 (VG)	3.22 (E)
BMWP^{THAI}	PRM	69 (G)	46 (M)	77 (G)	57 (G)
	MON	56 (G)	36 (M)	29 (M)	45 (M)
	PSM	36 (M)	41(M)	60 (G)	46 (M)
	WIN	57 (G)	78 (G)	29 (M)	59 (G)
ASPT^{THAI}	PRM	6.9 (C)	6.6 (C)	7 (C)	6.33 (C)
	MON	8 (C)	6 (C)	5.8 (D)	6.4 (C)
	PSM	7.25 (C)	6.8 (C)	7.5 (C)	5.75 (C)
	WIN	8.14(C)	6.5 (C)	7.25 (C)	7.38 (C)
SingScore	PRM	156.67 (E)	144 (E)	155 (E)	140 (E)
	MON	175 (E)	126.67(E)	135 (E)	103.33 (E)
	PSM	153.33 (E)	150 (E)	168 (E)	153.33 (E)
	WIN	175 (E)	133.33 (E)	165 (E)	170 (E)
SIGNAL Score	PRM	8.79 (HH)	6 (HH)	6.76 (HH)	7.08 (HH)
	MON	8.13 (HH)	9 (HH)	5.88 (MP)	5.75 (MP)
	PSM	6.13 (HH)	6.38 (HH)	7.7 (HH)	5.73 (MP)
	WIN	7.67 (HH)	6.63 (HH)	8.17 (HH)	7.75 (HH)

M – Moderate, G – Good, C – Clean, D – Doubtful, E – Excellent, VG – Very Good, HH – Healthy Habitat, MP – Mild Pollution

Again the occurrence of *Baetis* sp. and *Offadens* sp. (Baetidae, Ephemeroptera) in abundance could suggest that they are tolerant to the anthropogenic influences (Arimoro et al 2011, Suhaila et al 2011). *Baetis* sp. is also considered to change its assemblages based on its tolerant capability with the surrounding environment (Margolis et al 2001). Arimoro and Muller (2010) concluded that the overall composition and density of Ephemeroptera is based on the physico-chemical and biological factors of the environment. *Simulium* sp. (Simuliidae) and *Thienemannimyia* sp. (Chironomidae) belong to the order Diptera and are indicators of organic pollution (Simpson and Bode 1980). Yule (2000) stated that Simuliidae and Chironomidae are probably the most diverse and abundant group of all stream macroinvertebrates.

Diversity of insect fauna in aquatic ecosystems can be a significant factor as higher diversity indicates increased nutrients and larger microhabitat diversity and better water quality conditions (Hepp et al 2013). Shannon diversity index (H') was above 1 ranging from 1.119 to 2.284 during the study period (Fig. 6). The highest Shannon diversity index (H') and Margalef index values were recorded during PRM at U1 while highest Evenness index value was also recorded at U1 during MON. At U1 the values of Evenness index (e^H/S) did not fluctuate much in different seasons reflecting relatively even distribution of taxa in upstream. The Margalef index value being more than 3 indicated clean condition (Lenat et al 1980). This could be the reason that there were no eudominant taxa at this site since the aquatic insects inhabits simultaneously and harbor the immense resource available. Thus Berger-Parker index of dominance value was lowest during MON at U1. Aquatic insect diversity index of Umrisa stream is comparatively similar to the diversity index of Aghanashini River studied by Balachandran et al (2012).

Biological Indices are family-level water pollution index based on the tolerance values and sensitivity grades assigned to those aquatic macro invertebrate families against pollutants. FBI scores revealed variations in different seasons and sites (Table 1). FBI values obtained inferred excellent water quality in all the seasons except PSM at U1. U2 had excellent water quality only in MON while U3 had excellent water quality in all the seasons except WIN. U4 had excellent water quality during WIN. No site showed poor water quality. $BMWP^{THAI}$ Score based on aquatic insect community revealed U1 to have good water quality during the three seasons except PSM where water quality was moderate. U2 had good water quality in WIN and moderate water quality in rest of the seasons.U3 had moderate quality of water during MON and WIN, and good quality during PRM and PSM. U4 possessed moderate water quality at MON and PSM while good water quality during PRM and WIN.

Table 2. Interpretation table of the Biological Indices used in assessing the water quality of Umrisa stream

Interpretation											
FBI (Hilsenhoff, 1988)		$BMWP^{THAI}$ (Mustow 2002 and Mason 2002)		$ASPT^{THAI}$ (Mustow 2002 and Mason 2002)		Singscore (Stark and Maxted, 2007)		Signal score (Gooderum and Tsyrlin, 2002)	
Range	Water quality	Range	Water quality	Range	Water quality	Range	Water quality	Range	Water quality
0.00 -3.50	Excellent	0 - 16	Poor quality	> 6	Clean water	< 80	Poor	>6	Healthy habitat
3.51 - 4.50	Very good	17 - 50	Moderate water quality	5 – 6	Doubtful quality	80 - 90	Fair	Between 5 and 6	Mild pollution
4.51 - 5.50	Good	51 - 100	Good water quality	4 – 5	Probable moderate pollution	100 - 119	Good	Between 4 and 5	Moderate pollution
5.51 - 6.50	Fair	101 - 150	High water quality	< 4	Probable severe pollution	120 +	Excellent	<4	Severe pollution
6.51 - 7.50	Fairly poor	151 +	Very high water quality						
7.51 - 8.50	Poor								
8.51 - 10.0	Very poor								

According to ASPT^{THAI} Score, Umrisa stream appeared as clean water quality at all seasons for all the four sites except U3 during MON. Overall the quality of stream water according to BMWP^{THAI} and ASPT^{THAI}, throughout the study period was moderate to good. The site that showed consistency to a good water quality was U1, which appeared moderate only once that is, during the winter season (WIN). Human intervention could be the only reason of minor fluctuations between moderate and good water quality of the stream water across the seasons and sites. Again SingScore indicated excellent water quality of stream Umrisa in different seasons and sites. SIGNAL Score indicated healthy habitat at U1 and U2 in all the seasons while at U3 and U4, mild pollution appeared during MON (U3 and U4) and PSM (U4). According to Gitarama et al (2016) among the biomonitoring scores, FBI is more suitable to use, as the index is more specific in the assessment of the sensitivity of aquatic organisms towards their environmental conditions.

CONCLUSIONS

Aquatic insects of stream Umrisa used as biological indices tool has helped to reveal the water quality. Overall, these indices indicated good water quality in upstream. However, as it flowed downstream, sign of deterioration was evident. The distribution, composition and sensitivity of aquatic insect communities are therefore, useful as bioindicators in biomonitoring of any freshwater system.

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Appraisal of Nutritional Values and Antimicrobial Activities of Garlic, Cinnamon, Black Pepper and Aloe Vera Powder

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Abstract: The present study was conducted to evaluate the nutritional value of Garlic, Cinnamon, Black pepper and Aloe vera powder along with their in vitro antimicrobial activities**.** Analysed values of the herbs reflected the appreciable contribution toward nutritional basket of the user. Crude protein content of these herbs varies from 3.16 (aloe vera) to 13.69 per cent (garlic powder). Black pepper has comparatively high fat percentage (3.66%). Aloe vera Powder was identified as good source of calcium, zinc and iron. Antimicrobial properties of these herbs powder were checked by using disc diffusion method against the most common pathogen *E. coli* and *Salmonella spp*. Ethanolic extract at three different levels for each herb was used, garlic and aloe vera extracts were used at 1.0, 1.5 and 2.0 percent levels and cinnamon and black pepper extracts at 0.5, 1.0 and 1.5 per cent levels. *E. coli* is sensitive to black pepper at 1.5 per cent level and show intermediate to low sensitivity to 1.0 and 0.5 percent black pepper extract. *E. coli* exhibited intermediate sensitivity to 1.0 and 1.5 per cent ethanol extract of cinnamon. Ethanolic extract of black pepper at 1.0 and 1.5 per cent levels also exhibited antimicrobial properties against *S. typimurium*. The black pepper and cinnamon beside having nutritional value for consumer posses antibacterial activities against *E. coli* and *S .typimurium.*

Keywords: *Aloe vera*, Black pepper, Cinnamon, Garlic, Antimicrobial activity, Nutritional composition

Herbs are other plant based products are used in various traditional medicines since the time immemorial. The use of herbs and other natural products also known as phytogenic or phytobiotic has become increasingly popular in human as well as in livestock owing to their multiple positive effects on the health (Puvaca et al 2013). These natural products or herbs improves the gut micro-flora (Peric et al 2009), modify the digestive secretion/morphology (Jamroz et al 2003), which increases/ improves the digestibility of the nutrients and ultimately the performance (Kroismayr et al 2008). They exert their beneficial effect by two means (Hashemi and Davoodi 2011) as flavouring agents, which include appetizing, sensory, palatability and flavour enhancing properties and another as enhancing biological activities, which include antibacterial (Hashemi and Davoodi 2010), antiviral (Burt 2004), antifungal, antioxidants (Windisch et al 2008), anti-inflammatory, anti-stress, enhancing enzymatic digestibility and immuno-stimulatory activities (Hashemi and Davoodi 2011). The herbs are now gaining popularity as growth promoters, alternative to antibiotic growth promoters (Singh 2015) or for providing the designing effect in animal produce especially of poultry and pig farming origin. Garlic (*Allium sativum*) possesses antibacterial, antifungal, anti-parasitic, antiviral, antioxidant as well as antithrombotic, vasodilator and anti-cancerous properties Black pepper (*Piper nigrum*) has antioxidant properties and its consumption exerts several health beneficial effects by virtue of having innumerable therapeutic potential to cure fever, asthma, cold, cough and other general health disorders. Cinnamon (*Cinnamomum cassia*) having antimicrobial properties related to its cinnamaldehyde content followed by eugenol and carvacrol which possess antimicrobial activity against a wide range of bacteria (Chang et al 2013). Similarly, *Aloe vera* is having many beneficial effects such as anti inflammatory, anti-coccidial, antiulcer, immuno booster, etc.

Ample overseas studies are available indicating the positive influence of these herbs on the consumer health but data on nutritional composition *vis a vis* their antibacterial activities in our locally available herbs is scarce. So the present study was planned to evaluate these four commonly used herbs for their nutritional composition and antibacterial properties.

MATERIAL AND METHODS

Garlic bulbs were procured from Punjab Agricultural University, Ludhiana and bulbs were fragmented into pieces and paste was prepared, which was then sun dried and grounded to obtain whole bulb garlic powder (GP). Whole aloe leaves were procured from the farmer of Hoshiarpur

district of Punjab. These leaves were first dried by blowing solar hot air in the Animal Nutrition Department, GADVASU. These semidried leaves were then chopped and sun dried and grounded to obtain the requisite whole leaves *Aloe vera* powder (AVP). Cinnamon bark and black pepper were procured from local market, dried and grounded to obtain the cinnamon (CNP) and black pepper powder (BP), respectively. Proximate principles viz dry matter (DM), crude protein (CP), ether extract (EE), crude fibre (CF), ash and acid insoluble ash (AIA) and hosphorus (P) of herbs were carried out as per standard methods (AOAC 2000). Calcium (Ca), trace minerals (copper (Cu), Zinc (Zn), iron (Fe), manganese (Mn) and gross energy(GE) were estimated by Talapatra method (Talpatra et al 1940), atomic absorption spectrometer and adiabatic bomb calorimeter techniques, respectively. For pH estimation of herbs - 100 g powder of each herb were taken in 100 ml of distilled water and were mixed well and left for 48 hours. Again shaken to mix well and filtered using Whatman filter paper no.1. The pH of the filtered solutions was measured with the help of pH meter. *In vitro* antibacterial studies of these herbs were conducted in Department of Veterinary Microbiology, GADVASU, Ludhiana. The grounded herbs were mixed with pure ethanol to prepare 1.0, 1.5, 2.0 concentrations .The mixtures were kept for 5-7 days in tightly sealed vessel at room temperature protected from direct sunlight and mixed several times daily with a sterile glass rod. The mixture is filtered through muslin cloth and procedure was repeated 3-5 times until a clear colourless supernatant extraction liquid was obtained. Antimicrobial activities of herbs were tested by using the paper disc agar diffusion method (Mukherjee et al 1995). Standard strains of *E. coli* and *Salmonella* spp. available in the department were used in this study. In order to detect potential antimicrobial activity in the plant extract, paper discs of approximately 7 mm diameter were soaked in extraction solutions of different concentration. Entire surface of agar plate was inoculated with the culture of bacteria used for present study. The paper discs soaked in each of the test solution containing different extract solution at varying concentration were placed separately in each quarter of the plate under aseptic conditions. Three discs per plate (three replication) were kept for each of the extraction. The plates were then maintained at room temperature for 2h allowing the diffusion of the solution. All plates were then incubated at 37°C for 24 hour.

RESULTS AND DISCUSSION

Nutritional composition of herbs: Highest moisture content was in black pepper and lowest was in AV powder (Table 1). Protein content of these herbs varied from 2.81(AVP) to 13.69 (GP). Highest fat content was observed in BP (3.66) followed by AVP, GP and CNP.

The crude fibre content was highest in CP (30.00) and lowest in GP (10.82). Total ash and AIA content of these herbs showed highest percentage in AVP followed by GP, CP and BP, respectively. The maximum calcium content was analysed in AVP followed by CP, BP and garlic, respectively in a sequential manner. Copper content in these herbs varied between 4.37 (AVP) and 15.84 (BP). Zn content was maximum in AVP followed by GP, CP and BP, respectively.

Table 1. Nutritional composition of herbs

Parameters (%)	Garlic powder (GP)	Cinnamon powder (CNP)	Black pepper powder (BP)	*Aloe vera* powder (AVP)
DM	91.22	90.15	88.31	92.77
CP	13.69	5.26	10.71	3.16
EE	1.63	1.61	3.66	1.85
CF	10.82	30.0	21.09	25.80
Ash	8.76	5.74	5.09	15.67
AIA	2.34	0.15	0.05	3.00
Ca	0.2	0.95	0.50	3.10
P	0.43	0.10	0.13	0.27
Cu ppm	4.37	6.68	15.84	4.37
Zn ppm	32.09	16.87	12.58	50.58
Fe ppm	188.5	184.0	85.40	372.9
Mn ppm	1.414	ND	ND	1.325
Gross energy (Kcal kg^{-1})	3615.30	4553.8	3668.13	3132.31
pH	4.02	4.62	4.41	5.19

DM= Dry matter, CP= Crude protein, EE= Ether extract, CF= crude fibre, AIA= Acid in soluble ash, Ca= Calcium, P= Phosphorus

Iron content was highest in AVP (372.9 ppm) and lowest in BP (85.40 ppm). Gross energy content of these four herbs ranged between 3132.31kcal kg^{-1} (AVP) and 4553.8 kcal kg^{-1} (CP). Nwinuka et al (2005) reported 4.88, 17.35, 0.68 and 0.73 per cent moisture, crude protein, ether extract and total carbohydrate with 3676.4 kcal kg^{-1} energy in garlic powder. Pure garlic powder contained 5.61, 16.8, 0.76, 3.18, 0.21 percent moisture, protein, fat, total ash, acid insoluble ash and 332cal energy in 100gm (Raeesi et al 2010). Nutritive value of cinnamon as reported by Gul and Safdar (2009) posses 5.1, 3.5, 4.0, 2.4, 33.0, 52 percent moisture, crude protein, crude fat, ash, crude fibre, NFE and 2580 kcal kg^{-1} gross energy. However, Farhath et al (2001) reported higher energy value of cinnamon. This might be due to variation in cinnamon species evaluated. In black pepper, values reported by Shafiq et al (2010) for moisture, ash and crude protein content are close to the analysed values observed in this study however, ether extract value is lower. Similarly values for moisture, total ash, acid insoluble ash, ether extract and energy value of whole leave *Aloe vera* powder are in agreement with Haque et al (2014) except crude protein (10.5%), which was substantially higher than the CP (2.81%) obtained in the present study. Ahmed and Hussain (2013) reported the higher values for ash, crude fibre, protein and fat in *Aloe vera* leaves powder as compared to the values obtained in the present study. This difference in composition of these herbs observed could be due to variation in variety over different areas, sowing practices, soil composition, harvesting method, processing methods and procedural difference of evaluation.

***In vitro* antibacterial studies of herbs:** Both *E. coli* and *Salmonella typhimurium* were resistant to garlic extract at all the three levels (Table 2). Similarly, no antibacterial activities of *Aloe vera* extracts were noticed against both the bacteria studied. *S. typhimurium* was resistant to all the cinnamon levels and *E. Coli* to 0.5% extract of cinnamon, however, show intermediate sensitivity to 1.0 and 1.5% cinnamon extract. *E. coli* was sensitive to 1.5% black pepper extract and has intermediate sensitivity to 1.0 % and low to 0.5%. Similarly, *S. typhimurium* was sensitive to 1.5% black pepper extract and show low sensitivity to 1.0% black pepper extract. The results of earlier studies provide evidence that some medicinal plants might indeed be potential sources of new antibacterial agents even against some antibiotic- resistant strain (Kone et al 2004). Present results are contrary to Shafique et al (2010) who reported that *E. coli* and *Salmonella typhimurium* are resistant to ethanolic extract of black pepper and cinnamon at the level of 30µl/disc. However, Thakare (2004) observed that cinnamon extract at 130mg $disc^{-1}$ exhibited antibacterial activity against *E. coli*, *S. typhimurium* and *E. faecalis.* Contrary to present study, Kwon et al (2011) reported the significant antibacterial activity of *Aloe vera* peel extract in distilled water against *E. coli* and *Vibrio* spp. The alkaloid (piperine, piperidine in black pepper and cinnamaldehyde, cinnamate etc in cinnamon) and essential oils present in these herbs might be responsible for these antibacterial activities.

Table 2. *In vitro* antibacterial studies of herbs

Herbs	Extract concentration (%)	Effect on microorganism	
		E. Coli	*S. typhimurium*
Garlic	1.0	-[1]	-
	1.5	-	-
	2.0	-	-
Aloe vera	1.0	-	-
	1.5	-	-
	2.0	-	-
Cinnamon	0.5	-	-
	1.0	++[2]	-
	1.5	++	-
Black pepper	0.5	++	-
	1.0	++	++
	1.5	+++[3]	+++

1 "- " refers to no antibacterial effect of corresponding plants to the mentioned bacterial strain at mentioned dose. 2"++"and 3"+++" refers to intermediate and high antibacterial effect respectively of corresponding plants to the mentioned bacterial strain at mentioned dose.

CONCLUSION

The garlic and black pepper powder are o good source of protein and fibre, cinnamon of copper while aloe vera of zinc and iron. Besides nutritional value, black pepper and cinnamon posses' antibacterial activities against *E. coli* and *Salmonella typimurium.* So, these herbs can be used in poultry and piggery where they can be used as viable alternative to much hyped antibiotic growth promoters without altering the nutritional composition of feed.

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Effect of Different Land Use Systems on Soil Carbon Storage and Structural Indices in Abakaliki, Nigeria

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***Abstract*:** Land use systems were studied to determine their relative capacities for soil carbon storage) and its effect on structural indices in 2015 and 2016. Soil samples collected from three depths in each LUS were analyzed for SCS, bulk density, total porosity, aggregate stability and dispersion ratio. Most of the parameters showed moderate (CV%>20) to high (CV%>50) coefficients of variation and non limiting values for soil productivity and stabilization in some seasons and depths. Sewage sludge dumped soil use consistently maintained higher SCS and soil stabilization more than other land uses in some seasons and depths. Carbon iv oxide emission and high soil structural stabilization could be achieved by practice of good land use system.

Keywords: Carbon storage, Capture, Indices, Land use system, Soil

Soil carbon storage has emerged as a plausible strategy for mitigating increasing atmospheric concentration of carbon iv oxide. As a geo-engineering technique, it involves long term storage of CO_2 and other forms of carbon for mitigation of global and climate change. The process entails capturing waste carbon dioxide from large point sources such as fossil site where it is deposited underground so that it does not enter into the atmosphere (Fanchi and Bertard 2016). Through this process, fossil fuel emissions, global warming, climate change and ocean acidification could be attenuated. Agriculture is placed strategically as a means of combating carbon iv oxide emission as it provides veritable plants for sequestering carbon iv oxide and finally converting it to organic matter (Velasco 2016). Management practice that could ensure soil carbon storage (SCS) is imperative and should conform to principles obtainable under sustainable agriculture. These include reduced tillage, erosion control, diversified cropping systems, improved soil fertility programmes and efficient land use systems should be encouraged as carbon sink practices. In contrast, since the conversion of forests for agricultural production, urban development and adoption of unconventional practices due to population pressure, problem of CO_2 emission has escalated (Nwite and Alu 2017). Thus, engineering proposals have been made for removing CO_2 from the atmosphere. However, research in this area is still in its infancy (Sanz-Perez et al 2016). The release of these gases has continued unabated to increase in the atmosphere occasioning agitation for good land use techniques for adoption by farmers and experts to capture and store CO_2 in the soil through better management. The objectives of the study were therefore to characterize soil carbon storage and understand dynamics of some structural indices for soil stabilization under different land use systems in Abakaliki, Nigeria.

MATERIAL AND METHODS

Site description: The study was carried out at different locations in Abakaliki area of Ebonyi state South eastern Nigeria for two consecutive years. The experimental site is located at latitude 06°4 /N and longitude 08°65 /E in the derived savannah zone of Nigeria. The rainfall pattern of the area is bomodal, April to July and September to November with a short spell in August popularly called “August break”. The minimum average rainfall is 1700 mm with maximum annual rainfall of 2000 mm for the year. The mean annual temperature ranges from 27 to 31°C throughout the year. The relative humidity is high during rainy season reaching 80 per cent (Ekpe et al 2005) and declines to 65 per cent in dry season. Abakaliki agricultural zone lies within “Asu River” and is associated with brown olive sandy shales, fine grained sandstone and mudstone. Abakaliki area is primarily characterized by growth of tall trees often with layers, bushes, herbs and shrubs. There are abundant economic trees such as palm tree (*Ealais guinensis*), mango (*Mangifere indica*) and orange (*Citrus* spp). Indigenous people are mainly farmers with few engaging as civil servants and artisans. The soil is unconsolidated to 1m depth and

belongs to the 0 order of Utisol, which is classified as Typic Haplustult.

Land uses: The forest land (FL) is located at government forest reserve at Azugwu, Abakaliki and are dominated by *Gmelina aborea* trees with shrubs and herbs. Poaching and felling of trees are prohibited by the government in the forest. The refuse dumpsite (RD) is at Azuiyiokwu, Abakaliki along Enugu-Abakaliki express and this existed for over 10 years. Farmers cultivate around the surroundings of the dumpsite and grow crops such as maize, cassava, yam and vegetables. Alley Cropping System (AC) was established for more than ten years ago at Ebonyi State University. The alley consists of *Gliricidia sepum* and *Pannicuum* maximum which are pruned yearly. The alleys are used for maize, yam and vegetable production. Sewage sludge dump soil (SD) is at Igbeagu-Unuhu Abakaliki which existed for more than fifteen years. Farmers grow maize, okro, vegetables, yam and cassava around the dumpsite. The continuously cultivated soil (CCS) farm is established at the Ebonyi State University. The soil is continuously tilled on yearly basis with or without amendments and crops grown are rice, maize, yam and vegetables.

Soil sampling: Soil samples were collected in October 2012 and 2013 respectively from the six land use systems. These samples were collected from three depths of 0-20, 20-40 and 40-60 cm in each of the study land use and samples were composited, air dried at room temperature of 29°C and sieved through a 2mm sieve for determination of soil carbon storage. Core samples were used to determine selected soil physical properties.

Soil analysis: Bulk density was evaluated by core method. The core used has a height of 6cm and diameter of 5cm. Soil bulk density was determined as:

$$BD = \frac{\text{weight of oven dry soil(g)}}{\text{Volume of soil(cm}^3\text{)}}$$

Where volume of soil = $\Pi r^2 h$

$$\text{Total porosity (TP)} = (1 - \frac{Bd}{Pd}) \times \frac{100}{1}$$

Where Tp = total porosity, Bd = Bulk density , Pd = particle density assumed to be 2.70gcms^{-3}

Aggregate stability was determined by the method of Kemper and Roseanu (1986) while dispersion ratio determination was as outlined by Nidi-kizz et al (1984). Soil carbon storage was calculated as by C% = 100 x soil bulk density (gcm^{-3}) area (1ha(m^2)) x soil depth (cm) (Mbah and Idike 2011).

Data analysis: Soil data after laboratory analysis for the two years were used to obtain means and coefficients of variation (cv%). Variability was ranked low variation (% cv<20), moderate variation (% cv=20-50) and high variation (%cv>50) according to Aweto (1982).

RESULTS AND DISCUSSION

Soil carbon storage: The mean soil carbon storage ranged from 1-963-3.602 and 2.682-4.682 gcm^{-2} for seasons and depth (Table 2). The per cent Co-efficients of variation was 65.14 and 37.89 for carbon storage at 0–20 cm depthsy for 2015 and 2016. Coefficient of variations was generally more appreciable in 2016 at the different depths when compared to their counterparts in same depths in 2015. Compared to 2015, higher soil carbon storage in the different depths of different land uses in 2016 except in few cases. Soil carbon storage was consistently highest in sewage sludge dumped soil although with values in 2016 exceeding those of 2015 at different depths for the seasons compared to values stored in other land uses. Carbon contents stored in the soil under different land uses decreased as depths increased in 2015 and 2016 giving least values at 40 – 60 cm depths. The trends of soil carbon storage under different land uses and depths were SD>RD>FL>AC>GL>CCS and 0 – 20>30 – 40>40 – 60cm for the two seasons. The managing a soil with sewage sludge could mitigate carbon dioxide emission approximately

Table 1. Total carbon storage in different soil depths (gcm^{-2})

Location	2015				2016			
	0-20 cm	20-40 cm	40-60 cm	Total	0-20 cm	20-40 cm	40-60 cm	Total
FL	3.708	2.327	1.447	7.482	6.243	5.584	2.536	14.546
RD	3.142	2.171	2.545	7.858	6.420	5.580	2.530	14.530
GL	3.997	3.157	2.137	9.291	2.902	1.790	1.520	6.212
AC	2.669	1.673	1.697	6.039	4.135	1.497	1.318	6.950
SD	5.527	3.993	2.498	12.018	6.772	5.276	4.177	16.225
CCS	2.567	1.790	1.455	9.291	1.435	0.958	1.084	3.477
Mean	3.602	2.519	1.963		4.682	3.448	2.695	
CV (%)	37.89	35.45	25.47		47.22	65.14	42.67	

FL – Forest land, RD – Refuse dump, GL – Grass land, AC – Alley cropping, SD – Savage Sludge dump, CCS – Continuously cultivated soil
CV – Coefficient of variation

between 58-61 and 13-18 per cent for 2015 and 2016 compared to continuously cultivated soil. The high carbon storage in sewage dumped soil could be linked to effective conversion efficiency of CO_2 by sewage sludge soil into stored carbon (Table 1). Similarly, higher carbon storage at 0-20 cm depths for the seasons at lower depths suggests relative efficiency of top soil to mobilize and store carbon. This is due to the vegetations or even in non-vegetation land use systems which allow for mobilization of organic carbon at upper surface. Low carbon storage at lower depths of soil could be due to lessivage as well as losses due to carbon dynamics (Mbah and Nwite 2013). The low carbon storage under continuously cultivated soil is attributable to poor nutrient mobilization, dissipation due to exposure to high temperature and leaching losses (Zak et al 2000). High carbon storage under different land use systems except in continuously cultivated soil demonstrate their relative effectiveness to convert carbon into stored form and reduce evolution of carbon iv oxide. The management practice involving any of these land use systems except continuous soil cultivation would have purifying effect on the atmosphere by mitigating carbon iv oxide emission (Mbah and Idike 2011). The high carbon content in the soil is of agricultural importance as it would increase not only soil productivity but increase its structural stability and resilience to degradative forces. Edmondson et al (2014|), underscored the effect of good agricultural practices and observed that soils hold approximately 75% of ecosystem organic carbon and recommend against any practice that jeopardizes positive effects of vegetation on soil organic carbon and soil properties.

Bulk density: The bulk densities ranged between 1.45-1.67 and 1.39-1.60 Mgm^{-3} for seasons and depths, respectively. The coefficients of variation were 8.04-13.33 and 8.38–15.12 across the depths and seasons, respectively. The bulk densities obtained at 0-20cm depths for 2016 and 2017 seasons were lower than their corresponding values at 20-40cm and 40-60cm depths for the two seasons. Continuously cultivated soil consistently yielded highest bulk densities which ranged from 1.73-1 to 1.65-1.90 Mgm^{-3} for the three depths for 2016 and 2017 seasons compared to their counterparts under other different land use systems. Bulk densities were lowest for sewage sludge dumped soil at the depths . In characterizing the different land uses in terms of improvement in bulk density, it is SD>FL>RD>GL> AC>CCS across the depths and seasons. Lowest bulk densities obtained in sewage sludge dumped soil for two seasons when compared to their counterparts in other land use systems could be linked to higher carbon storage in the land use (Table 1). High carbon content in soil increased its volume and thereby decreased its density. Low bulk density of soil has advantage of increased porosity (Vogelmann et al 2010) with accompanied adequate aeration. Higher bulk densities as depths increased could be attributed to the diminishing carbon content with soil depth. Decrease of carbon content with depth is attributable to dynamic nature of organic carbon and probably due to dissipation. The generally higher bulk densities recorded in continuously cultivated soil at three depths could be as a result of compactive effort of working implement and trafficking during tillage operation (Anikwe 2006). Furthermore, in the course of tillage, organic carbon is exposed to rapid dissipation and deterioration. The bulk densities obtained in different land uses exaggerate carbon content stored in them which is dependent on their relative conversion efficiency of CO_2. In different land use systems except in continuously cultivated soil, bulk densities for root penetration are within non-limiting values (Anikwe 2006). Low coefficients of variation at lower depths compared to 0-20 cm depths for the two seasons implies that upper soil properties influence structural

Table 2. Effect of different land use systems on soil bulk density at different soil depths (Mgm^{-3})

Land use	2015			2016		
	0-20 cm	20-40 cm	40-60 cm	0-20 cm	20-40 cm	40-60 cm
FL	1.30	1.36	1.45	1.27	1.30	1.40
RD	1.39	1.45	1.70	1.43	1.56	1.52
GL	1.50	1.55	1.70	1.53	1.55	1.64
AC	1.60	1.70	1.75	1.45	1.50	1.54
SD	1.20	1.30	1.40	1.16	1.28	1.35
CCS	1.73	1.80	1.85	1.65	1.68	1.90
Mean	1.45	1.54	1.67	1.39	1.51	1.60
CV (%)	13.44	11.25	8.04	15.12	8.38	9.68

See Table 1 for treatment details

stabilization and productivity of soil more than subsoil ones.

Total porosity: Coefficient of variation was moderate at 0 – 20cm depths in 2015 and remained low in 2016. The mean values ranged from 36.1-44.9 and 39.3-46.9 per cent for the depths and across seasons defying a particular trend. Highest total porosities were in sewage sludge dump land use at 0-20cm depths across seasons and depths and decreased at lower depths at both seasons when these values are compared to those obtained under other different land uses for depths and seasons. Generally, total porosity declined with increase in soil depth for the two seasons and is largely reflected trend of bulk density and carbon storage under different land uses at both depths and seasons. The trend in enhancement of total porosity by the different land uses is SD> FL> RD >GL>AC>CCS. Increase in values of total porosities in second season at the different depths compared to first season could be attributed to mechanical errors in sampling techniques rather than influence of land use system. The general reductions in total porosity as depth increased and study seasons could be linked to many factors. High bulk density reduces pore space (Okolo et al 2015). Furthermore, continuous traffic and agricultural activities on land (Akamigbo 2010) for some period increase bulk density and decrease soil porosity. On the other hand, total porosities obtained in different land uses suggest impacts of the land uses on improvement of soil porosity. Organic carbon increases soil volume and therefore reduces soil bulk density. Low soil density is a positive indicator for enhanced porosity, which is significant in assessment of soil for many agricultural and engineering manipulations. Continuous cultivation which compared to other land uses should be avoided for sustainable structural stability. The total porosities for different land uses except in continuous cultivation across depths and seasons and at 20-40 and 40-60cm for the seasons ranged from critical to limiting values for soil productivity (Obi 2000).

Aggregate stability: Mean values of aggregate stability ranged from 10.36-14.28 and 11.88-14.40 mm for depths and seasons. The range of coefficients of variation was <19.19 > 47.10 and < 16.54>24.81 for 2015 and 2016 for aggregate stability at different depths for the seasons. Although, there were variations in aggregate stabilities of the different land uses, sewage sludge dumped soil consistently maintained highest across the depths and seasons, though described as low. The aggregate stability was higher at 0-20cm depths and decreased as depths increased for the two years and improved in the land use systems as SD>FL>RD> GL>AC>CCS. Higher aggregate stability obtained under sewage sludge dumped soil, forest land and refuse dumped soil when compared to their corresponding values under grass land, alley cropping and continuously cultivated soil land uses is in tandem with the organic carbon content stored in these soils (Table 1). Organic carbon has colloidal materials which can bind soil particles into stable aggregates. Organic carbon content of the soil improved the aggregate stability of soil and increased its stabilization. Anikwe (2002) showed that organic carbon increased biological activities and hence aggregate stability of the soil. Well aggregated soil is desirable for high agricultural productivity as it will retain and supply nutrients, moisture and besides resist collapse due to degradative forces. Mbah (2009) reported that aggregate stability is an index for gauging soil productive capacity. The variations in aggregate stability under different land uses could be as a result of varied impacts of the land uses on soil property. Amalu (2012) notes that forestation or reforestation, grassland reforestation, conservation tillage, continuous cultivation, cover crops or amendment practices have relative impacts on soil properties such as aggregate stability. The decrease in aggregate stability as depths increase is attributed to diminished effect of organic carbon content at lower depths. The amorphous substances from plants or animals which are high on 0-20 cm depth have more active binding sites than clay materials. Incidently, all the aggregate stability values at the three depths and across

Table 3. Effect of different land use systems on total porosity at different soil depths (%)

Land use	2015			2016		
	0-20 cm	20-40 cm	40-60 cm	0-20 cm	20-40 cm	40-60 cm
FL	51.0	48.0	45.0	52.0	51.0	44.0
RD	48.0	45.0	34.0	46.0	42.0	42.0
GL	43.0	41.0	34.0	42.0	41.0	38.5
AC	39.0	34.0	33.3	45.0	43.0	41.0
SD	55.0	47.0	41.0	60.0	43.0	42.0
CCS	33.5	32.0	29.5	36.5	34.0	28.5
Mean	44.9	41.2	36.1	46.9	42.3	39.3
CV (%)	21.17	16.49	16.86	17.42	12.82	14.24

See Table 1 for treatment details

Table 4. Effect of different land use system on aggregate stability (%)

Land use	2015			2016		
	0-20 cm	20-40 cm	40-60 cm	0-20 cm	20-40 cm	40-60 cm
FL	15.05	12.41	11.13	15.26	12.40	11.13
RD	14.82	13.05	12.91	14.82	13.05	12.93
GL	12.17	10.21	11.05	12.20	10.21	10.05
AC	13.13	13.103	11.95	13.18	13.03	11.95
SD	19.05	16.15	15.10	19.85	16.31	15.17
CCS	11.44	10.12	10.02	11.41	10.12	10.02
Mean	14.28	12.49	10.36	14.40	12.52	11.88
CV (%)	19.19	21.66	47.10	24.81	18.21	16.54

See Table 1 for treatment details

Table 5. Dispersion ratio under different land use systems at different depths (%)

Land use	2015			2016		
	0-20 cm	20-40 cm	40-60 cm	0-20 cm	20-40 cm	40-60 cm
FL	3.83	3.61	2.38	3.88	3.60	3.10
RD	3.79	2.70	2.51	3.62	2.70	2.52
GL	2.78	2.72	2.65	2.81	2.72	2.65
AC	2.80	2.79	2.70	3.21	2.78	2.70
SD	4.84	3.63	2.85	4.85	3.64	2.85
CCS	2.77	2.75	2.75	2.78	2.76	2.75
Mean	3.47	3.03	2.64	3.53	3.03	2.76
CV (%)	24.18	14.98	6.33	22.15	15.06	7.07

See Table 1 for treatment details

seasons fall into low values (Obi 2000) for strong stabilization and soil productivity. This result could be possible probably due to poor management practices of burning and high tropical sunshine which might have diminished and masked effect of organic carbon on soil aggregation.

Dispersion ratio: The average dispersion ratio (%) were 2.64-3.47 and 3.03-3.53 for the depths and seasons, respectively (Table 4). Coefficients of variation were 24.18 and 22.15 per cent at 0.20cm depths for 2015 and 2016 and ranged from 6.33-14.58 and 7.07-15.06 per cent at the other depths for the seasons. Dispersion ratio consistently remained higher under sewage sludge dump soil across the depths and seasons when compared to values obtained under other land uses. The trend followed by dispersion ratio both in depth and seasons is SD>FL>RD>AC> GL>CCS. The dispersion ratios were higher at 0-20cm depths and decreased at 20-40 and 40-60cm depths for the seasons, although all fell under low values for soil stabilization. With the low values recorded in dispersion ratio, the soils under different land uses could be regarded as low dispersive. However, this is a positive impact as dispersed soil are prone to mechanical disintegration or collapse, erosion, silting and generally would have problem of low stability (Obi 2000). The higher dispersion obtained at 0-20 cm depths suggest that top soil is more dispersive than subsoil. This could be as a result of a number of actions such as impact of overburden, clay content and drying and wetting circle. Low dispersive soils are better adapted to absorb shocks and overcome problems of degradation or stresses and remain resilient; hence high structural stability.

CONCLUSION

Evidence from this study has shown that different land use systems have varied capacities to capture and store soil organic carbon as well as enhance soil structure. Soil parameters were generally more robust on topsoil and depreciated with lower depths. In terms of reduction of Co_2 emission and structural stabilization, sewage sludge dumped soil land outperformed other land uses. Topsoil properties are better adapted for soil carbon storage and structural stabilization than subsoil and as a result much attention should be given to management system that improves top soil. This research recommends appropriate land use management systems, which positively induce soil carbon storage and facilitate structural stabilization.

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Plant Diversity at Fly Ash Disposal Site of Thermal Power Plant Gandhinagar, Gujarat

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***Abstract*:** Present study aimed to observe floral diversity at fly ash dumpsite from Gandhinagar Thermal power plant, Gandhinagar, Gujarat, India. Sampling was done by quadrats for quantification of vegetation and data was analysed for different quantitative parameters. Fifty-seven plant species from 19 families were recorded in the present study. Floral diversity showed increasing trend with decreased density of plants. *Prosopis juliflora* was dominant species at all studied areas. Diversity index show lower frequency or density of the plants at all the five dumpsites of the fly ash also less evenness of plants was observed from these sites. Present study provides data that may be helpful in identifying the natural flora of the fly ash dumpsites that can be further helpful for ecorestoration and ecostabilization of such contaminated site.

Keywords: Fly ash, Floral diversity, Diversity index, Ecorestoration, Ecostabilization

Electricity generation using coal is a conventional and widespread method in present world. With increase in energy production using this conventional fuel leads to the generation of tremendous amount of by product called fly ash or flue-ash. These are fine particles substances with the capability to move with flue gases. Indian coal is of mostly sub-bituminous rank followed by bituminous and lignite (brown coal). The ash content in Indian coal ranges from 35 to 50 per cent (Padam Raj 2010). According to report of FAU (2013) by the year 2017 expected fly ash generation per annum will be 300 to 400 million tons. Chemically, fly ash is composed of ferro alumino silicate minerals containing considerable quantities of Ca, K and Na, along with other trace elements such as Cu, Zn, Mn, Mo, Ni and Se (Jastrow et al 1981) and great diversity can be observed in the mineral composition of fly ash. Depending upon the content of Ca, Fe, Si, Al fly ash is classified as Class F and Class C (ASTM C618). Chemical composition of fly ash is greatly determined by the chemical content of type of coal used in thermal power plants.

Fly ash is disposed off basically either of two methods first is dry disposal system and second is wet disposal system. Both of these methods releases this hazardous by product into the environment. Heavy metals of fly ash can be released into environment under different conditions posing threat to wide spectra of our environment including land, air and water bodies. Therefore management of fly ash is utmost important in present scenario. In present era fly ash management is generally carried out by afforestation techniques or utilizing fly ash in different sectors such as making of bricks, cement, in wooden industries etc. Though great efforts are made in the direction of utilization of fly ash in different sectors yet its stocks are increasing due to high percent of generation as compared to utilization percentage. Its constituents also limit its usage in agriculture as it can damage ecosystem of soil, in turn whole system associated to it. Management of fly ash through natural flora provides us ecological as well as socio economic benefits (Pandey et al 2014). Such techniques may help us to accomplish sustainable phytoremediation and cleaner production. Focusing on the above status on fly ash remediation to solve problem of soil, water contamination there is urgent requirement for appraisal of plants growing in the vicinity of fly ash for the purpose of remediation. Thus, for eco restoration of fly ash dumpsites study of native or non native plant species was conducted to identify potential plants with affinity to survive in such harsh conditions and may be fruitful in remediation task of heavy metals found in fly ash.

MATERIAL AND METHODS

Study area: Gandhinagar thermal power station, Gandhinagar, Gujarat located at 23° 14° 57° N latitude and 72° 40° 15°E longitude and is coal based power station. It is located on the bank of Sabarmati River. There are two units of 120MW each (1 and 2) and another three units of 210 MW each (3, 4 and 5) with a total installed capacity of 870 MW. Area has summer, winter and monsoon as the three main seasons with tropical wet and dry climate. Outside of

monsoon season generally climate is dry. Weather is sever hot from March to June with maximum temperature range of 36 to 42°C (97 to 108 °F), and minimum temperature of 19 to 27°C (66 to 81°F). Winter days are pleasant with chilling night during December to February. Average maximum temperature is around 29°C (84°F), minimum is 14°C (57°F), with extremely dry climate. The average annual rainfall is around 803.4 mm (31.63 in). Southwest monsoon brings a humid climate from mid-June to mid-September.

Sampling: Plant diversity study was conducted for one year from the October, 2015 to 2016. Five sampling site was studied at ground level and named as site 1 to 5. Fly ash dumpsites were located outside the main city of Gandhinagar. Sites were located along Sabarmati River, rest of the sides of dumpsites were surrounded by fields and wastelands. Site 1 to 4 was at a distance of 3 km while site 5 was located at a distance of approximately 10 km from main Gandhinagar Thermal power plant location site 1 to 4 were surrounded by Lekawada, Bhundiya and Phatapur area of Gandhinagar. Similarly, site 5 was also located along the Sabarmati River near Dolarana Vasa and Old Pimplaj area of Gandhinagar, other sides were fields and wasteland. Site 1 to 4 seemed to be fresh dumpsites with very low plant diversity while site 5 was old dumpsite with larger frequency of plants identified. Quantification of vegetation was done by quadrate method. 12 quadrates (5 X 5m and 1 X 1m) at each site were randomly laid at distance of 1 km and in each quadrate total numbers of plants were counted. Quantitative parameters like abundance, density, frequency, relative density (RD), Relative frequency (RF) was determined by method of Curtis (1959).

Collection and authentication of plant samples: Plant samples were collected as whole (leaves, flowers, stem and roots) from selected sites for preparation of herbarium and authentication. Authentication and identification of plant species was identified and confirm from GEER foundation, Gujarat.

RESULTS AND DISCUSSION

Floral study at fly ash deposits: Present study, 57 plant species from 19 families were recorded from five fly ash disposal sites that were identified for floral identification in the vicinity of thermal power plant of Gandhinagar (Table 1). Variation in flora and number of flora was found that may be due to the difference of geographical locations of dumpsites. Also functional operation of the dumpsites may cause of variation in the physico-chemical parameters of the substrate that may cause difference in the five sites that were identified.

Floristic representativeness: The data on frequency, density, abundance, RD, RF, is shown in Figure 1 a, b, c, d, e. Salient features of floral representativeness shows that plant species found in the dumpsites were mostly xerophytic. No tree form of vegetation found. Only woody shrubs followed by other small shrubs and herbs species were the vegetation found at disposal site. Out of 57 plant species found at site 8 species i.e. *Spilanthus calva, Prosopis juliflora, Cassia tora, Trichodesma indicum, Ipomea carnea, Calotropis procana, Crotalaria burhia* and *Nerium indicum* were present at all 5 disposal sites, 7 species i.e *Tephrosia purpunea*, *Commellinia benghalensis, Cyperus iria*, *Cassia abus, Caesalpinia cristata, Euphorbia hirta* and *Vernonia cinerea* were present at 3 disposal sites. Rest plant forms were present either two or one sites.

Prosopis juliflora was dominant species followed by *Calatropis procana* and *Ipomea sp*. Frequency of occurance was highest for *Prosopis* followed by *Ipomea* and *Trichosdesma indicum.* RD was found highest for *Trichosdesma indicum* followed by *Prosopis juliflora* and *Ipomea.* RF was highest for *Ipomea* followed by *Prosopis juliflora* and *Trichosdesma indicum.* Density of *Trichosdesma indicum* was found highest at fourth and fifth site at rest sites *Prosopis juliflora* with *Ipomea* was found with high density.

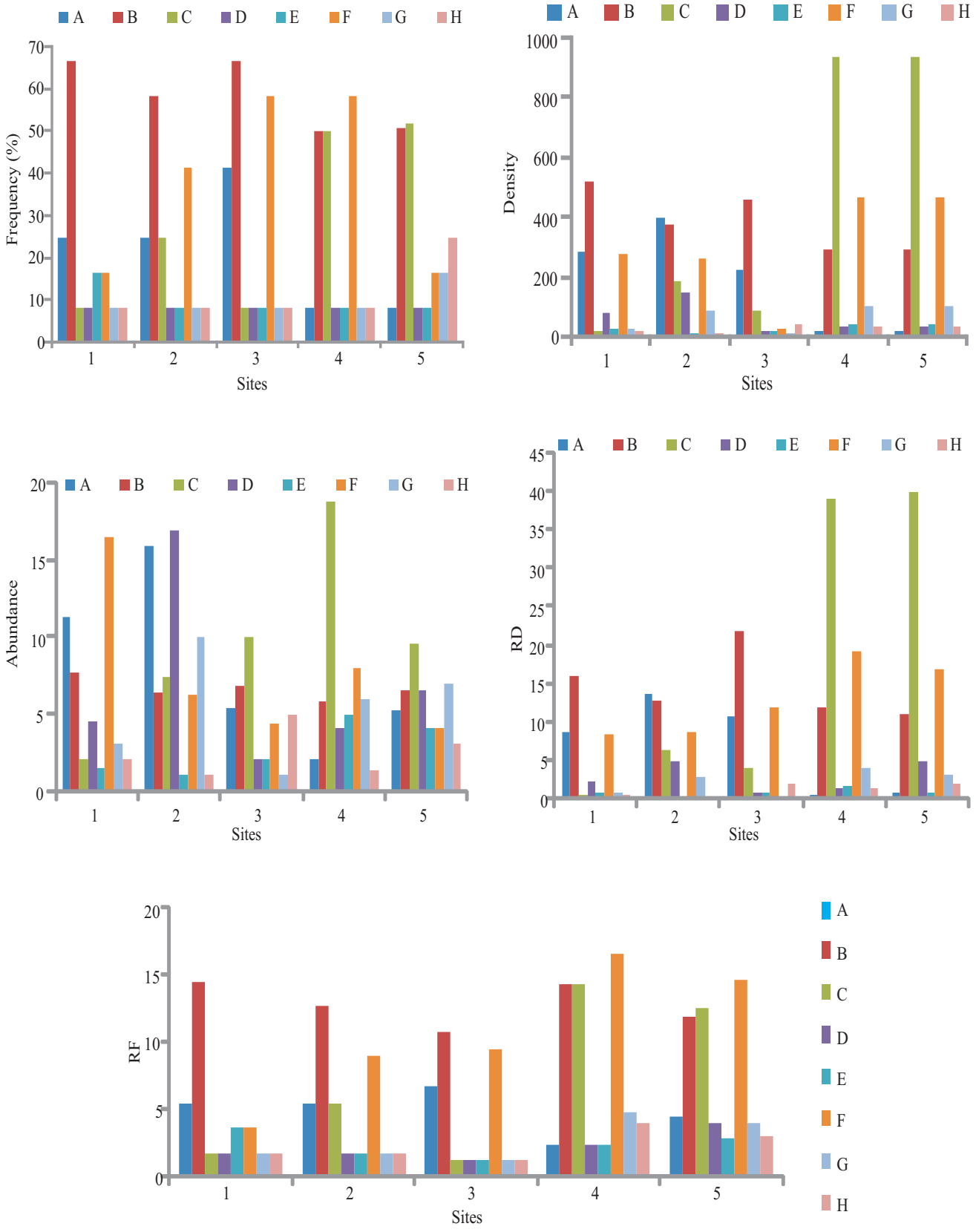
During the successional dynamics seeds of various plant found in surrounding areas or far away are shipped to FA dumping sites by either natural factors like wind, rain etc or through biological agents like animals, birds etc. Human interference may also be reason of vegetation at these barren dumpsites. Seeds once introduced to the site may germinate in appropriate season and within the temperature range. Only tolerant species 57 (referred in table 1) were the major species found at the site that survived in unfavorable condition of fly ash disposal sites. These endemic plant species at fly ash sites may be beneficial for ecological restoration of dumpsites. The majority of species belonged to Caesalpiniaceae and Fabaceae family. Species were present in both sapling and mature form in different time of sampling. Site was occupied by annual plant species. *Spilanthus calva, Prosopis juliflora, Trichosdesma indicum, Malvastrum coromandelianum, Tephrosia purpunea, Jatropha gossypifolia/racinus, Ipomea sp, Calatropis procana, Momordica carantia, Cassia abus, Bouganvia ehilensis, Euphoria hirta, Commellinia benghalensis, Crotalaria buhia, Vernonia cinerania, Launea procumbens* and *Convolvulus* sp. were the major species found at the sites.

Floral species exhibited minimum diversity index 1.4171 for site 3 which showed spices were less tolerant to the environment while highest diversity index was shown at site 2. This implies that plants present at this site were more adaptive to the environmental condition of the site. Higher diversity signifies more adaptability of the species to the

Table 1. List of plant species present at disposal site

Plant	Family	Sampling plots				
		1	2	3	4	5
Indigofera	Fabaceae	+	-	-	-	-
Prosopis juliflora		+	+	+	+	+
Tephrosia purpunea		-	+	+	-	+
Iandigofera cordifolia		-	-	+	-	-
Crotalaria burhia		+	+	+	+	+
Crotalaria notonii		-	+	+	-	-
Vigna		-	+	+	-	-
Spilanthus calva	Asteraceae	+	+	+	+	+
Vernonia cinerea		-	+	+	-	-
Parthenium hysterphorus		+	-	-	-	-
Vernonia cinerea		-	+	+	+	-
Acanthospermum hispidum		-	-	+	-	-
Bidens bipinnata		-	+	+		-
Launaea procumbens		-	+	+	-	-
Tridax procumbens		-	+	+	-	-
Diplocyclo palmatus	Cucurbitaceae	+	-	+	-	-
Trichosanthes cucumerina		-	+	+	-	-
Momordica charantia		+	+	-	-	
Sida acuta	Malvaceae	-	-	-	+	-
Malvastrum coromandelianum		+	-	-	-	-
Abutilon indicum		-	+	+	-	-
Commellinia benghalensis	Commelinaceae	+	+	-	-	+
Cyperus iria	Cyperaceae	+	+	+	-	-
Peristrophae	Acanthaceae	-	-	+	-	-
Justicia implex		-	+	+	-	-
Blepharis maderaspatensis			+	+	-	-
Dactyloctanium agypticus	Poaceae	+	+	-	-	-
Digiteria sangrinalis		+	+	-	-	-
Chloris species		-	+	-	-	-
Aristida sp.		+	-	-	-	-
Eragrostis		+	-	+	-	-
Setaria glauca		+	-	+	-	-
Cassia auriculata	Caesalpiniaceae	-	+	-	+	-
Cassia abus		+	+	+	-	-
Caesalpinia cristata		+	+	-	+	-
Cassia tora		+	+	+	+	+
Cassia unifora		-	+	+	-	-
Aerva javanica	Amaranthaceae	-	+	+	-	-
Achyranthes aspera		+	-	+	-	-
Pupalia lappacea		-	+	+	-	-
Alysicarpus bupleuriforius	Leguminosae	+	-	+	-	-
Goniogyna hirta		-	+	+	-	-
Trichodesma indicum	Boraginaceae	+	+	+	+	+
Jatropha gossypifolia	Euphorbiaceae	+	-	+	-	-
Euphorbia hirta		-	+	+	+	-
Hyptis	Lamiaceae	-	-	+	+	-
Solanum surattense	Solanaceae	-	+	+	-	-
Physalis angulata		-	+	+	-	-
Ziziphus nummularia	Rhamnaceae	-	-	-	+	-
Nerium indicum	Apocynaceae	+	+	+	+	+
Calotropis procana		+	+	+	+	+
Bougainvillea glabra	Nyctaginaceae	+	-	-	-	-
Bouganvia ehilensis		-	-	+	-	-
Evolvulus alsinoides	Convolvulaceae	-	-	-	+	-
Ipomea sp.		+	-	-	-	-
Ipomea carnea		+	+	+	+	+
Convolvulus sp.		-	-	-	+	-
Total		250	289	294	350	384

+= presence; -=absence of species



(A: *Spilanthus calva*, B: *Prosopis juliflora*, C: *Trichosdesma indicum*, D: *Crotalaria buhia*, E: *Cassia tora*, F: *Ipomea*, G: *Calatropis procana*, H: *Nerium indicum*)

Fig. 1. Frequency, density, abundance, RD, RF of major plant species found at disposal site

Table 2. Density index of selected site

Diversity index	Sampling plot				
	1	2	3	4	5
H	-1.7381	-1.9586	-1.4171	-1.5642	-1.4909
1-d	0.1854	0.1849	0.2785	0.2735	0.3013

environment. As the sensitive species, gradually shift from the habitat with the increase in extent of environmental stress, therefore, the diversity index is a reflection of environmental quality as well as adaptation of the species to the environmental variables (Datta et al 2015).

CONCLUSION

The leguminase and fabaceae are the dominant families at the dumpsite. *Prosopis juliflora* is fast growing plant specie with potential to grow efficiently in the fly ash dumpsite. They can withstand hostile condition of such climatic regions. This work is important for remediation of huge dumpsites. The study may also be used for ecological restoration of dumpsite. It also provides baseline data developing plan to ecological restoration of fly ash disposal site generated by combustion of coal.

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Estimation and Mapping Chlorophyll-a Concentration in Pulicat Lagoon, South India Using Sentinel 2A

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Abstract: Pulicat Lagoon located in the states of Andhra Pradesh and Tamilnadu, India is one of the second largest and diverse brackish ecosystems in India. Agricultural runoff and industrial effluents are being discharged into the lagoon resulting in polluted water. This leads to the increase in nutrient content of the lagoon. Therefore, the lagoon receives excessive nutrients that promote algal blooms decreasing dissolved oxygen availability, water quality, and ecosystem stability. This results in the growth of algae that affects the ecosystem of the lake. In the present study, performance of band math algorithm in estimating chlorophyll-a concentrations in the Pulicat Lagoon from the Multi-Spectral Instrument on board Sentinel-2A (MSI/Sentinel-2A) was assessed. The algorithm was calibrated and validated using *in-situ* measurements carried out at eight sampling locations. The chlorophyll-a concentration values as estimated by standard tests and varied from 0.79 mg/m^3 (top of the lake) to 1.63 mg/m^3 (bottom right of the lake). These variations in the chlorophyll values provide a significant pattern starting with low chlorophyll values in the top of the lake and it proceeds forward to the centre, there is an increase in chlorophyll values. Further down the lake and near the mouth of the lake, chlorophyll values tend to decrease due to the increase in pollution caused by the discharge of effluents from nearby industries and sea water intrusion. The values obtained by field measurement were validated against the data derived from remote sensing algorithm and a high correlation coefficient of 0.7779 was established. Hence, this study demarcates the regions with high Chlorophyll-a concentration in order to improve aquaculture in the study area.

Keywords: Pulicat lagoon, Chlorophyll-a, Sentinel 2A

Chlorophyll-a concentrations are an indicator of phytoplankton abundance and biomass in coastal and estuarine waters. They can be an effective measure of trophic status and are a commonly used measure of water quality. High levels often indicate poor water quality and low levels indicates good conditions. Chlorophyll-a levels fluctuate over time are often higher after rainfall, particularly if the rain has flushed nutrients into the water. Higher chlorophyll-a levels are also common during the summer months. Tidal regime is an important control on algal biomass and strong tidal mixing lowers Chlorophyll-a concentrations because the residence time of algae in the photic zone is reduced and also causes fine sediment to re-suspend and the elevated turbidity levels that result reduce the amount of light available for photosynthesis. Elevated concentrations of chlorophyll a can reflect an increase in nutrient loads and increasing trends can indicate eutrophication of aquatic ecosystems (Vittorio Brando 2015). The purpose of this study is to test and evaluate various images of Sentinel 2A in ENVI to map the concentration of chlorophyll-a using the best algorithm available for band math technique and to use remote sensing and GIS to study the biotic wealth of Pulicat lake and examine its implications for sustainable lagoon management.

MATERIAL AND METHODS

Analysis of chlorophyll-a using remote sensing data: Satellite images of Sentinel 2A, were obtained from USGS (Earth observatory) for the year 2013 to 2017. The images were selected on a cloud cover of less than 10 per cent, for non-erroneous approach. The collected images were pre-processed and masked. Band math (ENVI 2003) technique was used for all the images across different years to implement the following equation (1) to estimate Chlorophyll-a The images from Sentinel 2A for the years 2013 to 2017 were subsetted according to region of interest and were processed further using the algorithm defined earlier to generate the chlorophyll-a concentration.

Chlorophyll-a Concentration: (mg m^{-3})

$$\log_{10}(Chlor_a) = a_0 + \sum_{i=1}^{4} a_i (\log 10 \left(\frac{Rrs\ (\lambda blue)}{Rrs\ (\lambda green)} \right)^i$$

Measurement of Chlorophyll-a: Water samples have been collected in May 2016. This period corresponded to the pre-monsoon time of the year. With the help of a hand-held GPS device, the coordinates of the locations of samples were recorded. The collected samples were filtered through 0.45 µm pore size filters under vacuum pressure. Pigment extraction was made by manual grinding of filter papers for 1

min and soaking in acetone 90% for 10–12 h at 4.0 °C in the dark. The extracts were clarified by centrifugation (3000 rpm, 15 min) and the concentrations of Chlorophyll-a were determined by spectrophotometry.

RESULTS AND DISCUSSION

The Chlorophyll-a concentration is distributed unevenly during different seasons and variations were observed in both the satellite based derived values and field values. The variations in the chlorophyll-a concentrations were mainly due to the inflow of seawater during pre-monsoon and due to the riverine input during post-monsoon (Figure 1, Table 1). This uneven distribution of Chlorophyll-a over the region is perhaps due to the influence of seasonal concentrations of physical and chemical parameters viz., dissolved oxygen, nitrate and nitrite nitrogen, phosphates and ammonia present in brackish water. The mean chlorophyll values for the different years stand at 1.993, 1.881, 1.879, 1.842 and 1.901 mg/m^3 for the years from 2013 to 2014. From the average values of chlorophyll concentrations derived from the Sentinel – 2A images show that the variations between the years are minimal. Chlorophyll-a concentrations in the year 2013 and 2017 have similar variations as seen from the Figures 1 (a) and 1 (e). Similar is the case for the years 2014 and 2016 as in Figures 1 (b) and 1 (d). The concentration of Chlorophyll-a has increased dramatically in the year 2015. This may be attributed to decrease in average temperature in the region for the year. The variations in the chlorophyll-values in the region during sampling are attributed to two factors. The first reason is due to the fact that the lake is being given riverine water as input from three different sources. Rivers Arani, Kalangi and Swarnamukhi join in the Pulicat Lake providing changes in the characteristics of water changing the chlorophyll concentrations in the lake. Dhinamala et al (2015) observed that there are effluents flowing into the lake from the nearby sources such as North Chennai thermal power plant, Ennore port activities, local petroleum industries from Manali, Chennai as well untreated waste water from Chennai Metropolitan City. These two sources of input to the Pulicat Lake have immense effect in the characteristics of the brackish water and changes the Chlorophyll-a concentrations significantly. The increase in chlorophyll values was observed for 2015 and may be attributed to the disastrous floods that hampered life in November-December, 2015. Hence, chlorophyll values derived for the year 2015 tend to be on high margin in comparison with other years of observation in this study.

The Chlorophyll-a concentrations in the Pulicat Lake range between 0.79 mg/m^3 and 1.63 mg/m^3 (Table 1). The chlorophyll concentration is less near the lake mouth as there is an intrusion of sea water near the mouth of the lake. As explained in the previous section, the chlorophyll in the top and the center of the lake is high owing to the brackish water. Chlorophyll values in the bottom right of the lake tend to possess less value due to the water input from the rivers and effluents discharged into the lake. Fishing zones can be identified by identifying the chlorophyll concentration. Water having high chlorophyll concentration will be turbid in nature. This is due to the fact that incident sunlight energy is prevented from passing into the region.

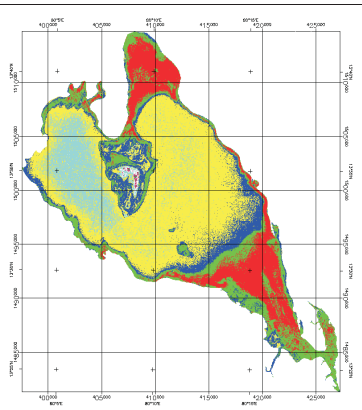
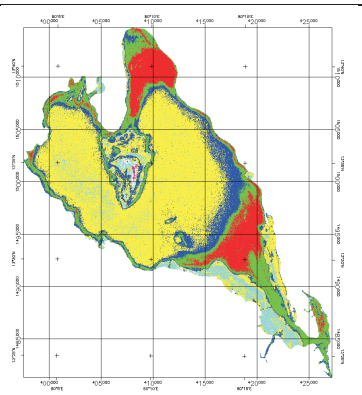
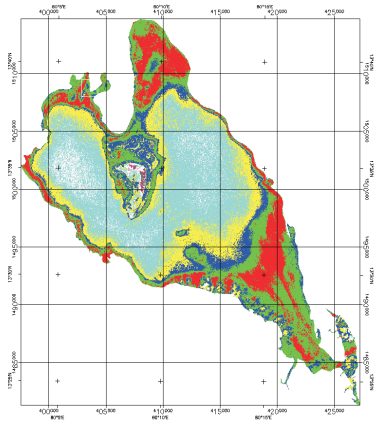
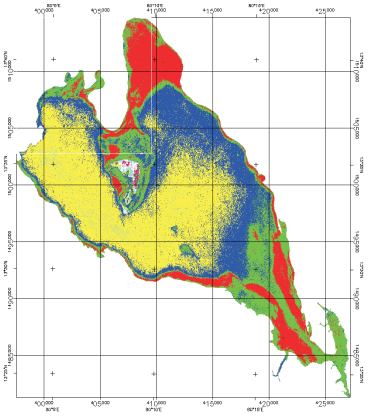
Validation: The deviation in the chlorophyll-a concentration values between the satellite-based values and the field values are very minimal and this shows that the algorithm has performed well in terms of extracting the Chlorophyll-a values (Fig. 3). In addition, the graphical plot shown in Figure 4, indicate that the estimated concentration of Chlorophyll-a derived from Sentinel 2A images were almost same as the actual field derived concentration and the correlation coefficient (R^2) is high equal to 0.7779. This is another highlighted feature of the performance of the algorithm in terms of closeness with the field values.

CONCLUSION

The multi-temporal biomass status of Pulicat Lagoon has been assessed and the spatial patterns of chlorophyll-a concentrations were estimated and mapped. Band Math technique used in the research assisted in the estimation of Chlorophyll-a, which in turn is vital in mapping lake water

Table 1. Chlorophyll-a concentrations of the water samples at different locations of the lake (May 2016)

Location	Latitude	Longitude	Chlorophyll- a (mg/m^3)	Characteristics of the location
A1	13.54	80.20	1.51	Centre of the lake with higher chlorophyll values
A2	13.65	80.15	0.79	Top of the lake
A3	13.60	80.12	0.82	Shallow region of the lake with less chlorophyll values
A4	13.55	80.07	1.22	Top left of the lake with average chlorophyll content
A5	13.50	80.15	1.63	Bottom left of the lake with high chlorophyll content
A6	13.48	80.23	1.47	Bottom right of the lake with high chlorophyll content
A7	13.44	80.29	0.92	Bottom of the lake near the mouth
A8	13.44	80.29	1.17	Bottom of the lake near the mouth

2013		0.7579 to 0.9941 mg/m^3 0.9941 to 1.2303 mg/m^3 1.2303 to 1.4665 mg/m^3 1.4665 to 1.7027 mg/m^3 1.7027 to 1.9390 mg/m^3 1.9390 to 2.1752 mg/m^3 2.1752 to 2.4114 mg/m^3 2.4114 to 2.6476 mg/m^3
2014		0.7824 to 1.0069 mg/m^3 1.0069 to 1.2315 mg/m^3 1.2315 to 1.4560 mg/m^3 1.4560 to 1.6806 mg/m^3 1.6806 to 1.9051 mg/m^3 1.9051 to 2.1297 mg/m^3 2.127 to 2.3542 mg/m^3 2.3542 to 2.5788 mg/m^3
2015		0.6726 to 0.9372 mg/m^3 0.9372 to 1.2018 mg/m^3 1.2018 to 1.4664 mg/m^3 1.4664 to 1.7310 mg/m^3 1.7310 to 1.9956 mg/m^3 1.9956 to 2.2602 mg/m^3 2.2602 to 2.5248 mg/m^3 2.5248 to 2.7894 mg/m^3
2016		0.7312 to 0.9908 mg/m^3 0.9908 to 1.2504 mg/m^3 1.2504 to 1.5099 mg/m^3 1.5099 to 1.7695 mg/m^3 1.7695 to 2.0291 mg/m^3 2.0291 to 2.2887 mg/m^3 2.2887 to 2.5483 mg/m^3 2.5483 to 2.8078 mg/m^3

Cont...

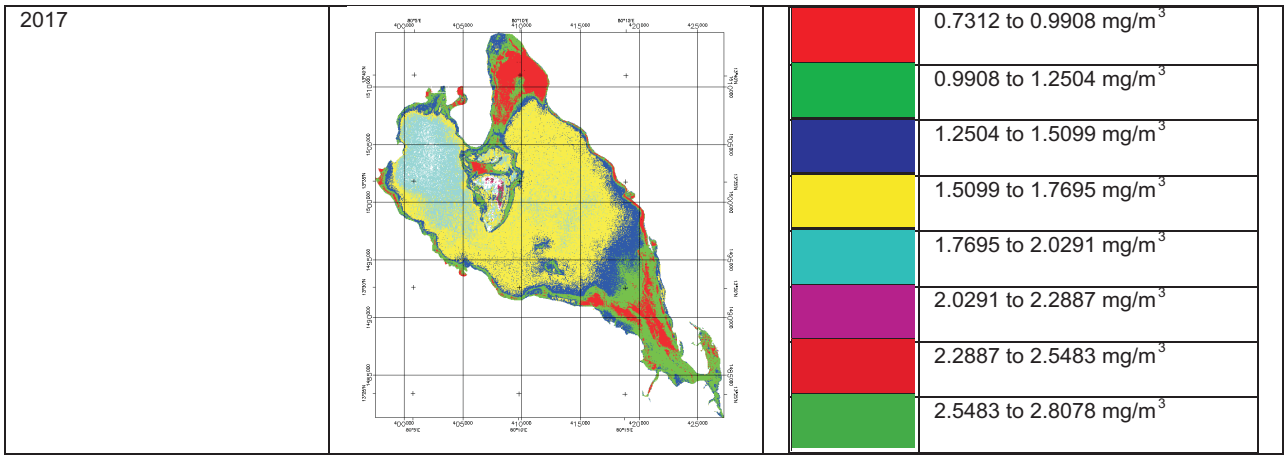


Fig. 1. Chlorophyll-a concentration in Pulicat Lake

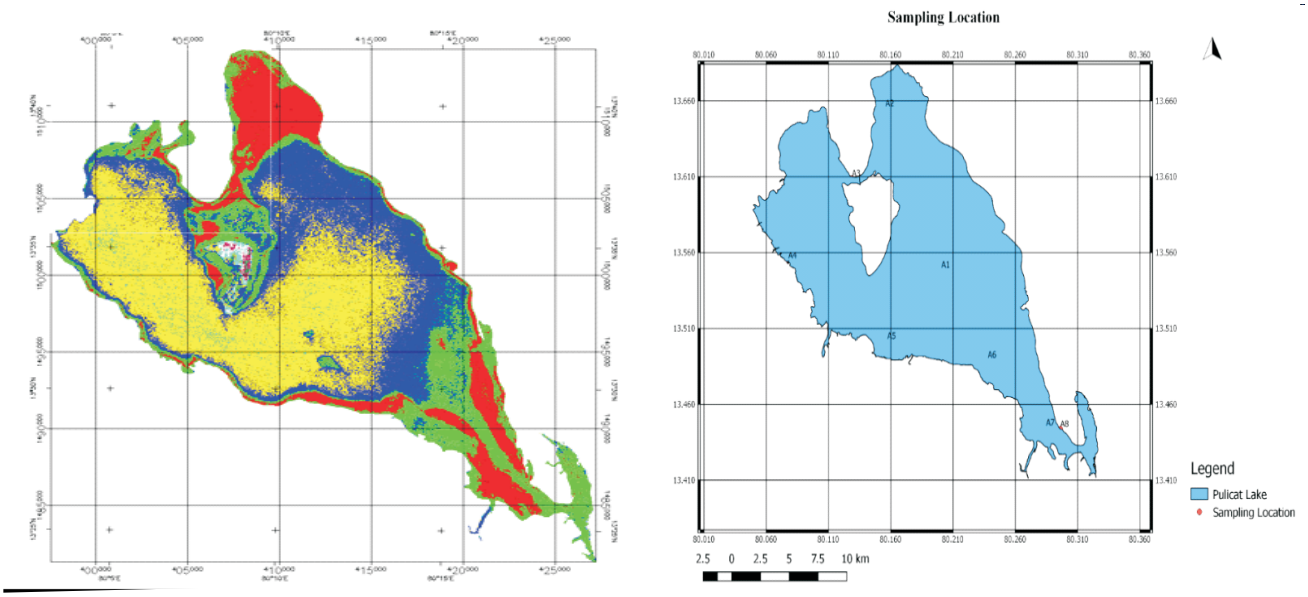


Fig. 2a. Spatial distribution of chlorophyll-a concentration validation of chlorophyll-a concentration in Pulicat Lake derived from Sentinel 2-A imagery. (b) Sampling locations to validate the remote sensing derived chl-A concentration and distribution in Pulicat Lake

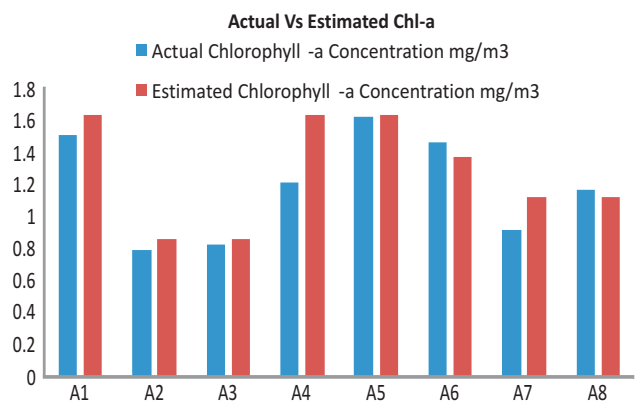


Fig. 3. Cholorophyll-a concentration values as derived from satellite image and field values

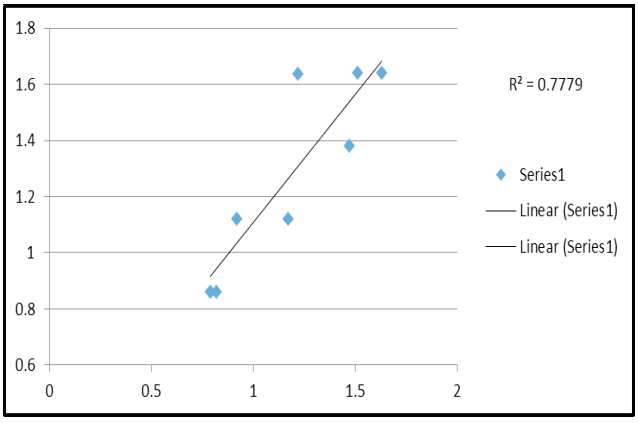


Fig. 4. Validation of satellite derived Chlorophyll-a concentration against field derived values

quality. A clear zone of high productivity was identified in the study area by visualizing the very high concentrations of chlorophyll-a. Fishing Zones were identified by Chlorophyll-a analysis as more fishes tend to live in high dissolved oxygen regions. This study reiterates the fact that Sentinel – 2 remote sensing images can be used for the successful and accurate mapping of biomass employing band math techniques.

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Effects of Soil Amendments with Bio-inoculants on Biomass Production of *Flemingia semialata* Seedlings

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***Abstract*:** Multi-location trials of containerised seedlings with of *Flemingia semialata* Roxb. developed in the nurseries of Department of forestry, Mizoram University and College of Forestry, OUAT to study the effect of *bio-inoculants* on root and shoot fresh biomass at various stages. Both the locations recorded similar trend, thus pooled together. At one month age though bio-inoculation had no remarkable response to root fresh biomass but had response to shoot fresh biomass, the latter acquired maximum value (0.185 g) in Rhizobium + Mycorrhizae with low fertilisation (125 mg N_2, 125 mg P_2O_5 and 125 mg K_2O per polypot). At 2, 4 and 6 months both the parameters had significant response to bio-inoculation. At 2 months *Rhizobium* + Mycorrhizae with medium fertilisation (250 mg N_2, 250 mg P_2O_5 and 125 mg K_2O per pot) recorded maximum root fresh biomass (0.214 g) and shoot fresh biomass (0.421 g) accumulation. Of course, at 4 months highest fresh root biomass (2.388 g) was with Rhizobium + Mycorrhizae with high fertilisation (375 mg N_2, 250 mg P_2O_5 and 250 mg K_2O per polypot) the treatment Rhizobium + Mycorrhizae with low fertilisation gave highest fresh biomass accumulation of root at 6 months (6.452 g) and of shoot at both 4 months (7.583 g) and 6 months (27.325 g).

Keywords: *Flemingia semialata, Rhizobium, Endomycorrhizae,* Biomass

Flemingia semialata Roxb. Synonym *Moghania semialata* and *F. congesta* var. *semialata* commonly called winged-stalk flemingia, a shrub of family Fabaceae and native of Uttaranchal and Andaman and Nicobar in India, Pakisthan, Myanmar and China (Lewis et al 2005). It has tendency of soil and water conservation and used as hedge in improved fallow in Jhum and Alley cropping. Because of its multifarious uses *F. semialata* has been used as plantation species in degraded lands and in agroforestry systems. Being exploited for socio-economic and environmental benefits it becomes necessary to standardise techniques for producing quality planting materials. The application of less expensive bioinoculants increases the productivity without harming the environment. The species being atmospheric nitrogen fixer it needs favourable environment and sufficient inoculum for its roots to be infected with *Rhizobium*. In this regard artificial inoculation of *Rhizobium* can boost nodulation potential at the initial growth at the seedling stage as well as after planting out. Mycorrhizal inoculation nowadays became vital for hosts as it provides highly extension of the host root system and absorbs minerals like N, P, K, Ca, S, Zn, Cu and Sr from soils which are translocated to the host plant and also produces enzymes, vitamins, cytokinins, and other compounds that increase rootlet size and longevity, help in absorbing and translocating water to host and play a vital role in nutrient cycling. The sound management of fertilization must attempt to ensure both an enhanced and safeguarded environment. The advantages of chemical, organic and biofertilizers is to make optimum use of each type of fertilizer and achieve balanced nutrient management for plant growth (Chen 2016). Keeping these in view, under the present investigations efforts have been made to study the effect of *Rhizobium*, *Endomycorrhizae* and inorganic fertilizers under various combinations on plant growth, root development and nodulation of *F. semialata* during nursery stage.

MATERIAL AND METHODS

The investigations were simultaneously carried out in nursery of Mizoram University, Aizawl, and Baramunda farm of Orissa University of Agriculture and Technology (OUAT) in 2013-2015. The former has latitude 23°44'N and longitude 92°40'E with an elevation 795 m above mean sea level (msl.), temperature ranges from 13°C to 36°C, and annual rainfall 2422 mm and soil is clay loam in Tanhril, Mizoram. The OUAT has latitude *:* 20° 15'N*,* longitude : 85° 52' E, elevation 45m above mean sea level, temperature ranges from 14.3°C to 37.1°C, annual rainfall1550 mm and soil is red loamy in Baramunda, Odisha. The treatment combinations were T_1 = control, T_2 = potting mixture, $T_3 = T_2 + N_1P_1K_1$, $T_4 = T_2 + N_2P_2K_2$,

T_5 = T_2 + $N_3P_3K_3$, T_6 = T_2 + *Rhizobium*, T_7 = T_2 + $N_1P_1K_1$+ *Rhizobium*, T_8 = T_4 + *Rhizobium*, T_9 = T_5 + *Rhizobium*, T_{10} = T_2 + Mycorrhizae, T_{11} = T_3 + Mycorrhizae, T_{12} = T_2 + $N_2P_2K_2$ + Mycorrhizae, T_{13} = T_2 + $N_3P_3K_3$ + Mycorrhizae, T14 = T_2 + Mycorrhizae + *Rhizobium*, T_{15} = T_3 + Mycorrhizae + *Rhizobium*, T_{16} = T_2 + $N_2P_2K_2$ + Mycorrhizae + *Rhizobium*, T_{17} = T_2 + $N_3P_3K_3$ + Mycorrhizae + *Rhizobium,* where $N_1P_1K_1$ means 125 mg N_2, 125 mg P_2O_5 and 125 mg K_2O, $N_2P_2K_2$ means 250 mg N_2, 250 mg P_2O_5 and 125 mg K_2O and $N_3P_3K_3$ means 375 mg N_2, 250 mg P_2O_5 and 250 mg K_2O and design was Completely Randomised Design (CRD) with 3 replications. The inoculum of *Rhizobium* was prepared following Somasegaran and Hoben (1985) and used to inoculate seeds. VAM culture developed using charcoal in, Indian Agricultural Research Institute, New Delhi was used in polybag soil before seed sowing. The inoculums used per polybag were 1ml *Rhizobium* and 2g of VAM. The seedlings were grown in polybags (21 x 30 cm) filled with well sieved soil potting mixture (ratio 1:1:1 of sand, soil and FYM) with usual liming dose 2.84mg/ kg of soil as per recommended dose of Forest Productivity Institute. Five samples per replication were drawn for observation. The fresh biomass of root and shoot were taken after separating those from the seedlings. There being similarity of trend observed in both of locations data generated from both of locations were pooled . The seedling cumulative increment time-wise of fresh biomass of all the treatments was separately represented location wise to study growth trends.

RESULTS AND DISCUSSION

Fresh biomass of root: Non-significant variations observed among the treatments after one month (Table 1). However, maximum root fresh biomass was with T_2 (only potting mixture) and T_{17} (high fertiliser dose with *Rhizobium* and Mycorrhizae). Neither soil amendment nor bio-inoculant could add any root growth at this earlier stage. The reason may be inadequate root development initially to support, which became unable to acquire nutrients (Morgan and Connolly 2013). The significant differences were observed among treatments at two months in fresh biomass of root. The maximum fresh root biomass accumulation (0.214 g) at this stage it was in T_{16} (*Rhizobium* + Mycorrhizae with medium dose fertilisation) closely followed by T_{15} (*Rhizobium* + mycorrhizae with low dose fertilisation) and T_{14} (Mycorrhizae + R*hizobium*). The addition of Mycorrizae with *Rhiobium* was more viable and sustainable. Location specific field crop trial on bio-inoculants (Rao 2016) has been emphasized by Kumar et al (2017) on *Flemingia*. At the age of 4 months root fresh biomass was maximum with T_{17} (2.388 g) followed by T_{16}, T_{11}, T_{15}, T_{10} in decreasing order and least with T_{13}. Significant effects of bio-inoculants and soil amendments was observed with respect to control or T_1 (0.663 g) in all the treatments except T_4 (medium fertilisation), T_5 (high fertilisation), T_6 (*Rhizobium* inoculation) and T_8 (*Rhizobium* inoculation with medium fertiliser dose application). The treatments namely T_5 (high dose of

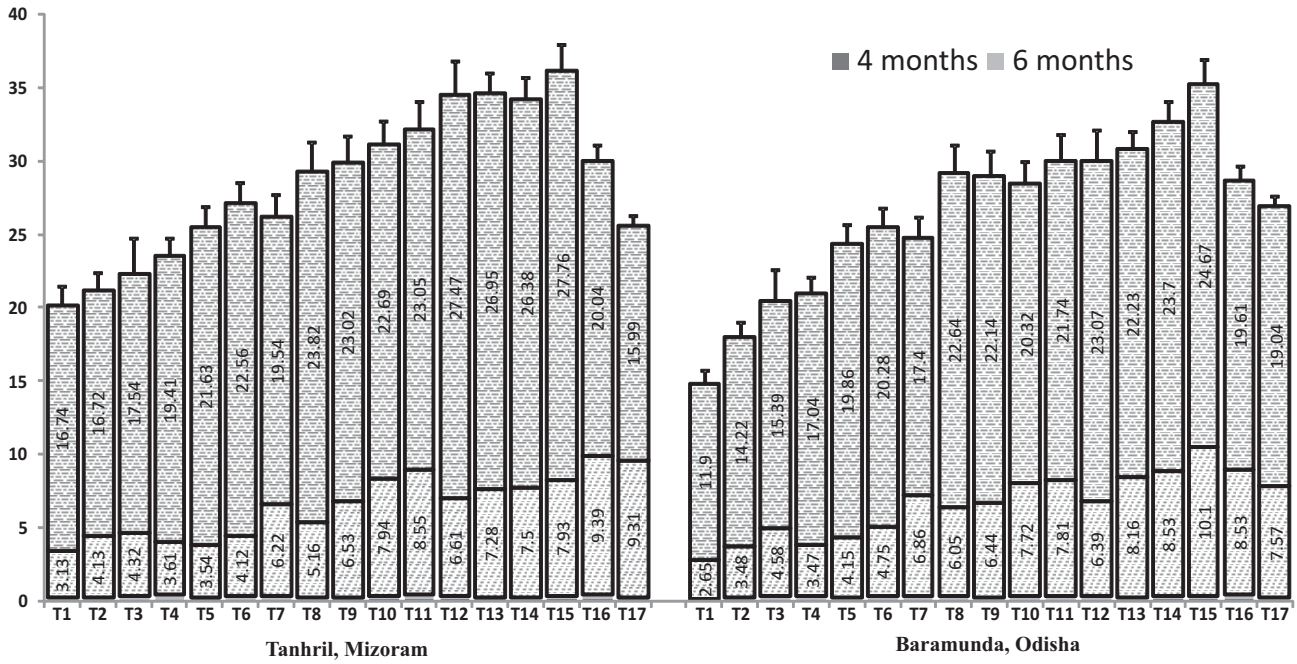

Fig. 1. Age-wise cumulative seedling fresh biomass (g) accumulation at both the sites affected by bio-inoculants and soil amendments in *F. semialata*

Table 1. Effect of soil amendments and bio-inoculants on accumulation of fresh biomass (g) of root of *F. semialata*

Treatments	1 month	2 months	4 months	6 months
T_1	0.0502[a]	0.063[a]	0.663[ab]	3.988[a]
T_2	0.058[b]	0.071 [abc]	1.131 [c]	4.502[abc]
T_3	0.032 [a]	0.096 [bc]	1.128 [c]	4.863 [bc]
T_4	0.033 [a]	0.096 [bc]	0.763 [a]	4.784 [bc]
T_5	0.024 [a]	0.081 [ab]	0.568 [ab]	5.075 [d]
T_6	0.027 [a]	0.099 [abc]	0.754 [a]	5.375 [d]
T_7	0.033 [a]	0.105 [abc]	2.143 [f]	5.463 [d]
T_8	0.031 [a]	0.074 [ab]	0.671 [ab]	5.863 [d]
T_9	0.026 [a]	0.071 [b]	1.645 [d]	5.311 [d]
T_{10}	0.026 [a]	0.079 [ab]	1.809 [d]	4.388 [ac]
T_{11}	0.030[a]	0.093 [b]	2.156 [f]	5.401 [d]
T_{12}	0.032 [a]	0.085 [ab]	1.508 [d]	5.438 [d]
T_{13}	0.026 [a]	0.095 [abc]	0.473 [b]	5.388 [d]
T_{14}	0.029 [a]	0.174 [abc]	1.144 [c]	4.775 [bc]
T_{15}	0.033 [a]	0.183 [bc]	1.861 [e]	6.452 [e]
T_{16}	0.026 [a]	0.214 [c]	2.284 [fg]	5.102 [d]
T_{17}	0.023 [a]	0.071 [ab]	2.388 [g]	4.151 [e]
F (comp.)	1.345	1.078	76.370	9.867
SE (±)	0.015	0.06	0.107	0.283
CD (p=0.05)	NS	0.119	0.211	0.561

Values are pooled means of locations. Means with the same letter are not significantly different ($p \leq 0.05$)

Table 2. Effect of soil amendments and bio-inoculants on accumulation of fresh biomass of shoot (g) of *Flemingia semialata*

Treatments	1 month	2 months	4 months	6 months
T_1	0.075 [a]	0.235 [a]	2.54 [a]	13.362 [a]
T_2	0.085 [ab]	0.273 [abc]	2.96 [a]	15.121 [ab]
T_3	0.085 [ab]	0.345 [ef]	3.595 [bc]	16.411 [ab]
T_4	0.095 [b]	0.365 [f]	3.14 [ab]	17.435 [bc]
T_5	0.115 [cd]	0.241 [ab]	3.61 [bc]	19.812 [cd]
T_6	0.105 [bc]	0.315 [de]	4.115 [cd]	20.770 [de]
T_7	0.112 [c]	0.345 [ef]	4.865 [de]	20.011 [d]
T_8	0.125 [d]	0.305 [cd]	5.342 [e]	23.315 [fg]
T_9	0.145 [e]	0.245 [ab]	5.141 [e]	24.255 [gh]
T_{10}	0.155 [e]	0.342 [def]	6.495 [f]	24.665 [ghi]
T_{11}	0.155 [e]	0.381 [f]	6.541 [f]	25.613 [ghi]
T_{12}	0.142 [e]	0.353 [ef]	6.452 [f]	26.665 [h]
T_{13}	0.151 [e]	0.273 [abc]	6.571 [f]	26.081 [j]
T_{14}	0.145 [e]	0.275 [bc]	7.245 [g]	26.914 [i]
T_{15}	0.185 [g]	0.421 [g]	7.583 [g]	27.325 [hi]
T_{16}	0.165 [f]	0.420 [g]	7.195 [g]	24.265 [gh]
T_{17}	0.143 [e]	0.245 [ab]	6.331 [f]	21.573 [def]
SE (±)	0.007	0.018	0.302	1.257
CD (p=0.05)	0.014	0.036	0.597	2.490

Values are pooled means of locations. Means with the same letter are not significantly different ($p \leq 0.05$)

fertilisation) and T_{13} (Mycorrhizae with high fertiliser dose indicated decrease in root biomass over control (Table 1). It clearly indicated that at this stage high dose of fertilisation alone or with Mycorrhizae proved harmful but the same when added with *Rhizobium* gave higher growth than in other treatment. The difference were non-significant are among T_2, T_3 and T_{14}, and T_5, T_8 and T_{13}.

At the age of 6 months significant relations were observed among the treatments (Table 1). Except T_2 (potting mixture) and T_{10} (Mycorrhizae) which did not show significant difference with T_1 (control), rest of the treatments namely showed significant increase in root fresh biomass over control. Highest fresh biomass of root at was d in T_{15} i.e., *Rhizobium* and Mycorrhizae along with substantial dose of fertilisation) which was significantly different from rest 16 treatments and followed by T_8 then in the descending order T_7, T_{12} , T_{11} and lowest was with T_1. N supplementation from fertilisation along with bio-inoculants increased nutritional status of seedlings which increased growth upto fertiliser bio-inoculant compatibility level. Sanz et al (2007) revealed fertiliser with bio-inoculants increased nutritional status and biomass production. Razaq et al (2017) observed that treatments of bio-fertilisers increased the root, shoot and total, seedling s by 29.7 to 107.27 per cent. The moderate fertiliser dose supportive for bio-inoculants beyond which it becomes harmful. Srivastava and Srivastava (2006) also observed increase in plant root weight through AM fungi inoculation in *Tecomela undilata.* Saia et al (2014) found Mycorrhizae increased biomass accumulation when added with *Rhizobium.* Liangbo et al (2015) observed yield increase in soyabean by 28-93 per cent more than only *Rhizobium* by addition of Mycorrhizae (*Glomus mosseae*).

Fresh biomass of shoot: Significant difference in fresh shoot biomass observed among the treatments at 1 month (Table 2) with maximum shoot fresh biomass with T_{15} (*Rhizobium* and Mycorrhizae with substantial dose of fertiliser) followed by T_{16}, T_{10} and T_{11}. All treatments except T_2 (potting mixture), T_3 (substantial dose of fertilisation) showed significant difference with T_1 (control) with respect to fresh shoot biomass. Non-significant relations was observed in T_2, T_3, T_4, T_5 and T_8 and in T_5, T_6 and T_7. The treatments T_{16} (*Rhizobium* with Mycorrhizae and medium dose of fertilisation) and T_{15} (*Rhizobium* with Mycorrhizae and substantial dose of fertilisation) imparted significant differences with rest of the treatments. Increasing fertilisation retards biomass accumulation which is evident as the study of Mahamooth et al (2016) revealed that high soil phosphorus

levels and prolonged nitrogen fertilization act as retardants to AM formation Significant difference was observed in shoot fresh biomass.

Similar trend was observed 4 months old seedlings . Treatments differed significantly with respect to fresh biomass of shoot at the age of 6 months (Table 2). Maximum value recorded with T_{15} followed by T_{14} then in the decreasing order T_{12}, T_{13} , T_{11} and T_{10}. The at par relations were observed inT_1, T_2 and $T_3$and in T_2, T_3 and T_4. Addition of more fertilisation proved harmful for biomass accumulation. This also observed by Mahamooth et al (2016). Mycorrhizae may be the reason for more root biomass in T_{15} (Mycorrhizae + R*hizobium* + substantial dose of fertiliser). Bown et al (2010) expressed that combined application of N and P increases root surface area, root length, and root-shoot mass. At the same time AM fungi tap a variety of nutrients from the soil and *Rhizobium* fix nitrogen from the atmosphere (Mehrotra 1995). Combined inoculation of Rhizobium and mycorrhizae added biomass (Bhatt et al1993, Khan and Uniyal 1999).

Fresh biomass of seedlings: The cumulative growth of fresh biomass of seedlings at 4 stages has been enumerated in Figure 1. Seedling fresh biomass at 6 months as sum of cumulative of 4 growth stages was highest in T_{15} (Rhizobium + Mycorrhizae + substantial fertilisation) lowest in T_1. The quantum of seedling biomass accumulation in Mizoram was of this order T_{15} (36.1 g) followed by T_3 then in descending order T_{12}, T_{11}, T_{10}. In Odisha maximum biomass was in T_{15} (35.22 g) followed by T_{14},T_{13}, T_{11}. Tewari and Kaushal (2008) studied multilocation of bamboo.

CONCLUSION

Biomass is regarded as an important indicator of ecological and economic processes in vegetation and reflection of the productivity of a site; dominance of plant biomass clear indication of efficient use of nutrient, water and solar resources of that site. In all the cases nutrient acquisition by plant became dependent on nature of association between bio-inoculants and extraneous nutrient addition. Well-developed plant root served as key to express nutrient resources to readable biomass. Root protects shoot by responding earliest to rhizosphere disturbances and sacrificing all privileges to latter availing earliest. Biomass accumulation more favoured with combined action of *Rhizosphere* and mycorrhizae along with substantial dose of fertilisation to support the system, its further addition proved detrimental expressed through decrease in biomass accumulation.

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Groundwater Potential Mapping Using Dempster – Shafer Theory of Evidence for Tiruvannamalai District, India

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***Abstract*:** An attempt was made to delineate the zones with high groundwater potential for Tiruvannamalai district, Tamilnadu, India. GIS based Dempster Shafer Evidential Belief Function model is used to predict the groundwater potential zone. The influencing thematic factors such as geology, geomorphology, soil, lineament density, drainage density, land use/land cover, slope, groundwater depth and rainfall were selected and mapped. The four series of mass functions of EBF models (belief, disbelief, uncertainty and plausibility) were estimated for the selected thematic factors using likelihood ratio algorithms. Dempster's algorithm rule was applied to integrate the mass functions of each evidential thematic layer. The Dempster Shafer theory model has high prediction accuracy of 91.81 per cent to delineate the groundwater potential zones. The proposed methodology is an accurate and comprehensive prediction model for groundwater potential zone mapping. Therefore, ground water potential map generated using Dempster – Shafer Theory of Evidence can be effectively used for planning of groundwater exploration and land use planning

***Keywords*:** Groundwater potential zones, Dempster Shafer Evidential Belief Function model, Evidential Mass Function, Belief Function

Rapid industrial, population growth and urbanisation has increased the demand of water for various purposes like agricultural, domestic and industrial (Omid et al 2014). The demand of water is met out by the surface and subsurface water resources. The shortage and uneven distribution of rainfall has reduced the surface water resources. This has increased the dependence on subsurface water resources for various activities. Groundwater is a subsurface treasure which is the main portion of the water supply in arid and semi-arid regions. The inherent qualities of groundwater such as widespread availability, limited vulnerability and drought reliability has made it a valuable natural resource. The increase in the regular lowering of water table has raised the concern and need for judicious and scientific resource management and conservation. The traditional methods of groundwater exploration such as geological, drilling and geophysical methods are extremely costly, require skilled manpower and time-consuming (Mohamad et al 2013). Therefore, need arises to emphasis on modern techniques to quantitatively estimate the available water resources. Geographic information system (GIS) and remote sensing (RS) has provided a cost-effective means of groundwater potential mapping since it can handle huge amount of spatial data and can be used effectively in decision making process (Adiat et al 2012). The major advantage of this modern technique is different surface features can be prepared using satellite imagery in GIS platform which serves as an indicators of groundwater potential prediction.

In most of the studies probabilistic models such as frequency ratio, weight of evidence, evidential belief, logistic regression Shannon's entrophy, analytical hierarchy process (Adiat et al 2012, Shekhar and Pandey 2015), fuzzy logic (Erhan Sener et al 2018) and artificial neural network have been used for mapping groundwater potential. Most of these methods can either address stochastic uncertainty or systemic uncertainty. But Dempster Shafer theory of evidential belief function model can effectively analyse both stochastic and systemic uncertainty. Due to this ability DST model has been widely used in number of scientific applications (Carranza et al 2008, Tangestani 2009). The main objective of this study is to map the groundwater potential for Tiruvannamalai district using dempster shafer theory of evidential belief function. Tiruvannamalai district has inadequate public water supply which has led to the increase demand for groundwater during the past decades. Therefore, a quick and less expensive methodology is needed to estimate the groundwater potential. No such studies have been reported in Tiruvannamalai district till now, therefore, the current study will be of great help for the decision makers in groundwater management and to identify suitable locations for drilling wells.

MATERIAL AND METHODS

Study area: The Thiruvannamalai district is one of the 32

districts in the state of Tamil Nadu and is bounded by longitude 79°07'E and latitude 12°25'N. The average annual temperature and precipitation of our study area is 28.2°c and 1033mm, respectively. The difference in precipitation between the driest month and wettest month is 215mm. The variation in temperature throughout the year is 7.9°c. The total area is 6191 km^2 inhabited by a population of 4,164,875. In the study area, there are 24 number of rain gauge stations. Figure 1a shows the boundary of the study area, well location and rain gauge stations.

Dempster shafer theory of evidential involves four main steps. The step is to collect the well yield data and split them into two groups that is training and testing group. The second step involves identification and construction of spatial data base for influential thematic factor. The third step is to generate the groundwater potential map using Dempster shafer theory of evidential belief model. The final step is to validate the results and to calculate the model accuracy.

Well yield inventory: The groundwater well yield data were obtained from water resource division, Tiruvannamalai district. The data involves locations of the wells and groundwater depth. In total, 202 wells were located out of which 140 (70%) wells were used as training set data and 61 (30%) were used as testing set data (Fig.1a). The training well data set was used to build the model by exploring the relationship between well point locations and influencing factors. The testing data set is used to validate the result and check the effectiveness of the model to predict the groundwater potential.

Generation of influential thematic layer: Nine surface hydrological parameters were considered to explore the relationship between the well points and influencing factors. The factors are geology, geomorphology, slope, soil, lineament density, drainage density, rainfall intensity and groundwater depth. The generation and influence of these factors are mentioned below.

Slope map: Slope map is generated from DEM and divided into five classes and the ranges which are very low (0°-3°), low (3°-10°), medium (10°-20°), high (20°-35°) and very high (>35°) (Fig. 1b). The western region of our study area shows very high slope due to the presence of many mountains in that region. At the same time, eastern region contains relatively flatter area.

Soil map: The study area contains only two type of soil chromic luvisols and lithosols. Most of the area is covered by chromic luvisols soil (Fig. 1c). Chromic luvisols has high infiltration property compared to lithosols. Lithosols are present in the forest region.

Land use/Land cover map: Land use map is generated from LISS IV satellite by using ERDAS 2013 package using unsupervised classification method. Land use map shows surface characteristics of the study area. The major land use types in the study area are cropland, built-up, vegetation, water body and scrubland (Fig. 1d). The crop land has the highest infiltration compare to other categorise and also built-up area has the lowest infiltration rate.

Drainage density map: The drainage density map was created from drainage map using line density method in ArcGIS. Drainage density map is defined as the ratio of the sum of the stream length to the area of the study area. The mathematical representation of drainage density is

$$D_d = \sum_{i=1}^{i=n} \frac{D_i}{A}(km^{-1}) \quad (1)$$

Where, ΣD_i = total length of all stream (km), A = the area of the grid (km^2).

Drainage density map is finally divided into three classes, (i) Low (0-0.191 km/km^2), (ii) Medium (0.191-0.5396 km/km^2), (iii) High (0.5396-1.349 km/km^2) (Fig 1e).

Geology map: Geology map is prepared from the mineral map of geological survey of India on a scale of 1:50000. It shows the lithology of the study area. The bed rock geology of this study area consists of migmatites, chamockite gnesis and pyroxene granulites, copper, granites, granitoid and gnesis, lower gondwana and undifferentiated gondwane (Fig. 1f). The maximum area is covered by chamockite gnesis and pyroxene granulites rocks. Copper is present in very small area.

Geomorphology map: The geomorphic features were interpreted from IRS P6 LISS IV and geology map. The study area is characterised by anthropogenic origin, denudational origin, denudational origin-moderately dissected hills and valleys, fluvial origin-bajada, lacustrine origin, structural origin-moderately dissected hills and valleys and structural origin-moderately dissected upper plateau (Fig. 1g). The maximum area is covered by denudational origin.

Lineament density map: The lineament lines were extracted from Landsat 7 ETM images. These lines were further analyzed and quantified. Lineament map shows the geomorphic lineaments drainage parallel, structural lineament dyke, structural lineament fault, structural lineament joint and fracture lineament. The lineament density was calculated and mapped using line density method in ArcGIS. Edet et al (1998) has defined the lineament density as total length of all recorded lineaments divided by the area to be mapped. The mathematical expression is

$$L_d = \sum_{i=1}^{i=n} \frac{L_i}{A}(km^{-1}) \quad (2)$$

Where, ΣL_i = Total length of all the lineament (km), A = Area under consideration (km^2).

In this study area, lineament density was classified in to

five classes 0-0.0099 km/km^2 (Very Low), 0.0099-0.0275 km/km^2 (Low), 0.0275-0.0617 km/km^2 (Medium), 0.0617-0.1055 km/km^2 (High) and 0.1055-0.159 km/km^2 (Very High) (Fig. 1h).

Rainfall map: The daily rainfall value for a period of 30 years (1987-2017) was collected from the district water resource department. The study area contains 24 rain gauge stations. Inverse Distance Weighted (IDW) interpolation technique was used to interpolate the average annual rainfall values of each location into thematic layer showing average annual rainfall distribution in the area. Finally, the map is categorized into five classes 0.004-5.602 mm (very Low), 5.602-8.401 mm (low), 8.401-11.365 mm (medium), 11.365-14.745 mm (high) and 14.745-20.997 mm (very High) (Fig. 1i).

Groundwater depth map: Groundwater depth data was collected from water resource department. The groundwater depth for the 202 wells is mapped in ArcGIS. The spatial distribution of groundwater depth is obtain using inverse distance weighted (IDW) interpolation technique. Finally, the map is grouped into four classes 0.555-70.83 m (low), 70.83-105.11 m (medium), 105.11-143.68 m (high) and 143.68-219.1 m (very high) (Fig. 1j).

Evidential belief function model: According to Dempster and Shafer DST creates a framework to establish the Evidential Belief Function (EBF) which can be integrated using a set of Dempster's rules of combination. Mogaji et al (2014) has stated the four series of mass functions of EBF models which are namely belief (Bel), disbelief (Dis), uncertainty (Unc) and plausibility (Pls). The main advantage of this model is its uncertainty mass function i.e. its ability to map the target zone and at the same time predict the degree of uncertainty of the particular zone. This capability of the model makes the model reliable and superior to the other spatial data integration model. The belief function indicates the lower probabilities and the plausibility functions represent the upper probability. The properties of these probabilities are explained as below:

$Bel(H) \leq Pls(H)$ - (3) $Pls(H) = 1 - Bel(H)$ -(4)

Where, H represents the negative form of H and Belief H is the Disbelief function. The degree of uncertainty is given by the difference between Belief and Plausibility. An et al (1994) has clearly detailed the basic equations needed to establish the Evidential belief mass functions and these equations are given below (eqn 5 to eqn 14). These equations of mass functions quantify the relationship between groundwater well locations and the factors controlling the groundwater potential in the study area. This model works based on algorithm of likelihood ratio function. If i number of thematic layers are considered in a study area then each layer will have evidence E_i for the target proposition T_P. If E_{ij} is the evidence of the jth class attribute of a particular thematic layer then the likelihood ratio supporting the positive target proposition is given below

$$\frac{\frac{N(L \cap E_{ij})}{N(L)}}{\frac{N(E_{ij}) - N(L \cap E_{ij})}{N(A) - N(L)}} \quad (5)$$

Where, N(L) s the total number of wells, N (E_{ij}) is number of wells occurred in E_{ij}, N (E_{ij}) is the number of pixels in E_{ij} and N (A) is the total number of pixels in the study area.

The belief function is given by the equation below.

$$Bel = \frac{\lambda(T_p) E_{ij}}{\Sigma \lambda(T_p) E_{ij}} \quad (6)$$

The likelihood ratio for the opposite target proposition is calculated using the following equation 7. The equation 8 gives the disbelief function.

$$\lambda(T_p)_{Eij} \frac{\frac{N(L) - N(L \cap E_{ij})}{N(L)}}{\frac{N(A) - N(L) - N(E_{ij}) + N(L \cap E_{ij})}{N(A) - N(L)}} \quad (7)$$

$$Dis = \frac{\lambda(T_p)_{Eij}}{\Sigma \lambda(T_p)_{Eij}} \quad (8)$$

Plausibility function and uncertainty function is calculated using the equation 9 and 10 respectively. The sum of the belief, uncertainty and disbelief is equal to one, when the degree of uncertainty is equal to zero i.e., that pixel does not contains groundwater potential. The belief and plausibility varies from 0 to 1.

$Pls = 1 - Dis$ - (9) $Unc = Pls - Bel$ -- (10)

After calculating the mass functions for all the factors considered the Dempster's rule of combination is used to estimate the integrated mass functions (Dempster 1968). The Dempster's rules of combination have both commutative and associative attribute i.e. the different grouping or ordering of evidence combination does not affect the final result (Carranze et al 2008, Mogaji et al 2014). The combination rule used in this study to combine two factors A and B is given below

$$Bel_x = \frac{Bel_A Bel_B + Bel_A Unc_B + Bel_B Unc_A}{\beta} \quad (11)$$

$$Dis_x = \frac{Dis_A Dis_B + Dis_A Unc_B + Dis_B Unc_A}{\beta} \quad (12)$$

$$Unc_x = \frac{Unc_A Unc_B}{\beta} \quad (13) \qquad Pls_x = Unc_x Bel_x \quad (14)$$

Where, Bel_x is the lower degree of belief for each factor, Dis_x is the degree of disbelief for each factor, Unc_x is the degree of uncertainty for each factor, Pls_x is the higher degree of belief for each factor and X denotes each factor type. B is a normalization factor which is called as the degree of conflict. George and pal 1996 defined β as a measure of conflict between the pieces of evidence. The mathematical expression of β given below

$$\beta = 1 - Bel_A Dis_B – Dis_A Bel_B \qquad (15)$$

RESULTS AND DISCUSSION

The belief map compared with the disbelief map, indicates that the area with high belief values exhibits low value of disbelief. The cell with high belief and low disbelief value indicates high groundwater potential. For the slope factor, high belief value of 0.672 was in the medium class (10°-20°) and low disbelief value of in the low class (3°-10°). This implies that the medium and low classes of the slope factor have a positive association with the groundwater potential. This is mainly due to the fact that the area with low and medium slope will have less runoff and more infiltration (Mogaji and Lim 2017). The rest of the classes in the slope factor have minor effect on groundwater potential (Table 1). In drainage density, a high belief of 0.39 and low disbelief of 0.285 was observed for the medium drainage density. This clearly indicates that the medium drainage density class has strong affinity towards the groundwater potential. Similarly, the very high lineament density category shows a high belief of 0.411 and low disbelief of 0.191. Therefore, the very high lineament density category is strongly associated with high groundwater potential. The remaining classes of lineament density have a minor effect on the groundwater potential.

The area with medium rainfall (8.401-11.365 mm) has the high belief value of 0.213 and low disbelief value of 0.191 (Table 1). Similarly, the crop land has a high belief value of 0.319 and low disbelief value of 0.163. The above results indicate that the area with medium rainfall and crop land cover has high groundwater potential. The cells with very high groundwater depth have the high belief mass functions value of 0.424 and cells with low groundwater depth has low disbelief function of 0.192.

The area with denudational origin has a high belief mass function values of 0.734 and low disbelief value of 0.004 reflecting high probability for high groundwater potential . The remaining classes of the geomorphology shows a very low value of belief which indicates that they do not play a major role in groundwater potential identification. In geology, a high belief value of 0.451 was for undifferentiated gondwane and low disbelief value of 0.026 for chamockite gnesis and pyroxene granulites. The area with chromic luvisols soil type shows high belief (0.635) and low disbelief (0.364) (Table 1). This implies that area with chromic luvisols soil has a high probability for high groundwater potential. The above discussion clearly indicates that cells with moderate to high belief values correlates with cells with low disbelief value i.e. the integrated disbelief mass function map compliments the integrated belief mass function map (Mogaji et al 2014).

The uncertainty mass function map which is the uniqueness of this model provides the information to improve the accuracy (Carranza and Hale 2002). Comparison between the uncertainty map and belief map clearly shows that the area with low belief value has high value of uncertainty and vice versa. The area with high belief value has low uncertainty value this illustrates that the belief about the high groundwater potential in that area is reliable.

The comparative analysis between the four mass function maps indicates high belief value is correlated with low disbelief, high plausibility value and low uncertainty value in an area. This concludes that the belief function map is the most appropriate map for evaluating the groundwater potential zone (Mogaji and Lim 2017). In this study, the estimated belief mass function values are used to find the groundwater potential. The belief values are a series of continuous values ranging from 0.0782 to 0.4784 and it is classified into five classes of groundwater potential (very low, low, medium, high, very high) using natural break method (Fig. 2e). The very low category covers 10.21per cent (632.1 km^2). This category is mainly found in the north-eastern region of the study area. The low groundwater potential category occupies larger area of the study area i.e. 46.56 percent (2882.5 km^2) (Fig. 2e). The medium zone occupies 30.32 percent (1877.1 km^2) of the study area and mostly found in the central part of the study area.

The high and very high zones cover 12.91 percent (799.3 km^2). This category of groundwater potential map concentrates in the northern region of the study area. Validation is the fundamental step in the development of the groundwater potential map and it is important for determining the predictive ability. The accuracy assessment was performed by comparing the groundwater potential map and the well test data set. The groundwater potential index of the above model is converted into values between 0 and 1 using linear membership function for the purpose of validation. After the conversion of the values from 0 to 1, the values are classified into ten classes with intervals of 0.1. Then, validation is performed by comparing the known well location data with the groundwater potential map of ten classes (Table 2). When the groundwater potential index value is below 0.4, the well occurrence ratio is 8.2 per cent. When the index value is above 0.4, the occurrence ratio is very high (91.81%)

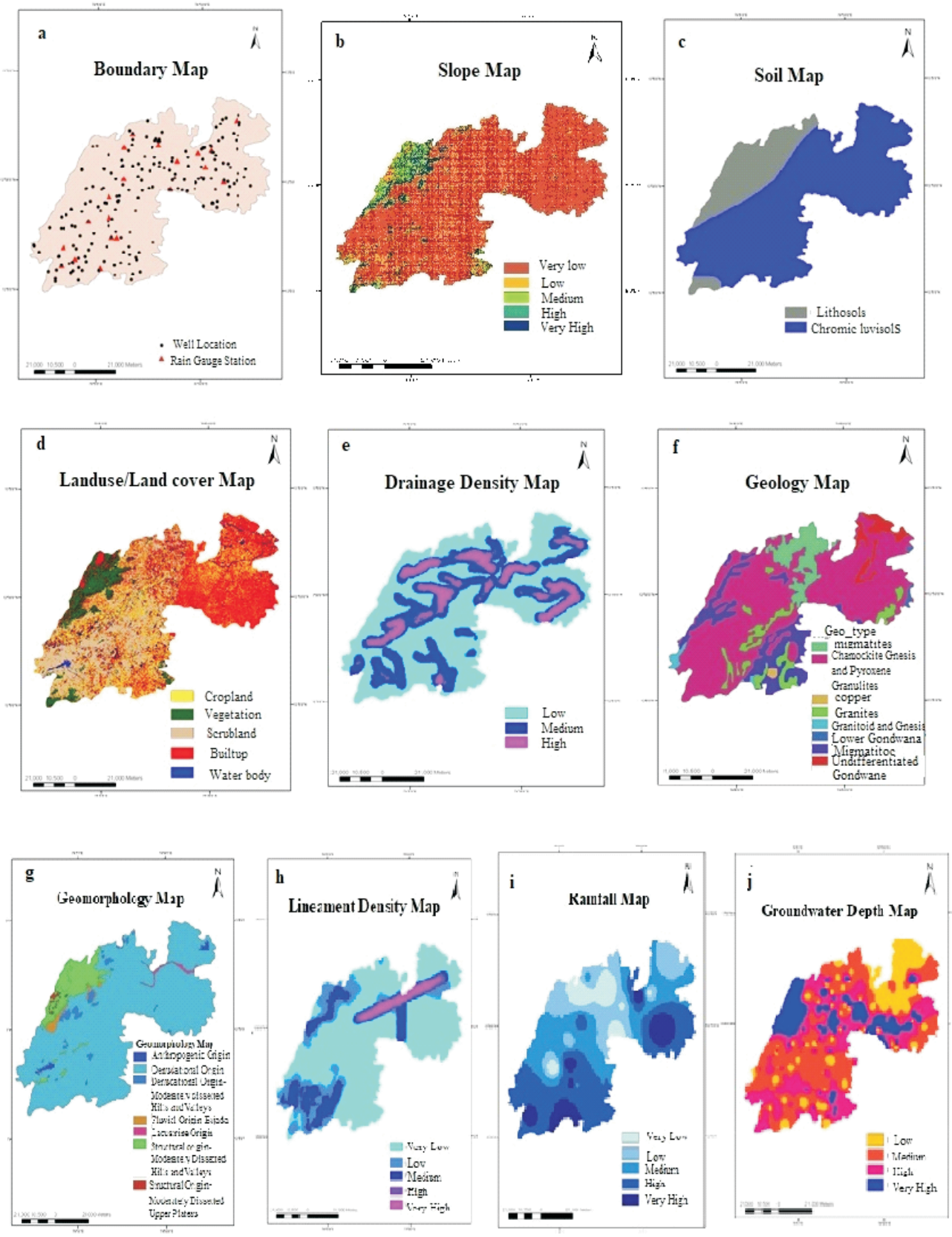

Fig. 1. Thematic layers: **a** boundary map, **b** slope map, **c** Soil Map, **d** landuse/land cover map, **e** drainage density map, **f** geology map, **g** geomorphology map, **h** lineament density map, **i** rainfall map, **j** groundwater depth map.

Table 1. Values of Dempster Shafer mass functions for category of groundwater potential factors

Factor	Category	Number of class pixel	Pixels (%)	Number of wells	Well (%)	Frequency ratio	Dempster Shafer mass functions			
							Belief	Disbelief	Uncertainty	Plausibility
Slope	Very low	179312	0.02	69	0.31	11.458	0.372	0.109	0.519	0.891
	Low	228367	0.03	127	0.57	16.562	0.537	0.067	0.396	0.933
	Medium	27337	0.004	19	0.08	20.701	0.672	0.142	0.186	0.858
	High	169103	0.25	4	0.01	0.070	0.002	0.205	0.793	0.795
	Very high	439268	0.67	0	0.00	0	0	0.475	0.525	0.525
Drainage density	Low	23377	0.57	104	0.47	0.825	0.25	0.398	0.352	0.602
	Medium	11531	0.28	80	0.36	1.290	0.39	0.285	0.325	0.715
	High	5767	0.14	35	0.15	1.127	0.34	0.315	0.338	0.685
Lineament density	Very low	26633	0.66	148	0.67	1.01	0.187	0.196	0.617	0.804
	Low	6067	0.15	30	0.13	0.898	0.166	0.204	0.63	0.796
	Medium	4883	0.12	22	0.10	0.818	0.152	0.205	0.643	0.795
	High	828	0.02	2	0.009	0.437	0.081	0.202	0.717	0.798
	Very high	1404	0.03	17	0.07	2.216	0.411	0.191	0.398	0.809
Rainfall	Very low	3366	0.08	24	0.10	1.312	0.252	0.194	0.554	0.806
	Low	8723	0.21	39	0.17	0.820	0.157	0.209	0.634	0.791
	Medium	10749	0.26	65	0.29	1.112	0.213	0.191	0.596	0.809
	High	13600	0.33	70	0.31	0.945	0.181	0.205	0.614	0.795
	Very high	3814	0.09	21	0.09	1.012	0.194	0.199	0.607	0.801
Groundwater depth	Low	5638	0.14	68	0.31	2.231	0.382	0.192	0.426	0.808
	Medium	11575	0.28	30	0.13	0.475	0.081	0.291	0.628	0.709
	High	18994	0.47	67	0.30	0.647	0.111	0.316	0.573	0.684
	Very high	4045	0.10	54	0.24	2.473	0.424	0.200	0.376	0.800
Soil	Chromic luvisols	31556	78.34	132	86.27	0.632	0.364	0.635	0.001	0.365
	Lithosols	8723	21.66	21	13.73	1.101	0.635	0.234	0.001	0.636
Geology	Migmatites	1649	4.21	4	2.61	0.62	0.025	0.11	0.89	0.865
	Chamockite gnesis and pyroxene	3093	7.89	119	77.8	10.210	0.418	0.026	0.974	0.556
	Copper	2557	6.52	2	1.31	0.199	0.008	0.114	0.886	0.878
	Granites	26127	66.66	7	4.58	0.068	0.002	0.312	0.688	0.686
	Granitoid & gnesis	317	0.81	2	1.31	1.620	0.066	0.107	0.893	0.827
	Lower gondwana	201	0.51	0	0	0	0	0.109	0.891	0.891
	Migmatites	5107	13.1	13	8.5	0.651	0.026	0.114	0.886	0.860
Geomorphology	Anthropogenic origin	33809	86.14	0	0	0	0	0.59	0.41	0.41
	Denudation origin	777	1.98	145	0.95	18.109	0.734	0.004	0.262	0.996
	Denudation origin – moderately dissected hills & valleys	3477	8.86	3	1.96	0.192	0.007	0.085	0.908	0.915
	Fluvial origin – bajada	232	0.59	1	0.65	1.106	0.044	0.079	0.877	0.921
	Lacustrine origin	467	1.19	0	0	0	0	0.08	0.92	0.92
	Structural origin-moderately dissected hills & valleys	199	0.51	4	2.61	5.241	0.212	0.078	0.71	0.922
	Structural origin-moderately dissected upper plateau	290	0.74	0	0	0	0	0.08	0.92	0.92
	Anthropogenic origin	33809	86.14	0	0	0	0	0.59	0.41	0.41
Land use/land cover	Built-up	208363	0.29	88	0.40	1.345	0.266	0.169	0.565	0.831
	Cropland	158131	0.22	80	0.36	1.612	0.319	0.163	0.518	0.837
	Scrubland	246654	0.35	34	0.15	0.439	0.087	0.259	0.654	0.741
	Vegetation	533504	0.07	2	0.009	0.119	0.023	0.213	0.764	0.787
	Water body	313801	0.04	15	0.06	1.523	0.302	0.194	0.504	0.806

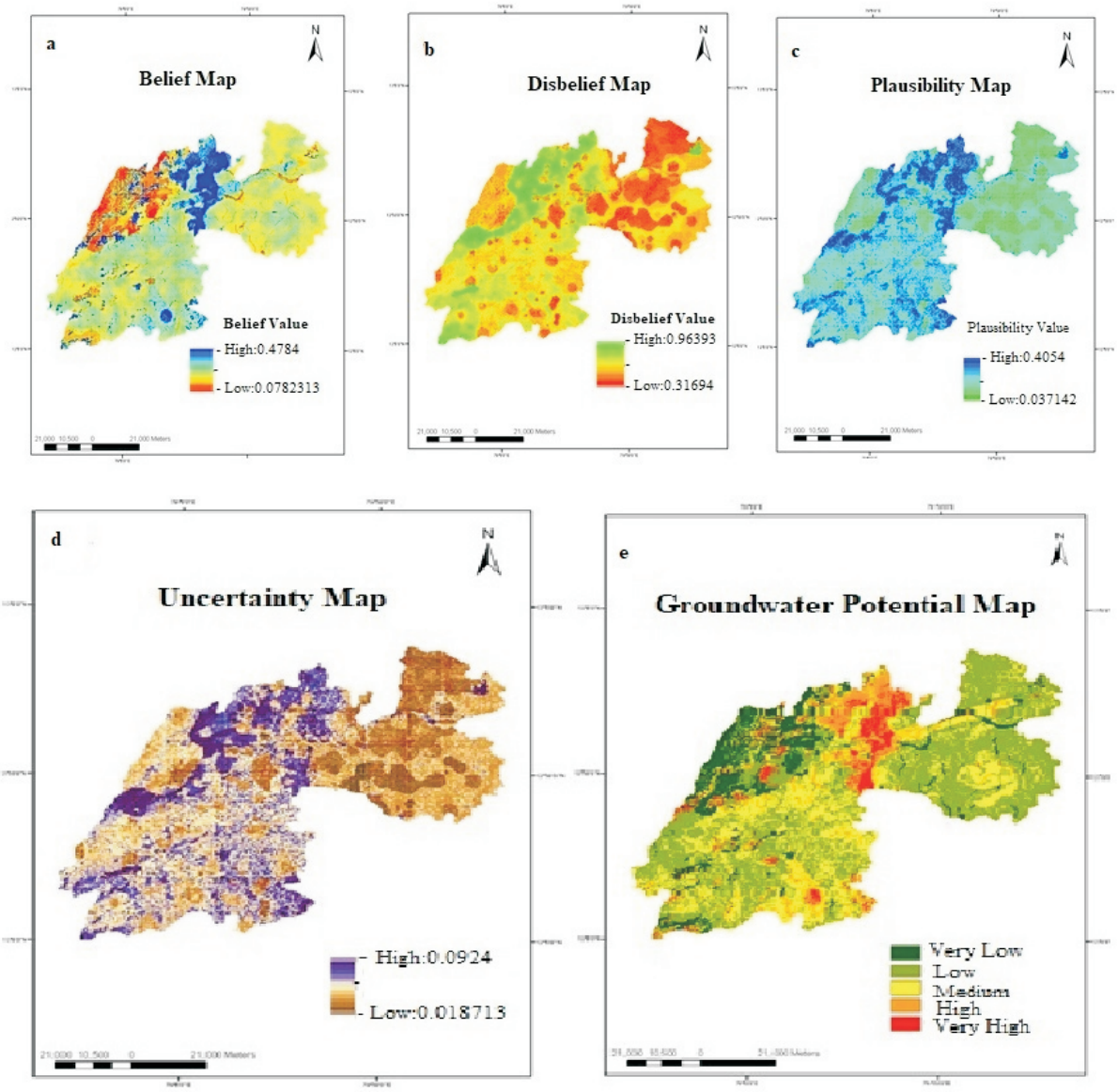

Fig. 2a. Belief map, **b** Disbelief map, **c** Plausibility map, **d** Uncertainty map, **e** Groundwater potential map.

Table 2. Validation of groundwater potential map

Classes	Number of wells	Percentage	Cumulative percentage
0 - 0.1	0	0	0
0.1 - 0.2	0	0	0
0.2 – 0.3	0	0	0
0.3 – 0.4	5	8.2	100
0.4 - 0.5	12	19.67	91.81
0.5 – 0.6	7	11.48	72.14
0.6 – 0.7	7	11.48	60.66
0.7 – 0.8	11	18.03	49.18
0.8 – 0.9	12	19.67	31.15
0.9 - 1	7	11.48	11.48

(Table 2). The well occurrence ratio above 0.5 groundwater potential index is calculated to find the prediction accuracy of the models. The well occurrence ratio above 0.5 is 91.81% (Table 2). This proves that Dempster Shafer theory model has high prediction accuracy to delineate the groundwater potential zones. The results ascertain that the Dempster Shafer model has a unique capability to predict the groundwater potential zone and their respective degree of uncertainty.

CONCLUSIONS

To predict the groundwater potential a total of nine sets of factors which were believed to control the flow, infiltration, precipitation and storage of water in the area were selected.

Dempster Shafer Evidential Belief Model was identified to map the groundwater potential for the study area. The main advantage of this model is that it can represent the uncertainty thereby produce a reliable prediction. The evidential mass functions of different thematic layers were generated using likelihood ratio and integrated using Dempster's rule. The groundwater potential map generated using Dempster Shafer model was validated and found to have 91.81 per cent accuracy. Hence this study establishes GIS based Dempster Shafer Evidential Belief Model as an accurate and reliable prediction model. The proposed methodology is an accurate and comprehensive prediction model for groundwater potential zone mapping. It also predicts the degree of uncertainty of the predicted groundwater potential map which reduces the biasness in environmental decision making process. The results of this research work can be used by decision makers and planners of Tiruvannamalai district. The accuracy of this model can be improved by adding more thematic layers to the study.

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Time Variant Growth Approximation Model for Estimation of Crop Yield and Water Regulation using Environmental Factors (FCG)

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Abstract: In this research work, new approach of time variant growth approximation model has been proposed for computing the amount water required to the cultivated crop and to estimate the yield of the crop for all the time window and region. The source of data were obtained from the weather data collected through the source of Agro climate research Centre, Tamil Nadu Agricultural University, Coimbatore, Tamil Nadu, India for Coimbatore and Ammapet region. In this proposed method, initially the yield traces are split into a number of time spaces according to the plant being considered, and performs approximation under specified conditions. The growth approximation technique computes time oriented growth weight for each plant based on various irrigation methods (fluid), climate and geological parameters. Additionally, the method estimates the water regulation factor for each time window and generates a water key factor value. The water key factor denotes the level of water to be regulated to improve the crop yield using the environmental factors (FCG) like water, climate, and geology. The results of yield estimation efficiency produced by this model are 98% which was higher in comparing with the other methods. The estimated crop yield and water regulation to the cultivated crop achieved by the proposed new approach was 82500 Kg/ ha and 140 mm respectively. The results of this proposed method shows improvements in comparing with the other methods. Hence this time variant growth approximation model proposes new innovative approach in estimating the amount of water needed to crop and estimating the crop yield for all seasons and regions .

Keywords: Precision agriculture, Crop Yield, Water Regulation, FCG, Time variant model, Growth Approximation

The rapid increase in human population worldwide necessitates the importance of higher crop yield. To achieve the target, novel scientific approaches are being considered. The growth of plants often depends on various factors (Kiwi (2013) namely temperature (Kariyama 2014), humidity, nature of the soil (Lavina and Chadha 2013), irrigation pattern and other environmental factors. Each one of the above parameters plays a pivotal role on the specific crop yield. In addition to the above, the role of fluid, climate and geology (FCG) on the yield of commercially important crops have been well established wherein the fluid represents the irrigation and the climate denotes temperature/humidity and the geology means the nature of the soil. By regulating the individual components of FCG, the yield can be improved significantly. The crop yield is depending on various factors as specified above. Certain crops such as paddy and wheat (Hardaha et al 2012) cannot be cultivated in all the soil pattern which requires specific soils. Similarly for a plant to be growing better and to produce specific yield, it requires specific patterns of water irrigation (Irawan et al 2013) with specific humidity/temperature conditions. When one of the factors hikes or lowers, then the yield of the crop gets reduced. So there are many conditions to be monitored to achieve the specific crop yield.

The present scenario necessitates the requirement of a water management/regulation (Adeloye et al 2011, 2012) scheme capable of monitoring the growth of plants and produce reliable and reproducible results to improve the crop yield. Additionally, the water regulation scheme has to maintain the logs about the earlier crop and the details about the water have been poured with the conditions. By identifying the related traces of water poured and the area of land and time details, the crop yield achieved can be identified. Identified yield results with the previous states can be used to approximate the crop yield according to given conditions. Once the crop yield for specific conditions can be computed then the same can be approximated for the current conditions. Such an approximation scheme would support the crop yield estimation and could support the water regulation scheme. If the approximation has been performed then we can compute the required water level to be poured for the plant. Hence the main objective of this research work is to develop a crop yield estimation model and water regulation scheme by using artificial neural network

(Sudheer et al 2013) to estimate the crop yield and also to estimate the requirement of amount of water to the cultivated crop for all seasons and regions (Huang et al 2012).

MATERIAL AND METHODS

The framework for the development of the methodology is for the crop yield estimation and water regulation. The Fig. 1 outlines the general approach and the methodology reported in this paper, describes the various components of the methodology in the following sections.

Data source and description: The weather data set was obtained from Agro Climate Research Centre, Tamil Nadu Agricultural University, Coimbatore, Tamil Nadu, India. The trained data set used for tomato crop yield estimation and water regulation for Ammapet and Coimbatore region is given in Table 1. The temperature, humidity, rainfall (Nastos et al 2011) are the environmental factors affecting the crop yield estimation. The yield is the historic tomato yield value from 2015 - 2017.

Parameters for tomato yield estimation: The parameters considered for tomato yield estimation were temperature (ºC), humidity (%), rainfall (mm) during the cultivation period, water for irrigations, area (ha), plant height,(cm) and tomato yield (kg ha^{1}) from 2015-2016.

Artificial neural networks: The artificial neural network consists of three layers (Fig. 1). The first layer is input neuron which accepts the data and sends it to second layer of neurons. The second layer also called hidden layer which accepts the data from input layer and processes it and sends it to third layer of output neurons. The third layer accepts processed data from hidden layer and creates output (Liu et al 2013).

Time variant growth approximation model: The model reads the crop yield data set and split them into number of sectors according to the time factor. From the time variant log, the method identifies the related log, and estimates the crop yield by computing the crop yield weight. The same is performed for all instances identified from the log. Using the same, the approximation method estimates the crop yield for the current conditions given. Similarly, the same approximation technique is used to estimate the water regulation factor. The water key value is computed using the estimated water regulation factor. The entire process has been split into number of stages as shown in the architecture (Fig. 2).

Preprocessing: The crop trace present in the dataset has been read and the method splits the trace into different sectors based on the time window. At each time window trace, there will be number of logs belongs to the same crop. The method identifies the distinct crop trace and list of traces belongs to the same. The preprocessing algorithm splits the entire log into time variant sectors and identifies the distinct traces

Algorithm:

Input: Crop Trace CT
Output: Time variant Trace Tvts
Start
Read Crop trace CT
Identify list of time window Tw
Tw = $\int_{i=1}^{size\ (CT)} \sum Distinct(Ti)\varepsilon CT$
For each time window Ti from Tw
Identify logs and split them
Tvt (Ti) = $\int_{i=1}^{size\ (CT)} \sum CT\ (i).T == Ti$
End
Initialize Distinct trace DT
Stop.

Time variant growth approximation: The time variant growth approximation is performed based on the traces being split. For the same crop trace a number of trace will be there and final yield obtained in one of the trace. But the yield being achieved based on the other factors available in the rest of the traces. The method collects all the factors and computes the time variant growth weight. Computed growth weight will be used to estimate the crop yield in the future. The algorithm computes the growth weight for different plants and computed growth weight will be used to estimate the crop yield

Algorithm:

Input: Time variant Trace set Tvts
Output: weight set Ws
Start
For each distinct trace Ti
Compute water factor
wf = $\int_{i=1}^{size\ (CT)} stdDev(\sum Tvts\ (i).WaterPoured) + \sum Ts\ (i).Rain$
Compute Temperature factor Tf = $\int_{i=1}^{size\ (Distinct\ (Ts))} stdDev\ (\sum Tvts\ (i).Temp$
Compute Humidity Factor Hf = $\int_{i=1}^{size\ (Distinct\ (Ts))} stdDev\ (\sum Tvts\ (i).Hum$
Compute Soil Factor Sf = $\int_{i=1}^{size\ (Distinct\ (Ts))} \frac{Yield}{Soil}$
Compute growth weight Yw = $\frac{Sf\ x\ Wf}{Tf + Hf}$
End
Stop

Time orient water approximation: The water approximation represents the water content required for the growth of plant and how it affects the yield of the crop. The method computes the water approximation value for different time window. The computed water approximation value will be used to estimate the crop yield.

Algorithm:

Input: Time orient trace set Tvts
Output: Water approximation value wav
Start
For each time window Ti

For each distinct trace

Compute water approximate value

Wav = $\int_{i=1}^{Tw} \frac{\sum Yield}{\sum Tw.Water}$

End

End

Compute water approximate value wav = $\frac{\sum Wav}{size\ (T)}$

Stop

The above discussed algorithm computes the water approximate value and computed value will be used to estimate the crop yield and water regulation.

Crop yield estimation and water regulation: The crop yield is estimated based on computing the time orient growth approximation value for different time window (Huang et al 2012). By computing the growth weight for each time window, then the standard deviation can be computed. For the similar set of features, the crop yield can be estimated using weight computed. Similarly the water regulation value will be computed using the water approximated value. The estimation of the crop yield (Cy) along with estimate of the water regulation (Wrv) is obtained from algorithm which belongs to section of crop yield estimation and water regulation.

Algorithm:

Input: Trace T

Output: Crop yield Cy, water regulation Wav

Start

For each time window Ti

Growth weight gw = Time-Variant-Growth-Approximation (Ti, T)

Water-approximate value Wav = Water Regulation (Ti,T)

End

Compute crop yield Cy = $\int \frac{\sum crop\ yield}{\sum Growth\ weight} X\ Growth\ weight\ (Current\ Time)$

Compute Water Regulation value Wrv = $\int \frac{\sum crop\ yield}{\sum Water\ regulation} X\ Wav\ (Current\ Time)$

Stop.

RESULTS AND DISCUSSION

The proposed time variant growth approximation model has been implemented and examined with huge number of logs for various cultivated regions. The method produces the results of regulation of the amount of water needed to the cultivated crop and the crop yield for the entire situation and the details are shown in the following sections. The evaluation details are shown in the Table 2 being used to evaluate the performance of the proposed yield estimation algorithm. The proposed model has been evaluated for its performance in various factors and compared with the performance of other existing methods (Joshi et al 2013).

The crop yield estimation efficiency (%) in C2HG, Relational Model, MVGA was 95.0, 96.5 and 98 and did not show much variation but was low in FFBANN. However, the

Table 1. Sample of trained data set for one ha area

Date (March)	Day	Temp. (ºC)	Humidity (%)	Water used for irrigation (mm)	Plant growth (cm)	Yield (kg/ha)
8	70	28.15	81	5	140.8	800
9	71	27.5	78	5.5	142.63	0
10	72	27.6	81	5.5	144.46	0
11	73	26.3	81	5.5	146.29	0
12	74	28.5	65	5.5	148.12	900
13	75	26.3	81	5.5	149.95	0
14	76	28	84	5.5	151.32	0
15	77	26.1	81	5.5	152.69	0
16	78	27.85	84	5.5	154.06	1100
17	79	28.1	76	5.5	155.43	0
18	80	28.1	80	5.5	156.8	0
19	81	26.8	66	3.0	158.17	0
20	82	28.5	84	3.0	159.54	1400

No rainfall during March 8-20

Table 2. Details of evaluation

Parameter	Value
Tool used	Matlab 2014
Size of trained data	30000
Time window	3 years

Table 3. Comparison of results of various methods

Parameter	FFBANN	C2HG	Relational model	MVGA
Yield estimation efficiency (%)	84.7	95.0	96.5	98
Yield achieved (Kg/ha)	20100	64000	71500	82500
Time Complexity (m/s)	11.9	10.8	8.47	7.24
Water regulation performance (mm)	440	320	288	140

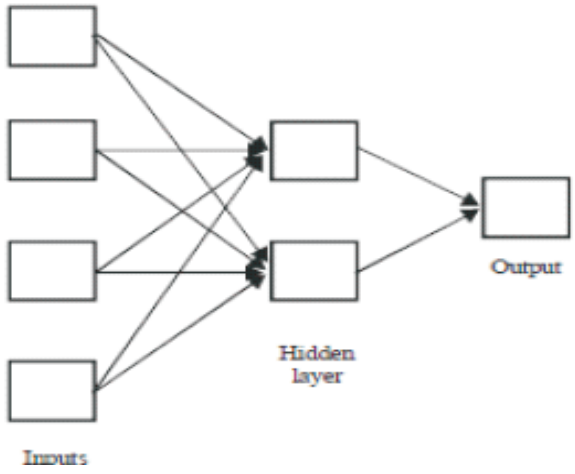

Fig. 1. Artificial neural network (Shastry et al 2016)

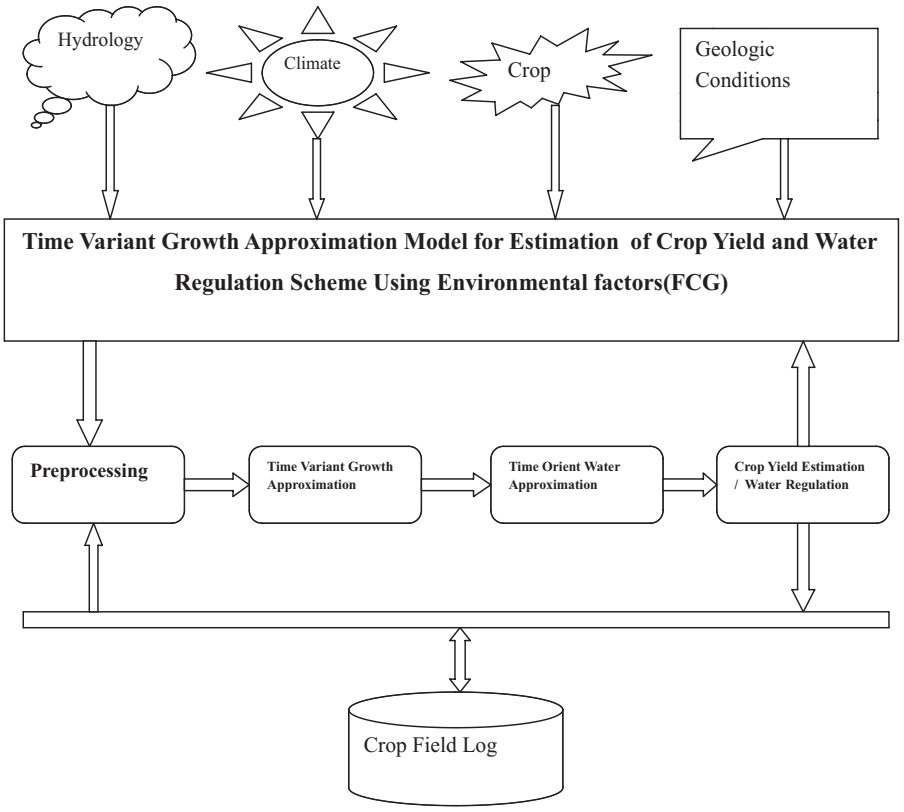

Fig. 2. Architecture of time variant growth approximation approach

proposed multi variant growth approximation model has produced higher yield estimation efficiency in comparing with the other methods. The crop yield achieved has been evaluated for various methods varied from 20100 (C2HG) to 82500 kg /ha (MVGA) and shows that the proposed model has produced higher yield compare to other methods. The time complexity was maximum in FFBANN (11.9 m/s) and minimum in MVGA (7.24m/s). The proposed multi variant growth approximation model has produced less time complexity than other three methods considered. The result of water regulation performance achieved has been evaluated for these four methods but MVGA model has produced better results on water regulation required and the performance has been improved (Table 3).

CONCLUSION

An efficient time variant growth approximation model is described in this work. The model split the whole log into number of time window (month) and for the entire unique time window, the individual logs list were identified. The method computes crop yield and water regulation value. This work proposes a new scheme for computing the tomato crop yield estimation using environmental factors like water, climate, and geology. Hence this proposed model has been the best method in estimating the tomato crop yield and regulating the water required for all season and regions in comparing with the previous methods in order to obtain sustainable productivity. This proposed new model will help in computing the need of water and estimating the yield of the tomato crop in considering the changes in environmental factors.

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Calibration and Validation of CERES-Wheat (DSSAT v4.6) Model for Wheat under Irrigated Conditions: Model Evaluation and Application

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Abstract: In this study, a manual method was applied to calibrate and validate CERES-Wheat (DSSAT v4.6) for the flowering day, maturity day, leaf area index and grain yield of Rabi wheat (cv. HD2733) using the experimental data of 7 years (2008-2014) with sowing date range between 18-23 November. The model was validated with independent data sets of 2012-13 and 2013-2014of cropping seasons which were not used for models calibration. The model simulations were acceptable for calibration as well as validation period, as the model evaluation indicators showed R^2 within the range of 0.60 to 0.73, RMSE between 1.25 to 218, MAE (1 to 194), *D*-index (0.77 to 0.88) and percent error (0.79 to 8.50) against observed and simulated phenology and grain yield of wheat. Evaluation with the measured data showed that performance of model was realistic as indicated by the accurate simulation of crop phenology, LAI and grain yield against measured data. Climate variability results depicted that short exposure of crop to extreme temperature from 5 to 7°C resulted in significant reduction in days to anthesis, physiological maturity and 29% average decline in yield of wheat. It was concluded that, to bring accuracy in the simulation outcomes of models, new cultivars should be calibrated to minimize uncertainty to allow judicious recommendations in response to climate variability.

Keywords: CERES-Wheat model, Calibration & validation, Climate variability, Wheat

Crop modeling facilitates development of innovative crop management strategies and agricultural sustainability under continuous changing climate as it expresses the response of crops to meteorological, edaphic and biological factors (Martin et al 2014). Crop modeling aids in decision making, forecasting of crop growth and development, minimizing yield gaps, selection of suitable genotypes and appropriate sowing dates for sustainable crop production under changing climatic scenarios (Anwar et al 2015, Asseng et al 2015). It is becoming a valuable tool for increasing the understanding of crop physiology and ecology and could be used to analyze and optimize, e.g., the planting regime (Dong et al 2014). An important task in experimenting with models is the testing of their performance in a wide range of circumstances to identify their scope of validity and limitations. Crop simulation models are site and crop specific in nature and should not be used in other areas until and unless validated under local conditions. Crop simulation models are key tools in studying the impact of climate variability on different crops. These models have the potential to reveal different adaptation options under different climatic scenarios (Li et al 2015). Climate variability led to a 40 per cent yield loss in spring wheat under water stress as simulated by a mechanistic model (Pavlova et al 2014). Similarly, high temperature/ heat stress during the crop life cycle reduced crop yield (Prasad and Jagadish 2015). The 5.3 per cent yield reduction for each 1°C rise in growing season average daily temperature was reported by (Innes et al 2015).

In Bihar, weather related extremes (heat and cold waves, floods, droughts, cyclones) have been a recurrent phenomenon, which affects more than 45 per cent of the geographical area of the state (Economic Survey 2014, Mahdi et al 2016). The regional vulnerability of wheat production to climate change and its extremes should be assessed at local level. Various models are being used around the world as tools for studying crop growth, development and yield in response to climate change variability. However, model application requires high quality, site-specific data on weather, soil, management and cultivar (Boote et al 2015). Studies have been initiated in Bihar too, but they require testing of various models to identify the models scope and limitations. Comparative evaluation of CERES-Wheat models and application has been rarely undertaken for wheat growth and development in Bihar. The present study was carried out with the objectives to calibrate and validate CERES-Wheat for ruling wheat cultivar 'HD2733' for growth, development and yield and to apply

CERES-Wheat models to study impacts of extreme temperature(heat stress) on wheat phenology and yield under irrigated conditions.

MATERIAL AND METHODS

Field experiment: Seven years (2008-2014) field experiment was conducted at Bihar Agricultural University, Sabour, Bhagalpur, Bihar and the experimental data of five years (2008-12) was sued for the calibration and last two years (2012-14) for validation. These experiments of wheat cv. HD2733, sown between 18-23 November under irrigated conditions were conducted with the recommended dose of fertilizers. The measured parameters such as, grain yield, biological yield, leaf area index, plant height, 100 seed weight, days to anthesis and days to maturity and N content in straw and grain were provided for the model as observed data for the calibration and validation of model.

Weather and soil data: The weather data (daily basis) on maximum and minimum temperatures, rainfall and sunshine hours of recent 46 years (1969-2014) of Sabour was obtained from National Data Centre, Indian Meteorological Department, Pune. Solar radiation from sunshine hours was calculated by the model based on Hargreaves method (Bandyopadhyay et al 2008). After the experiments, the soil of the study site was sampled in 20 cm increments to 165 cm with each layer analyzed separately (Table 1).

Model calibration: The model was calibrated by comparing the simulated yield with the observed yield for five years of experimental data. The genetic coefficients required in the CERES-wheat model were estimated by repeated iterations in the model calculations until a close match between simulated and observe phenology, growth and yield were obtained. The genetic coefficients determined for the wheat cultivar cv. HD2733 were used in the subsequent validation.

Model validation and criteria: For evaluation of calibrated genotypes, the simulated dates of anthesis and physiological maturity as well as yield and yield components were compared with the observed data. Different statistic indices were employed, including, Coefficient of Determination (R^2) (Eq. 1) to test the goodness of fit between observed and simulated values, root mean square error (RMSE) to measure the coincidence between measured and simulated values (Eq. 2) (Loague and Green 1991), mean absolute error (MAE) (Eq. 3) to measure how close simulations are to the eventual outcomes. The D-index, an index of agreement (Eq. 4) (Willmott et al 1985) to make cross-comparisons between model runs was applied to evaluate the model performance. Validation of the model was done using percent departure for 2013 and 2014 data.

$$R^2 = 1 - \frac{\sum_{i=1}^{n} (X_{obs_i} - X_{sim_i})^2}{\sum_{i=1}^{n} (X_{obs_i} - \overline{X}_{obs_i})^2} \quad (1)$$

$$RMSE = \sqrt{\frac{\sum_{i=1}^{n} (X_{obs_i} - X_{sim_i})^2}{n}} \quad (2)$$

$$MAE = \frac{\sum_{i=1}^{n} (X_{obs_i} - X_{sim_i})}{n} \quad (3)$$

$$d = 1 - \sqrt{\frac{\sum_{i=1}^{n} (X_{obs_i} - X_{sim_i})^2}{[\sum_{i=1}^{n} |(X_{obs_i} - \overline{X}_{obs_i})| + \sum_{i=1}^{n} |(X_{sim_i} - \overline{X}_{sim_i})|]^2}} \quad (4)$$

Where X_{obsi} is observed values and X_{simi} is modeled values at time/place *i*.

Sensitivity analysis: The widely accepted approach to analyze possible effects of different climatic parameters on crop growth and yield is by specifying the incremental changes to climatic parameters and applying these changes uniformly to baseline/ normal climate (Hundal et al 2007). Sensitivity analysis was performed to know the role short exposure (4-6 days) of extreme maximum temperature (heat stress) at different crop growth stages. This was done by increasing the maximum temperatures (mean) only from 5°C to 7°C from normal at different stages of crop growth without changing the minimum temperature. The carbon dioxide (CO_2) level was kept constant at 390 ppm in each run and simulation.

RESULTS AND DISCUSSION

Days to anthesis: The observed duration of days to anthesis varied between 90 to 93 days and that simulated by CERES-Wheat model from 89 to 95 days during the 5 years of crop cycle. The range of magnitude of deviation between simulated and observed days to anthesis varied between 1 to 3 days over the years. The results showed that the model underestimated the days to anthesis during the year 2012 whereas, it was overestimated during 2008, 2009, 2010 and 2011 by the model. The values confirm the robustness of the models as computed in terms of RMSE (1.36), MAE (1.02), R^2(0.76) and index of agreement (0.76) over 5 years of simulation indicated that model performed well in all the years (Figure 1) in simulating the days to anthesis. During validation period model overestimated the anthesis days by 2

days variation (Table 2).

Leaf area index: The average observed maximum LAI was 3.98 and the simulated LAI was 4.08 over 5 crop cycles (Fig. 2). The model overestimated the values of LAI in all years except 2008 under study. The average values for RMSE, index of agreement (D-stat), MAE, and R^2 for LAI were 0.16, 0.13, 0.83 and 0.70 respectively. The error percentages between observed and simulated values were below 5 per cent. This indicates that model performed well in simulating the LAI with regard to measured values during all years of study. Percent departure for LAI during validation period also remained below 5 per cent (Table 2).

Days to maturity: The observed duration of days to physiological maturity varied between 123 to 126 days. Similarly the corresponding values as the simulated by the model ranged between 124 to 127 days. The range of magnitude of deviation between simulated and observed days to physiological maturity varied between 0 to 0.81 days over five years. The results showed that the model overestimated the days to physiological maturity during the crop season of 2009-2012. The values of errors as computed in terms of RMSE (0.65), MAE (0.43),R^2 (0.84) and index of agreement (0.85) over the 5 years of simulation indicated that model performed well in all the years in predicting the physiological maturity dates of a wheat crop (Fig. 3). It is also observed that during validation the physiological maturity is well predicted by the model with error percentage less than 2 per cent (Table 2).

Grain yield: Grain yield is the product of radiation interception by crop canopy, radiation use efficiency and harvest index. Measured grain yield of wheat varied from 4543 to 5028 kg ha^{-1} while, model simulated grain yield ranged between 4741 to 5100 kg ha^{-1}. Over the 5 years of simulation, the model overestimated the grain yield in all the years except during the year 2008, where model underestimated the yield (Fig. 4). The range of magnitude of deviation between simulated and observed grain yield varied between 48 to 198 kg ha^{-1}. Model evaluation indices during calibration RMSE (126.18), MAE (100.57), R^2 (0.79) and index of agreement (0.77) and during validation percent departure (-4.0,-3.7) confirm the robustness of model to simulate grain yield with great accuracy.

Impact of increasing temperature (heat stress) on phenology and yield of wheat: Since higher temperature in the form of heat waves enhanced plant growth and forced the maturity, the different development stages of wheat cultivar

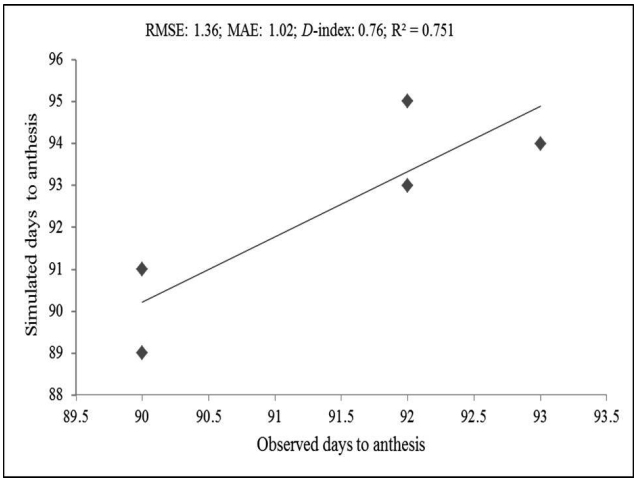

Fig. 1. Observed and simulated days to anthesis of wheat var. Hd2733

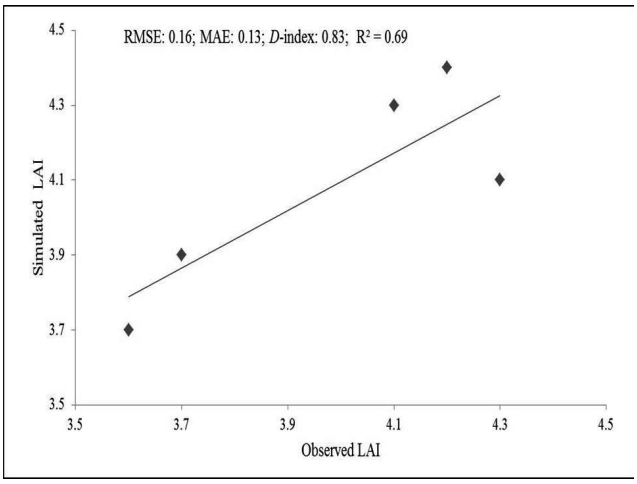

Fig. 2. Observed and simulated LAI of wheat var. Hd2733

Table 1. Soil properties used in the simulation

Depth (cm)	Sand (%)	Slit (%)	Clay (%)	LL ($cm^3 cm^{-3}$)	DUL ($cm^3 cm^{-3}$)	SAT ($cm^3 cm^{-3}$)	BD (g cm^{-3})	SSKS (cm/hr)
00-20	34	44	22	0.15	0.31	0.49	1.43	0.78
20-62	25	45	30	0.22	0.39	0.47	1.47	0.39
62-100	24	37	39	0.17	0.33	0.46	1.52	0.30
100-140	21	42	37	0.15	0.33	0.43	1.54	0.33
140-165	22	38	40	0.15	0.32	0.43	1.55	0.30

SSKS-saturated hydraulic conductivity, BD-bulk density, SAT-volumetric water content at saturation, LL-volumetric water content at wheat crop lower limit. DUL-volumetric water content at drained upper limit

(HD2733) occurred earlier in extreme temperature induced treatments compared to normal condition (without heat stress) (Table 2). Under normal condition, the days to anthesis and physiological maturity were 92 and 125.4 days, which were reduced significantly to 89/87.3 and 118.8/116 days for treatment experienced heat stress of +5°C and +7°C temperature respectively over normal at booting to anthesis. However, the magnitude of stress was more pounced on physiological maturity in treatments receiving heat stress at anthesis to milk stage. The days taken to physiological maturity were observed to be 117 days at +5°C and 115 days at +7°C over normal. Earlier, an increase of 0.5°C temperature to normal resulted in decrease in duration of crop by seven days (Parry and Swaminathan 1992). However, Yin et al 2009 reported that a 5°C increase in temperature above 20°C at anthesis stage increased the rate of grain filling and reduced the grain filling duration by 12 days in wheat crop. Wheat crop under normal sowing (mid November) does not generally experience higher temperatures at reproductive stage and requires higher GDD than the later growing one, which faces higher temperatures at the time of anthesis. Late sowing has witnessed to decreased the duration of phenology as compared to normal sowing due to fluctuated un-favourable high temperature during the growth period. (Kajla et al 2015). Owing to higher temperature stress, the final yield reduction was observed to

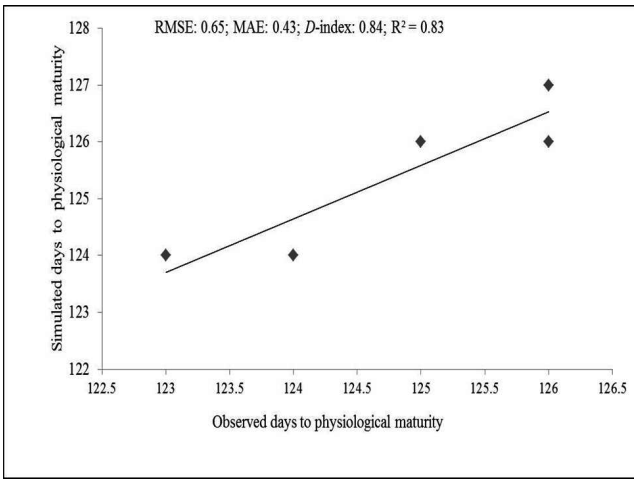

Fig. 3. Observed and simulated days to physiological maturity of wheat var. HD2733

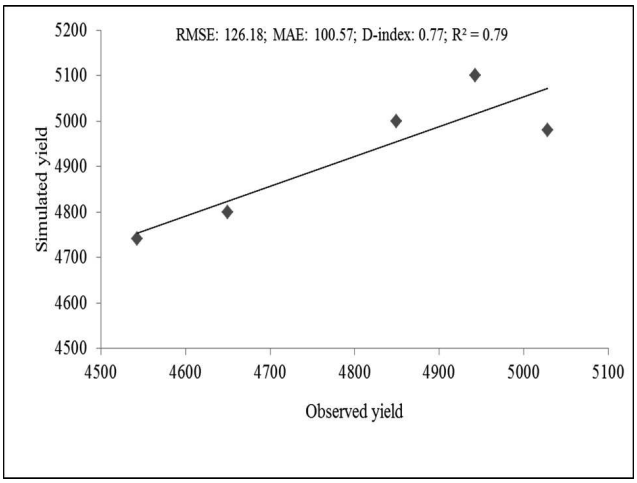

Fig. 4. Observed and simulated grain yield (kg ha^{-1}) of wheat var. Hd2733

Table 2. Validation of calibrated wheat var. HD2733

Year	Anthesis			LAI			Physiological maturity			Grain yield (kg^{-ha})		
	O	S	D	O	S	D	O	S	D	O	S	D
2013	91.0	93.0	-2.2	3.8	4.2	-10.5	121	122	-0.8	4758	4948	-4.0
2014	89.0	91.0	-2.2	3.3	3.6	-9.1	121	123	-1.7	4450	4615	-3.7

O=Observed yield, S=Simulated yield, D=% Departure

Table 3. Impact of increasing temperature (heat stress) at different crop growth stages on phenology and yield of wheat using CERES-Wheat DSSAT v4.6 model at Sabour

Treatment	Crop growth stages					
	Booting-Anthesis			Anthesis-Milk		
	Days to anthesis	Days to physiological maturity	Yield (kg/ha)	Days to anthesis	Days to physiological maturity	Yield (kg/ha)
Normal (No heat stress)	92.0	125.4	4924.0	92.0	125.4	4924.0
Temperature increased by +5°C	89.0	118.8	3840.0	91.0	117.0	3690.0
Deviation from normal (Days/Percent)	-3.3	-5.2	-22.0	-1.1	-6.7	-25.1
Temperature increased by +7°C	87.3	116.0	3660	90.0	115.0	3495.0
Deviation from normal (Days/Percent)	-5.1	-7.5	-25.7	-2.2	-8.29	-29.0

be 25.1 and 29.0 per cent at temperature of +5°C and +7°C respectively, which can be attributed to increased the rate of grain filling and reduced the grain filling duration (Yin et al 2009).

CONCLUSION

CERES-wheat model depicted great potential to simulate phenological stages (flowering and maturity day), LAI, and grain yield close to the observed field data of the crop. The model evaluation indices R^2, RMSE, MAE and D-index, confirmed the robustness of the wheat model. The validated model could be used as research tools to provide different management options under irrigated conditions. Short exposure of extreme temperatures (heat stress) had a negative effect on crop phenology and reducing the yield by 29%. As such these models can be used to select cultivars which can bring sustainability in yield by mitigating the impact of increased temperature on crop growth and development.

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Effect of Bioclogging and Biocementation on Permeability and Strength of Soil

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Abstract: Laboratory experiments were conducted to determine the permeability and strength of soil samples before and after bioclogging and biocementation processes. In bioclogging, the extracellular polymeric substance was applied as a thin layer over the surface of the soil placed in the permeameter in three dosages and the constant head permeability study was carried out for two different samples namely silty sand and well graded sand. SEM analysis was done in order to find the presence of Dextran particles filling the voids present in the soil. In biocementation, sand columns are formed and bacterial and cementation solutions are poured to the layers and left for about 2 weeks. The results indicate that though exopolysaccharide was produced it was not penetrated into the soil and plug the voids and therefore no reduction in the permeability of soils was observed. However, unconfined compressive strength test indicates that biocementation resulted in an increase in the strength of soil.

Keywords: Bioclogging, Biocementation, Exopolysaccharide, Dextran, Permeability, Bacterial solution, Cementation solution

Bioremediation such as bioclogging and biocementation prove to be an effective and efficient technique in soil stabilization and results in reduction in porosity and hydraulic conductivity of soil by filling of soil pores with pore-filling materials produced by bacterial process (Stephan Fuchs et al 2004). Accumulation of insoluble bacterial slime, poorly soluble biogenic gas, bacterial biomass etc in the soil pores makes the soil impermeable thereby reducing the porosity and permeability (Victoria et al 2008). Many bacterial species which is resistant to the changes in the osmotic pressure can be used in large scale soil clogging or soil grouting (Nathalie Ross et al 2001). Bacterial species such as *Leuconostoc mesenteroids*, *Caulobacter, Acinetobacter, Agrobacterium, Alcaligenes, Arcobacter, Cytophaga, Flavobacterium, Pseudomonas and Rhizobium* could be used in producing insoluble extracellular polymeric substance in clogging or binding the soil particles (Portilho et al 2006) and proved to be efficient in the formation of bio-barriers to control surface contaminations, leachate into the soil (Stewart and Fogle 2001). The void filling nature of biofilms allows for possible field applications to ground water, heal leaks and prevent internal erosion in structures such as earth dams and levees (Proto et al 2016). Microbiologically induced calcium carbonate precipitation (MICP) is a bio-geochemical process that induces calcium carbonate precipitation within the soil matrix (Kucharski et al 2005) and biocementation could be used as an alternative cementation technique to improve the properties of potentially liquefiable (Stephan Fuchs et al 2004). Calcium carbonate precipitate is formed when soil is mixed with urease producing microorganisms, urea and soluble calcium salts (Cheng and Cord-Ruwisch 2012). Previous work has shown that the strength and stiffness of loose, saturated sand increases by utilizing microbial induced carbonate precipitation (Shanahan and Montoya 2014). The increase in shear strength, unconfined compressive strength, stiffness and liquefaction resistance was reported due to calcium carbonate precipitation resulting from microbial activity (Victoria et al 2007) and the increase of soil strength from MICP is a result of the bonding of the grains and the increased density of the soil (Jian et al 2012). The methodology tested to examine the strengthening effects is using unconfined compressive strength tests (Joao Carmona et al 2016). Thus, bioremediation could be used as an alternative to these energy demanding and high cost techniques in permeability reduction and strength improvement (Guohongxian et al 2013).

The present investigation was undertaken in order to study the effects of bacterial clogging on the permeability of porous media by conducting constant head permeability test. To study the strength enhancement, column studies were conducted and the evaluation of strength was done by carrying out unconfined compressive strength test.

MATERIAL AND METHODS

Soil sample: Soil sample 1 (silty sand) was collected from an irrigation canal near Palani, Dindigul district (10.441179°N,

77.566356°E) and sample 2 (well graded sand) is a river sand collected from Noyyal River, Maadhampatti, Coimbatore district (10.966809°N, 76.851215°E). The samples were collected at a depth of 1m below ground level. Laboratory tests were conducted to determine the index properties of both the soil samples and the properties are summarized (Table 1).

Bacterial species: Two bacterial species *Sporosarcina pasteurii* and *Bacillus sphaericus* are obtained from Microbial Type Culture Collection (MTCC), Chandigarh. The species obtained were in freeze dried state and revival process was done by adding the bacteria into the nutrient medium and kept in autoclave for 24 hrs.

Bacterial solution: Nutrient medium is prepared by mixing 8g of nutrient broth in 150ml of distilled water and kept in autoclave for 24 hrs. Drop of revived bacterial solution is injected into the prepared nutrient medium, inoculated for 24 hrs and placed in the mechanical shaker for 3days at 28°C. Bacterial solution thus prepared was preserved and used for the biocementation process.

Cementation solution: Calcium chloride and urea are used to prepare the cementation solution. 110.98 g of calcium chloride was dissolved in 1 litre of water to obtain 1M $CaCl_2$ and 60.06 g of urea in 1 litre of water to obtain 1M urea. 1M $CaCl_2$ and 1M urea together is used as cementation solution. Both bacterial and cementation solutions are used to fill the pores of voids and increase the strength of soil mass and were preserved for use in the experimental study.

Permeability test: Constant head permeability test was used to determine the coefficient of permeability of relatively more permeable soil. Soil sample was placed in the permeameter and tamped to obtain required density. Three different dosages of Dextran were prepared by diluting it with distilled water to make 1, 2 and 3 g/10ml dosages. Dextran is a complex branched glucan which is a polysaccharide made of many glucose molecules composed of chains of varying lengths. It is synthesized from sucrose by lactic acid bacteria, *Leuconostoc mesenteroides* and *Streptococcus mutans* (Montersino et. al 2008). The Dextran solution was applied as a coating over both the soil samples in the permeameter. It was allowed to dry for about 30 minutes prior to the conduct of permeability test.

Sand column setup: The poly vinyl chloride (PVC) tubing of length 30cm and diameter 4.5 cm was used for the column study. Graded filter material was placed at the bottom of the column over which a filter paper was placed so that the solution gets drained off easily. Six sand columns were made, in which three columns are used for carrying out study on silty sand and the other three for well graded sand. The soil samples are packed in the sand columns in layers viz.

Table 1. Properties of soil

Properties	Values	
	Sample 1	Sample 2
Grain size	Sand= 67%	Sand= 99%
IS Classification	Silty sand (SM)	Well graded sand (SW)
Natural moisture content	17.65 %	-
Specific gravity	2.64	2.66
Liquid limit	26.8 %	-
Plastic limit	21 %	-
Shrinkage limit	18.3 %	-
Free swell	20 %	-
Maximum dry density	1.89 g/cc	-
Optimum moisture content	13.8 %	-
Co-efficient of permeability	4.85×10^{-4}	9.3×10^{-3} cm/sec
Cohesion	0.18 kg/cm^2	0.02 kg/cm^2
Angle of internal friction	18°	32°

single, 6 and 12 layers. Under surface percolation and fully drained condition, the retention capacity of both the samples was 150 and 90ml for both silty sand and well graded sand respectively. Bacterial and cementation solutions are introduced in the columns from the top of the sample in the sand column setup .

Percolation of bacterial and cementation solutions: Bacterial solution of about 75ml for silty sand and 45 ml for well graded sand was poured over the sample in the sand column followed by percolation of cementation solution of about 150 ml for silty sand and 90ml for well graded sand. The quantity of bacterial and cementation solution is divided into smaller volumes based on the number of layers of soil in the sand column. Solutions are poured over the packed sample in single layer column, poured over the surface of each layer in case of samples packed in multiple layers and it is left for about two weeks of reaction time (Fig. 1).

SEM analysis: A scanning electron microscope (SEM) produces images of sample by scanning the surface with a focused beam of electrons. The electrons interact with atoms in the sample, producing various signals that contain information about the sample's composition. 50g of soil sample passing through 75 micron sieve was collected from the experimental study and subjected to SEM analysis.

Unconfined compression test: Unconfined compression test was carried out on samples obtained from the sand columns after two weeks of reaction time. Specimen was placed in the unconfined compression testing machine and axial compressive force was applied to the specimen using proving ring of 2kN capacity. The axial deformation was measured using dial gauge of 0.002 mm sensitivity.

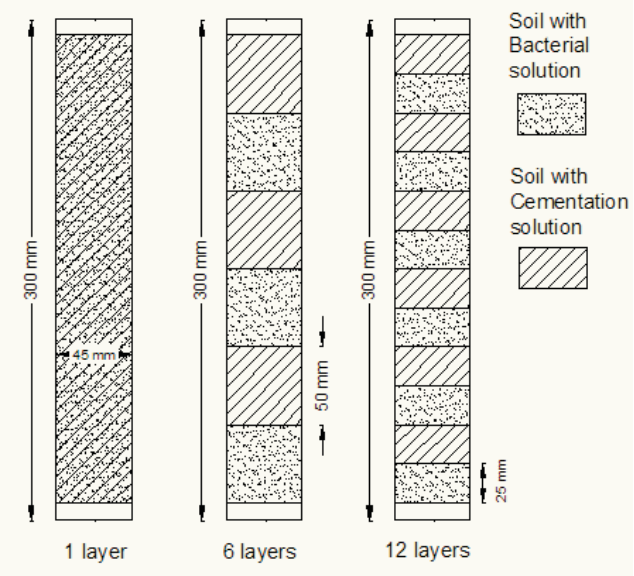


Fig. 1. Sand column setup placed with sand, bacterial and cementation solutions

RESULTS AND DISCUSSION

Bioclogging using permeability test: There is no much variation in the permeability values of the tested soil (Table 2). The Dextran coating has not penetrated into the pores of the soil mass and hence there is no reduction in the permeability of soils. If the consistency of Dextran is modified and allowed to get penetrated into the soil mass it may leads to plugging of voids of soil that result in the reduction in the permeability. Bioclogging is not effective in reducing the permeability when Dextran is applied as surface coating material over the soil mass.

SEM analysis: The scanning electron microscopic image Fig. 2 and Fig. 3) of untreated and treated silty sand showed that the Dextran material covers the surface of the solid particles as a thin layer of coating. The void spaces are not filled up completely with the material and hence no reduction in permeability of soils was observed. The same observation was obtained for well graded sand when treated with Dextran (Fig. 4 and Fig. 5). The size of the individual particles was larger compared to untreated sample due to thin film formation of Dextran around the soil grains. Bioclogging by Dextran as a surface coating material is ineffective in plugging the pores of soil and to reduce the permeability of soils.

Permeability reduction by biocementation: The coefficient of permeability of untreated samples and the samples treated with biocementation solution using both the selected bacterial species indicate that when cementation solution was applied to sand column, with sample placed in single layer there is no reduction in the permeability of soils (Table 3). But, permeability of both the soils decreased when solutions are poured in each layer separately in the case of multiple layers which results in better penetration of these solutions into the voids of the soil. As the thickness of the sample was small, the solutions have penetrated easily and clog the pores resulting in the reduction in coefficient of permeability.

Unconfined compressive strength test (UCS): When bacterial and cementation solutions are added to soil samples, the soil particle gets binded together resulting in a much harder material (Fig. 6). The increase in the strength of the soil samples before and after treatment with these solutions are shown (Fig. 7).

Results showed that, when the samples are treated with biocementation solution, the UCS strength gets increased

Table 2. Coefficient of permeability of soil by constant head permeability test

Type of soil	Coefficient of permeability (cm/sec)			
	Without dextran	Dextran dosages		
		1g/10ml	2g/10ml	3g/10ml
Silty sand	$4.85x10^{-4}$	$2.24x10^{-4}$	$1.62x10^{-4}$	$1.12x10^{-4}$
Well graded sand	$9.3x10^{-3}$	$5.39x10^{-3}$	$3.68x10^{-3}$	$3.0x10^{-3}$

Table 3. Coefficient of permeability of soil in biocementation process by column study

Sample	Coefficient of permeability (cm/sec)			
	Before bio-cementation	After biocementation		
		Single layer	6 layers	12 layers
Bacillus sphaericus				
Silty sand	$4.85x10^{-4}$	$3.47x10^{-4}$	$9.23x10^{-5}$	$4.63x10^{-5}$
Well graded sand	$9.3x10^{-3}$	$2.22x10^{-3}$	$6.35x10^{-4}$	$3.7x10^{-4}$
Sporosarcina pasteurii				
Silty sand	$4.85x10^{-4}$	$2.08x10^{-4}$	$6.17x10^{-5}$	$3.47x10^{-5}$
Well graded sand	$9.3x10^{-3}$	$1.67x10^{-3}$	$6.35x10^{-4}$	$2.77x10^{-4}$

Table 4. UCS of soil samples in biocementation process by column study

Sample	Unconfined compressive strength (UCS) (kPa)			
	Before biocementation	After biocementation		
		Single layer	6	12
Bacillus sphaericus				
Silty sand	36	39.4	41	44.8
Well graded sand	4	4.38	4.61	4.9
Sporosarcina pasteurii				
Silty sand	36	41.1	43.9	46
Well graded sand	4	4.45	4.84	5.1

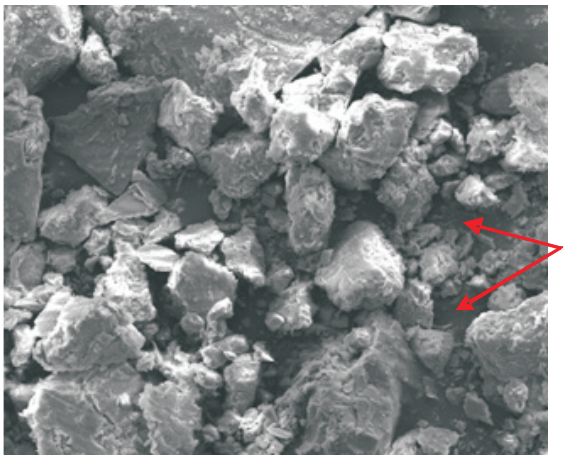


Fig. 2. SEM image of untreated silty sand

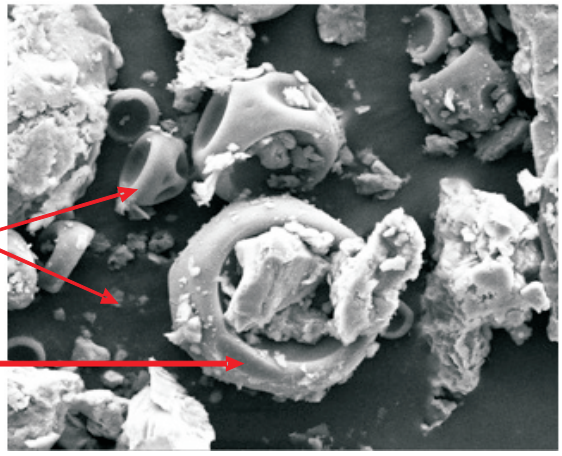


Fig. 3. SEM image of treated silty sand

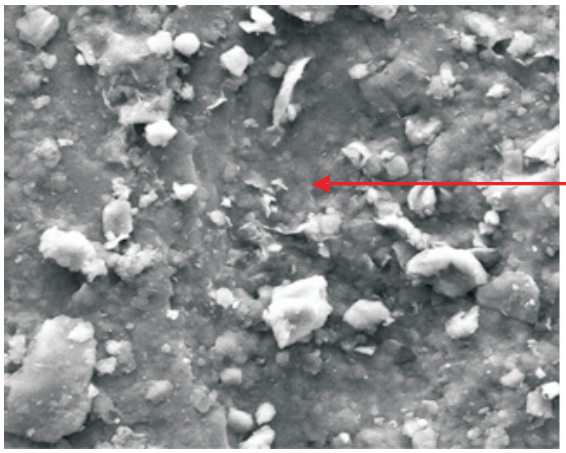


Fig. 4. SEM image of untreated well graded sand

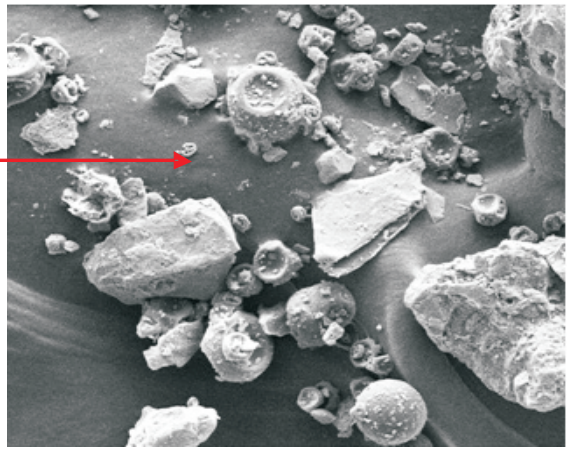


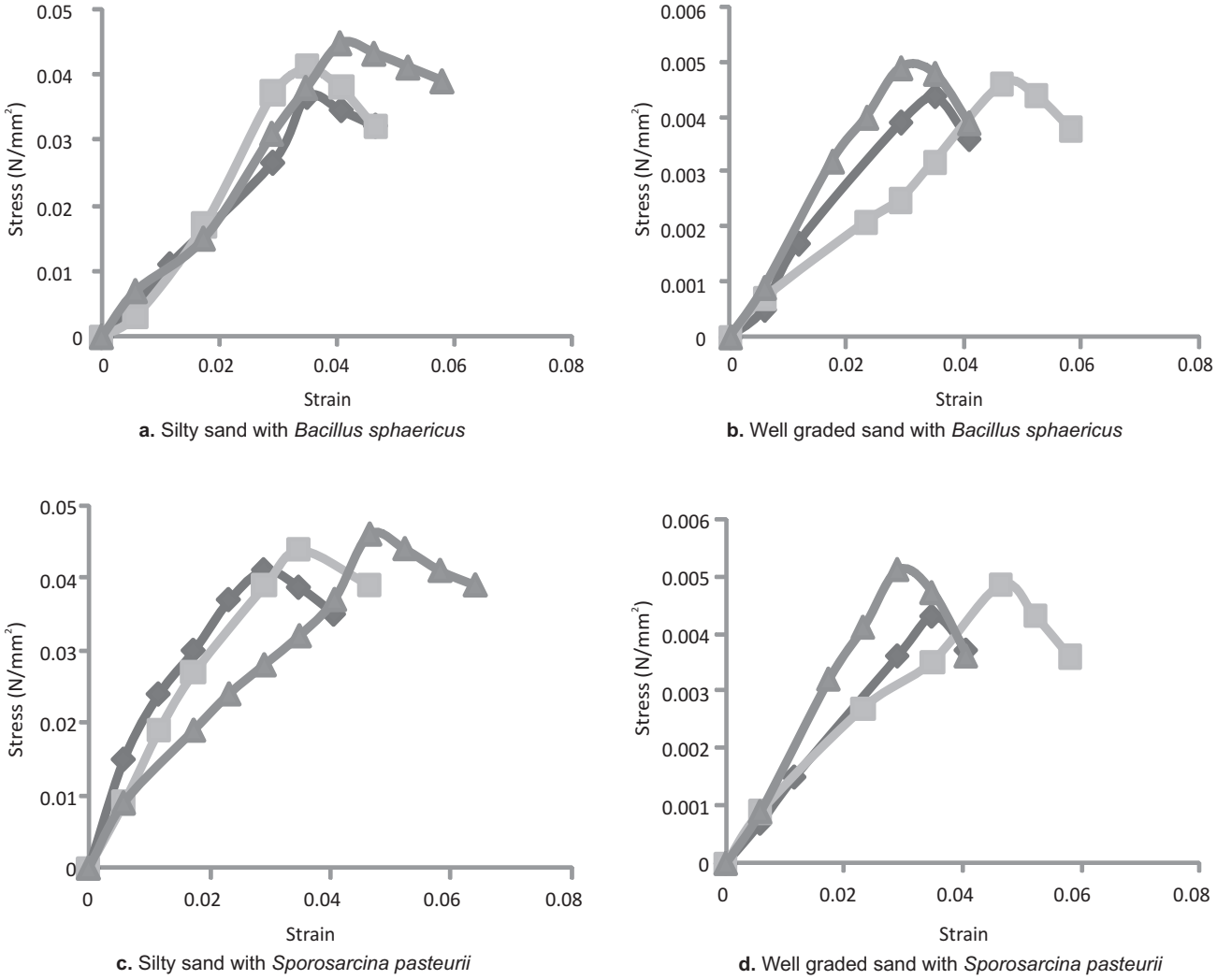
Fig. 5. SEM image of treated well graded sand

Fig. 6. Soil sample after biocementation process

(Table 4). The strength improvement is only marginal in the case of well graded sand and comparatively higher in silty sand. Moreover, soil treated with *Sporosarcina pasteurii* showed higher strength than the sample treated with *Bacillus sphaericus* species. The calcite cement has a preference to precipitate at the particle contact which increases the strength and stiffness of the soil (DeJong et al 2010). The increase in strength is due to urea hydrolysis process where urea is hydrolyzed by microbial urease to form ammonia and carbonate ions. The produced carbonate ions react with calcium ions and precipitate as calcium carbonate crystals. Sand grains are bound together by the calcium carbonate crystals which results in increased strength (Bachmeier 2002, Cheng and Cord-Ruwisch 2012).

CONCLUSION

Permeability reduction in both the soil samples were not achieved in the bioclogging process, as the exopolysaccharide Dextran has not penetrated into the pores



a. Silty sand with *Bacillus sphaericus*

b. Well graded sand with *Bacillus sphaericus*

c. Silty sand with *Sporosarcina pasteurii*

d. Well graded sand with *Sporosarcina pasteurii*

Fig. 7. UCS of soil samples treated after biocementation process

of the soil mass and plug the void spaces between the solid particles. SEM image showed that the Dextran surrounds the individual particles as a thin film coating and the particles increased size . Reduction in the permeability of soil mass was observed in sand column tests when the samples are placed in layers in the biocementation process. This is due to the reason that the bacterial solution and cementation solution penetrates into the pores of the soil mass and hence the volume of voids get reduced resulting in reduction in permeability of soil. Unconfined compressive strength test revealed that the particles are binded together with these solutions and the calcium carbonate compound formed during the biocementation process helps in increasing the strength of the treated sample.

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Spatial and Temporal Land Surface Temperature Analysis of Kashmir Valley (India)

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Abstract: The present study was undertaken to compute the normal maximum and minimum temperature in seven districts of Kashmir namely, Anantnag, Pulwama, Srinagar, Budgam, Baramulla Kulgam and Kupwara during 1980-2016. The normals were then used to study the weather extremes like heat waves and cold waves in the region. All the districts experienced heat waves of moderate intensity during summer. However, the cold waves in all the districts were of moderate to severe intensity. The district Baramulla was most severely affected by cold waves while district Srinagar was most affected district by heat waves.

Keywords: Temperature, Normal, Heat waves, Cold waves, Kashmir Valley

High mountains as a reservoir play a vital role in regional hydrological, biogeochemical, and atmospheric processes in rangeland ecosystem. Since the mid-twentieth century, these pristine areas have been experiencing earlier snowmelt with increased vegetation greenness by changed land surface temperature due to global warming. Thus mountain areas are considered for climate change studies. Land surface temperature (LST) is an essential parameter in the climate change studies. It plays a key role in the energy and water transfers between the ground and the atmosphere. LST is controlled by solar radiation and the land-atmosphere heat exchange (Manzo-Delgado et al 2004). Therefore, its spatial and temporal distributions reflect not only the variations of climate factors but also the land surface characteristics. Several studies have been conducted to study the spatial and temporal variations of LST (Manzo-Delgado et al 2004, Julien et al 2006, Westermann et al 2011). Apart from land surface temperature analysis heat and cold waves have been a part of LST called as extreme events, which cause enormous losses interms of lives and human discomfort and ailments arising out of them. These waves cause wide range of damage types. There have been various cases of death and injuries from direct exposure to heat/ cold. Although there are generally a higher human mortality rate in terms of extreme events. Weather related natural disasters and extreme events have increased considerably in recent decades (Mahdi and Dhekale 2016). In last few decades the climate of Kashmir Valley has witnessed a different change in climate and climatological

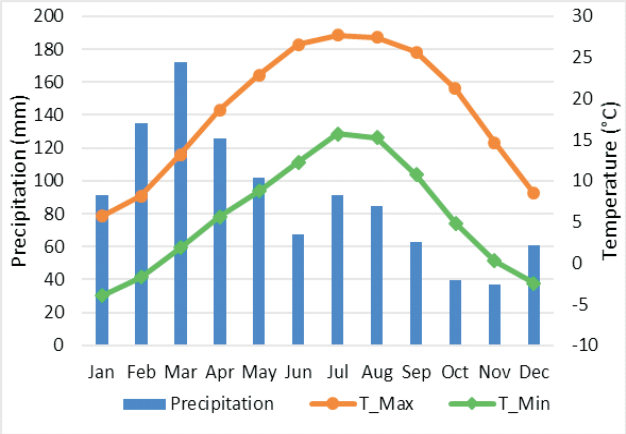

Fig. 1. Monthly normals of precipitation and temperature for Kashmir Valley during the period 1980-2016

variables as compared to the other parts of India. The maximum and minimum temperatures of the region have shown no significant increasing or decreasing trends (Parvaze et al 2017). In this study, the main aim is to use local weather (temperature) information at the district level, of an over 36 years period (1980-2016) to examine the climatology and trends in the occurrence, frequency and duration of heat and cold waves to generate the information at a local level, in order to address the challenges of climate change and its extremes in Kashmir valley

MATERIAL AND METHODS

Study area: The state of Jammu and Kashmir is located

between 32°17' and of 37°5' North latitudes and 73°26' and 80°30' and 81° East longitudes. Kashmir valley lies in the temperate zone of the state. The valley has an elevation range of 1500-4200 m a.s.l. The meteorological data for the study was obtained from Regional Meteorological Centre, Rambagh Srinagar. The climate parameters was obtained for a period of 36 years (1980-16). The study area with their GPS location in Table 1.

Climatological information about temperature at seven stations located in seven different districts of Kashmir valley was analyzed. The preliminary analysis for this study included computing the monthly and annual normal at the stations for the years 1980-2016.The extreme events that occurred in the past in all the districts were studied. The data required for the present study was obtained from Agro-meteorological Field Unit-Shalimar and Regional Meteorological Center-Shalimar. Daily values of Maximum and Minimum Temperature were obtained for the duration 1980-2016. The heat and cold wave/severe cold waves were classified as per the criteria provided by the IMD (2002), based on maximum and minimum daily temperature thresholds. Daily anomalies were computed and using the criteria given in the Table 2. Days that satisfied the heat wave (HW)/severe heat wave (SHW) and cold wave (CW)/severe cold wave (SCW) conditions were identified.

Table 1. GPS location of different districts of Kashmir Valley

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

RESULTS AND DISCUSSIONS

Temperature normal: The highest temperature was recorded on July 10, 1999 as 37.6°C at Kupwara station and the lowest temperature of -19.8°C at Gulmarg station on January 1, 1990. The monthly normal maximum temperatures in different districts are presented in Table 2 and the normal monthly minimum temperatures for different districts of Kashmir Valley in Table 3.

Heat and cold waves: The number of heat waves/ severe heat waves and cold waves/ severe cold waves was observed for three decades 1980-1989, 1990-1999 and 2000-2009 and the remaining 7 years from 2010-2016.

Data on the month-wise distribution of HW/SHW and CW/SCW events of Kashmir valley show that in the last 37 years, all the stations have witnessed heat waves (Table 4). The highest number of heat waves was in the Srinagar district. A total of 1853 heat waves were experienced in the district with 460, 472, 561 and 350 HWs during 1980-89, 1990-1999, 1999-2009 and 2010-2017.The least number of heat waves were experienced in Baramulla only 36 during 1980-2016. During 1980-89, no heat waves were experienced in the district. There were 20 and 15 incidences of heat waves during 1990-99 and 2000-09, respectively and only 1 heat wave during 2010-2016. The highest temperature of Kashmir valley was on July 10, 1999 in Kupwara as 37.6°C.

Kashmir Valley experiences a very long and harsh winter. Cold waves are very common in the region. The least recorded temperature in Kashmir Valley was -19.8 C in Baramulla on February 1, 1990. During the last 37 years (1980-2016), the district has experienced 2711 cold waves and 2255 severe cold waves. All other districts have also received very frequent spells of cold waves and severe cold waves which forced the farmers to go for protected cultivation and crop diversification

Table 2. Criteria for heat wave/severe heat wave and cold wave/severe cold wave for hilly region used in this study (India Meteorological Department)

Heat event	1. When the climate normal maximum temperature of a station is ≤40fiC: a. HW: Departure from climate normal is +5fiC to 6fiC b. SHW: Departure from climate normal is +7fiC or more 2. When the climate normal maximum temperature of a station is ≥40fiC: a. HW: Departure from climate normal is +4fiC to 5fiC b. SHW: Departure from normal is +6fiC or more 3. When actual maximum temperature remains 45ºC or more irrespective of normal 4. Maximum temperature
Cold event	1. When climate normal minimum temperature is equal to 10fiC or more: a. CW: Departure from climate normal is - 5fiC to - 6fiC. b. SCW: Departure from climate normal is - 7fiC or less 2. When climate normal minimum temperature is < 10fiC: a. CW: Departure from climate normal is - 4fiC to - 5fiC. b. SCW:Severe Cold Wave Departure from normal is -6°C or less. 3. Cold Wave should be declared when minimum temperature is 0°C or less and normal minimum temperature is above 0°C.

Table 3. Normal maximum temperature (°C) in different districts of Kashmir valley (1980-2016)

Month	Anantnag	Baramulla	Budgam	Kulgam	Kupwara	Pulwama	Srinagar	Kashmir
January	4.6	2.9	7.0	6.8	7.0	5.3	6.4	5.7
February	6.8	4.7	9.9	9.4	9.0	7.8	9.6	8.2
March	11.8	9.1	14.9	14.5	14.3	13.0	14.5	13.2
April	17.2	14.2	20.3	20.1	20.1	18.6	19.7	18.6
May	21.2	18.7	24.7	23.8	24.4	23.0	24.2	22.9
June	24.5	22.4	28.7	27.2	28.3	26.6	28.3	26.6
July	25.5	23.4	29.8	28.2	30.0	27.4	29.7	27.7
August	25.4	23.2	29.5	27.8	30.0	27.1	29.2	27.5
September	23.7	21.3	27.4	26.2	28.3	25.3	27.2	25.6
October	19.4	16.9	22.4	23.3	22.9	20.8	22.1	21.1
November	13.2	11.3	15.8	16.4	16.1	14.2	15.4	14.6
December	7.3	6.1	9.4	9.7	9.4	8.3	9.1	8.5
Annual	16.7	14.5	20.0	19.5	20.0	18.1	19.6	18.3

Table 4. Normal minimum temperature (°C) in different districts of Kashmir valley (1980-2016)

Month	Anantnag	Baramulla	Budgam	Kulgam	Kupwara	Pulwama	Srinagar	Kashmir
January	-6.8	-7.3	-2	-3.2	-2.8	-3.3	-2.3	-4.0
February	-4.5	-5.4	0.4	-0.8	-0.8	-1.1	0.1	-1.7
March	-0.5	-1.7	4.1	2.8	2.6	2.7	3.2	1.9
April	3.2	2.3	7.9	6.5	6.5	6.6	6.6	5.7
May	5.8	5.4	11.2	9.7	9.6	9.7	9.8	8.7
June	8.7	8.7	15	13.4	13.1	13.3	13.7	12.3
July	12.7	12.1	18.3	16.7	16.8	16.1	17.2	15.7
August	12.8	12	17.7	15.9	16.2	15.5	16.6	15.2
September	8.5	8.1	12.8	11.1	11.2	11.6	11.9	10.7
October	2.7	2.5	6.2	5.3	5.3	6.6	5.3	4.8
November	-1.6	-1.7	1.1	1	0.4	2	0.6	0.3
December	-4.3	-4.4	-1.5	-1.6	-2	-1.8	-1.7	-2.5
Annual	3.1	2.6	7.6	6.4	6.3	6.5	6.8	5.6

Table 5. Heat waves, severe heat waves, cold waves and severe cold waves in in different districts of Kashmir valley (1980-2016)

District	Years	HW	SHW	CW	SCW	District	Years	HW	SHW	CW	SCW
Anantnag	80-89	7	0	740	641	Kupwara	80-89	531	0	668	144
	90-99	21	0	720	569		90-99	240	0	769	106
	00-09	15	0	723	420		00-09	189	0	761	110
	10-16	52	0	523	288		10-16	146	0	509	58
Baramulla	80-89	0	0	780	750	Pulwama	80-89	55	0	643	180
	90-99	20	0	729	586		90-99	173	0	629	219
	00-09	15	0	683	448		00-09	82	0	658	74
	10-16	1	0	519	471		10-16	136	0	446	92
Budgam	80-89	102	0	609	116	Srinagar	80-89	460	0	679	117
	90-99	116	0	579	147		90-99	472	0	651	167
	00-09	113	0	551	112		00-09	561	0	688	147
	10-16	74	0	409	71		10-16	350	0	490	152
Kulgam	80-89	320	0	686	172						
	90-99	240	0	656	162						
	00-09	189	0	684	110						
	10-16	146	0	457	118						

as they found abrupt frost injury in plants.

CONCLUSIONS

The temperature data analysis of Kashmir valley gave an insight into the weather of Kashmir Valley. The 37 year normal were computed for seven districts of Kashmir valley namely, Anantnag, Pulwama, Srinagar, Budgam, Baramulla Kulgam and Kupwara. The annual normal maximum temperature was 18.3°C and the annual minimum normal temperature was 5.65°C. The valley experiences heat waves during summer season. However these waves are of moderate intensity with no severe heat waves recorded in the region for the period 1980-2017. Cold waves on the other hand are very common in Kashmir Valley having moderate to severe intensity.

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Effect of Detaslling and Gibberellic Acid on Growth, Yield and Antioxidant Compounds in Corn Silk

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Abstract: A field experiment was conducted during the autumn season of 2017 on two locations to study the effect of some subspecies Corn (sweet corn, corn oil and maize), Detasseling (De) and foliar application of Gibberellic acid (GA3) at concentration 100 mg.L^{-1} on growth parameters (plant height, leaves number, total chlorophyll and leaves area), yield components (grains number, aer number, weight 500 grains and production), corn silk parameters (fresh and dry weight, plant yield and production) and some antioxidant compounds (total carotenoids, ascorbic acid and glutathione) of corn silk. Results of analysis of variance showed that detasseling were given decrease significantly impact ($P<0.05$) on growth parameters and yield components, but it was increased corn silk parameters and its content of antioxidant compounds compare with control, while spraying GA3 were suggested superiority significant compare with control and detasseling treatments by increased growth parameters, which accumulated in grain production to be 15.47 and 16.20 ton.h^{-1} on two locations respectively. The combined treats between detasseling and spraying GA3 were given high amount of corn silk production and total carotenoids, ascorbic acid and glutathione on treat CO+De+GA3 which gave (9.91, 10.25, 97.23, 130.12, 15.89 and 17.26 mg.kg^{-1} DW) on two locations respectively.

Keywords: Detasseling, Subspecies Corn, Gibberellic acids, Silkcorn, Antioxidant compounds

Corn (*Zea mays* L.) is annual plant belong to family Gramineae and there are many medicinal uses of corn silk such as antioxidant activity (Maksimovic et al 2005, El-Ghorab et al 2005), antidiabetic activity (Li and Yu 2009), antitumor activity (Habtemariam 1998), mild stimulant (Hu et al 2010), diuretic, useful in acute and chronic cystitis, gout, kidney stones, nephritis and prostatitis (Velazquez et al 2005). Many researches on corn silk referred that it contained amount of antioxidant compounds such as carotenoids, flavonoids, phenolic compounds (Ganie et al 2016), glutathione (Ismail 2013), ascorbic acid (Khanna et al 2016), pigments (Khodary 2004), saponins, tannins, phytosterols, volatile oil and fixed oil (Ebrahimzadeh et al 2008). Detasseling consists of removing the tassels before pollen is released (Komatuda et al 2006) and investigations have shown that detasseling may influence grain yield positively (Rizwan et al 2015) or negatively (Pereira et al 2005, Sangoi et al 2006).

Some researchers have shown that spraying GA3 on leaves considerably increases the growth rate of corn (Wen et al 2010) and increased cell division, stem elongation, flowering (Taiz and Zeiger 2002) which finally lead to the increase of grain yield (Arteca 1996). Additionally, GA was increased amount of chlorophyll (Wareing et al 1968) leaf expansion and effective age of leaves (Koter et al 1983) which finally lead to the increase of grain yield per area. The objective of this investigation was to evaluate the effect of detasseling and spraying GA3 on three corn subspecies, and addition, measured some parameters of growth and yield of corn, silkcorn and some antioxidant compounds.

MATERIAL AND METHODS

The experiment was conducted during cropping autumn season of 2017 atvillage Khafaja (L1) within the latitude of 32.251 degrees north and longitude 44.325 degrees east and second (L2) on district Abu-Gharaq within the latitude of 32.314 degrees north and longitude 44.221 degrees east and the distance between them 25 Km, the soil texture at the experimental site location 1 was silt sand (28.5% silt, 13% clay and 58.5% sand) with approximately 2.05% organic matter, pH 7.6, EC 3.1 dSm^{-1}, nitrogen 28.7, phosphorus 20.4, potassium 7.41 mg.Kg^{-1} and in location 2 was silly clay sand (24.5% silt, 35.5% clay and 40% sand) with approximately 1.55% organic matter, pH 7.8, EC 1.4 dSm^{-1}, nitrogen 27, phosphorus 13.6, potassium 7.51 mg Kg^{-1}. The field was prepared conventionally and added diamino phosphate fertilizer (contain 48% P and 21% N) at levels 140 kg ha^{-1}, then dividing into plots, area for each experimental unit (plot) was 12 m^2 (4×3 m). Seeds of subspecies sweet (SC) and corn oil (CO) were KSC403 and KSC403

respectively obtained from Iran, while subspecies maize (M) was Baghdad 3 obtained from Agricultural Research Office - Ministry of Agriculture Iraq, seeds were planted at 20 July by hand on lines, the distance between lines 75 cm, between seeds 25 cm and about 10 cm, so each experimental unit have 60 plants that means the plant density was 44000 plant h^{-1}, after 14 days were urea fertilizer (46% N) at level 176 Kg $h^{-1}$was applied and second application was after 30 days of planting.

The treatments were consisted of culturing three subspecies SC, CO and M as control treatments, conducted manual detasseling process of plants (SC+De, CO+De and M+De) at two middle lines in plots before pollen maturity, spraying GA3 at concentration 100 mg L^{-1} (SC+GA3, CO+GA3 and M+GA3) and set combination between detasseling and spraying GA3 (SC+De+GA3, CO+De+GA3 and M+De+GA3), the GA3 was sprayed one time at vegetative stage when plants formed 6-7 leaves, the hand-spray was set on both leaf surfaces of plants and totally wet in order to accomplish faster and more effective absorption. The treatments were distributed in a randomized complete block design with three replicates for each location. Data were analyzed by using GenStat program and means were compared by Duncan Multiple Range Test (DMRT) at probability level 0.05 according to (Daniel, 1999).

The parameters of growth corn plant were measured at final stage of vegetative growth such as: plant length, leaves number and total chlorophyll, yield parameters as: weight of 500 grains and productivity and Silkcorn parameters were measured in flowering stage at 28 days after flowering include: Fresh and dry weight, plant yield and dry productivity, and some active ingredients of Silkcorn were measured. Corn silk was extracted by using a modified method of (Hu et al 2010), total carotenoids content estimated by Goodwin(1976), ascorbic acid by using titration method with reagent 2,6-dichlorophenolindophenol (AOAC 1980) and glutathione was measured by using reagent 5, 5 Dithiobis 2-nitrobenzoic acid (Alscher 1989).

RESULTS AND DISCUSSION

Growth parameters: The treatments gave significant effects ($P \leq 0.05$) on corn plants during vegetative stages (Table 1). Spraying GA3 were had significant impact on all subspecies compared with other treats, CO+GA3gave the high values on plant height, leaves number, total chlorophyll and leaf area which was 204.7 cm, 15.23 leaf $plant^{-1}$, 81.53 SPAD and 544.8 cm^2 respectively on L1and 218.0 cm, 15.73 leaf $plant^{-1}$, 83.53 SPAD and 557.9 cm^2 respectively on L2, compared with treat SC+De which gave the lowest values in L1 and L2. The results of combined analysis between locations show significant superiority of L2 on leaves area, this response may be belong to effectiveness of GA3 on leaves meristems and cell elongation consequently increase leaves area, fresh and dry weight.

Yield parameters: The CO+GA3 gave significant effects on amounts of grain number which both at L1 and L2 compared with treat SC+DE+GA3, M+GA3 was suggested high values on aer number on two locations compared with treat SC+DE+GA3, but this treat gave the high values on weight 500 grain compared with M+De, while, M+GA3 gave more production on L1 and L2 compared with SC+De+GA3 on L1 and SC+De on L2, respectively (Table 2). The combined analysis between locations show significant superiority of L2 on grain number, weight 500 grain and production, this results refer to the effect of spraying GA3 and accumulated all increasing of growth and yield parameters in production and in same time the detasseling process make unbalance in endogenous growth hormones that decreasing the photosynthesis rate and movement of nutrition between sink and source.

Silkcorn parameters: The effects on silkcorn parameters was significant in different treatments during flowering stages (Table 3). Combined treatments was also showed significant impact on all subspecies compared with other treats, CO+De+GA3 was gave the high values on fresh and dry weight, whereas M+De+GA3 treat gave the highest values on plant yield and production 5.73 g $plant^{1-}$.DW and 252.23 Kg h^{-1}DW on L1. The combined analysis between locations show that superiority significant of L2 on all silkcorn parameters, This response reflects the competitive ability of subspecies to obtain the pollens as well as the effect of gibberellic acid on increasing the elongation of silkcorn and may also to be due the high temperature in the period of readiness of polination and fertillization, which increased the elongation of silkcorn and its fresh and dry weight.

Antioxidant compounds: The De and GA3 effects on some antioxidant compounds on dry silkcorn, and these effects were significantly variable compared to the control treats (Table 4). Furthermore, Co+De+GA3 resulted in the highest values of total carotenoids, ascorbic acid and glutathione compared with treat SC. This results show that combined effect treatments resulting in increased accumulation of secondary metabolic compounds, and the location has significant effect on quantity of ascorbic acid and glutathione.

CONCLUSION

The detasseling treats were decreased growth parameters and yield components, but it increased corn silk parameters and its content of antioxidant compounds

Table 1. Effect of subspecies, detasseling and spraying of gibberellic acid on growth and yield parameters

Treatments	Growth parameters							
	Plant height (cm)		Leaves number (leafe.plant^{-1})		Total chlorophyll (SPAD)		Leaves area (cm^2)	
	L1	L2	L1	L2	L1	L2	L1	L2
SC	134.3	145.3	12.03	12.69	66.69	65.06	367.5	398.7
CO	201.2	209.3	14.13	14.57	69.73	72.42	430.0	501.3
M	191.2	208.8	14.97	15.07	71.15	73.46	472.9	527.8
SC+De	118.5	131.0	10.14	10.42	51.43	52.08	305.0	317.7
CO+De	181.5	183.0	13.93	14.15	66.75	68.77	429.2	478.8
M+De	171.6	182.8	13.40	14.07	76.28	70.40	442.0	469.8
SC+GA3	130.9	169.8	11.80	11.07	63.79	64.65	393.9	442.4
CO+GA3	204.7	218.0	15.23	15.73	81.53	83.53	544.8	557.9
M+GA3	194.3	198.0	14.77	15.20	75.19	79.20	521.6	534.8
SC+De+GA3	121.7	141.2	11.43	11.56	59.50	60.97	374.4	371.8
CO+De+GA3	183.1	193.4	13.90	14.55	70.59	74.19	435.4	460.6
M+De+GA3	164.1	198.4	14.77	14.85	90.30	96.13	479.2	540.9
LSD (0.05)	18.2	17.2	4.8	1.19	8.14	8.77	54.65	58.8
C.V.	6.5	5.6	1.08	5.2	6.8	7.2	7.5	7.4
F. probability for combined analysis of variance between locations (P value ≤0.05)								
Locations	N.S		N.S		N.S		0.013	
Treatments	0.001		0.001		0.001		0.001	
Treats × Locations	N.S		N.S		N.S		0.041	

Table 2. Effect of subspecies, detasseling and spraying of gibberellic acid on yield parameters

Treatments	Yield components							
	Grain Number (g.aer^{-1})		Aer Number (aer.plant^{-1})		W500G (g)		Production (Ton.h^{-1})	
	L1	L2	L1	L2	L1	L2	L1	L2
SC	325.5	349.9	1.73	1.79	126.7	124.3	6.26	6.84
CO	483.8	547.2	1.25	1.47	170.0	164.6	9.24	11.67
M	436.3	554.4	1.83	1.73	155.0	149.3	10.86	12.66
SC+De	215.8	233.6	1.89	1.82	143.3	142.6	5.25	5.34
CO+De	357.3	371.1	1.40	1.53	170.0	176.2	7.35	8.84
M+De	340.3	339.3	1.61	2.00	163.3	152.1	7.91	9.12
SC+GA3	377.1	407.8	1.80	1.82	121.7	132.6	7.33	8.64
CO+GA3	602.4	594.9	1.50	1.63	170.0	186.5	13.51	15.91
M+GA3	499.5	508.4	2.24	2.13	156.7	171.1	15.47	16.20
SC+De+GA3	209.8	228.5	1.87	1.77	150.0	152.8	5.20	5.42
CO+De+GA3	412.0	324.7	1.13	1.57	186.7	183.0	7.76	8.19
M+De+GA3	338.5	339.5	1.96	2.02	138.3	144.5	8.10	8.74
$LSD_{0.05}$	70.68	53.4	0.30	0.26	20.50	8.17	2.492	2.15
C.V.	10.9	7.9	10.6	8.8	7.8	3.1	16.9	13.1
F. probability for combined analysis of variance between locations (P value ≤0.05)								
Locations	0.049		N.S		0.017		0.019	
Treatments	0.001		0.001		0.001		0.001	
Treatments ×Locations	0.012		N.S		0.032		0.006	

Table 3. Effect of subspecies, detasseling and gibberellic acid on cornsilk parameters and antioxidant compounds

Treatments	Silkcorn parameters							
	Fresh weight ($g.are^{-1}$)		Dry weight ($g.are^{-1}$)		Plant yield ($g.plant^{-1}$ D.W)		Production ($Kg.h^{-1}$ D.W)	
	L1	L2	L1	L2	L1	L2	L1	L2
SC	10.25	10.37	1.03	1.34	1.77	1.97	77.88	86.50
CO	12.39	11.20	1.87	1.89	2.34	2.78	103.18	122.20
M	12.28	12.60	1.82	1.96	3.34	3.39	147.21	149.04
SC+De	13.75	12.70	1.40	1.98	2.64	2.44	116.50	107.15
CO+De	15.98	15.67	2.10	2.19	2.96	3.36	130.24	147.93
M+De	14.95	15.83	1.94	1.96	3.10	4.04	136.45	177.97
SC+GA3	14.87	13.62	1.89	2.35	3.45	4.27	151.97	187.87
CO+GA3	16.95	18.13	2.63	3.38	3.42	6.20	150.63	272.80
M+GA3	15.15	15.50	2.04	2.28	3.87	4.84	170.59	212.81
SC+De+GA3	13.10	15.77	1.62	2.48	3.99	4.40	131.71	193.66
CO+De+GA3	20.67	32.39	4.14	4.43	4.69	8.71	206.54	383.45
M+De+GA3	18.91	23.33	3.51	3.81	5.73	6.22	252.23	273.77
LSD (0.05)	1.05	0.95	0.28	0.31	0.58	0.81	25.70	35.92
C.V.	4.20	3.4	7.7	7.3	10.3	11.0	10.3	11.0
F. probability for combined analysis of variance between locations (P value ≤0.05)								
Locations	0.006		0.015		0.026		0.026	
Treatments	0.001		0.001		0.001		0.001	
Treatments ×Locations	0.001		0.001		0.001		0.001	

Table 4. Effect of treatments on antioxidant compounds

Treatments	Antioxidant compounds ($mg.Kg^{-1}$ DW)					
	Total Carotenoids		Ascorbic Acid		Glutathione	
	L1	L2	L1	L2	L1	L2
SC	4.63	4.26	73.67	84.61	6.65	15.69
CO	5.77	5.73	78.18	101.17	13.22	18.54
M	5.40	4.97	62.11	78.10	12.38	16.25
SC+De	6.42	6.29	79.83	104.15	16.23	33.13
CO+De	7.25	7.77	87.52	116.85	15.33	37.98
M+De	6.89	6.80	65.00	93.40	18.72	34.46
SC+GA3	6.99	7.66	71.50	106.96	10.56	14.13
CO+GA3	9.25	9.83	75.83	117.58	13.79	13.62
M+GA3	7.38	8.41	65.51	99.29	12.41	10.44
SC+De+GA3	8.14	8.71	93.73	109.73	15.16	10.16
CO+De+GA3	9.91	10.25	97.23	130.12	15.89	17.26
M+De+GA3	8.55	9.11	84.50	103.58	10.64	18.07
$LSD_{0.05}$	0.42	1.54	5.18	3.35	1.35	2.24
C.V.	3.50	12.20	3.90	1.90	6.00	6.60
F. probability for combined analysis of variance between locations (P value ≤0.05)						
Locations	N.S		0.001		0.001	
Treatments	0.001		0.001		0.001	
Treatments ×Locations	N.S		0.001		0.001	

compare with control, while spraying GA3 were increased growth parameters and yield components compare with control and detasseling treats and interaction between detasseling and spraying GA3 produced high amount of corn silk production and antioxidant compounds.

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Impact of Repeated Applications of Chemical Fertilizers in Mulberry Cropping System on Ground Water in Sericulture Villages of Tamil Nadu

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Abstract: A study was undertaken to find out the impact of repeated applications of inorganic fertilizers in mulberry cropping system on ground water in potential sericulture clusters of Tamil Nadu. Survey on fertilizers usages indicated that about 35.83 percent of sericulture farmers applying chemical fertilizers as per the recommendations and 26.66 percent of farmers indiscriminately using different types of inorganic fertilizers irrespective of recommendations. The ground water samples collected in the vicinity of the mulberry garden applied repeatedly with chemical fertilizers exhibited higher values of pH (8.96), electrical conductivity (0.423 dSm/m), total dissolved salts (3416 mg/L), nitrate (103.20 mg/L) , ammonia (1.95 mg/L), sulphate (198.36 mg/L), phosphate (1.12 mg/L) and potassium (3.25 mg/L) which were foundhigher than the permissible limit of WHO standards (with the respective values of 7-8.5, 0.250 dSm/m, 500 mg/L, 50 mg/L, 0.5 mg/L, 500 mg/L, 0.10 mg/L and 12 mg/L). The remnants of fertilizers in the ground water were reduced in relation to the reduction in doses of inorganic fertilizers. A holistic approach thus should be made for creating awareness among the sericulture farmers and popularizing organic farming strategies to prevent ground water pollution in mulberry ecosystem due to continuous application of chemical inputs.

Keywords: Mulberry, Chemical fertilizers, Remnants, Ground water, Pollution

Mulberry (*Morus alba* L.) is food plant of silkworm (*Bombyx mori* L.) cultivated over 2.8 lakh hectares (Arulmozhi Devi and Sakthivel 2018) in the country and exploited for sericulture. Silk productivity and profit of the farmers mainly depends upon the quantum as well as quality of mulberry leaves produced. Mulberry is a perennial tree and unlike agricultural crops once cultivated it is maintained to about 15-20 years with continuous agronomical practices. Under advanced package of practices of silkworm rearing with mulberry shoots, approximately 7.0-10.0 metric ton of foliage is harvested in bimonthly intervals from one ha of mulberry at each silkworm rearing. However under irrigated conditions, the plants are capable to rejuvenate the foliage shortly by devouring soil nutrients and become ready for subsequent harvests a month after each pruning. It causes depletion of about 28 kg of nitrogen (N), 11 kg of phosphorous (P) and 11 kg of potash (K) (Sakthivel et al 2014). Therefore, the farmers need to replenish the soil nutrients with recommended dosage of 350 kg of ammonium sulphate, 175 kg of single super phosphate and 45kg muriate of potash ha^{1} per crop for sustainable production of quality mulberry leaves (Dandin et al 2003). Chemical based inputs are invariably preferred and about 3.5 MT of chemical fertilizers is applied annually in one ha of mulberry plantation (Sakthivel et al 2014). Such continuous overuse of chemical fertilizers can pollutes the ground water due to leaching. A study was carried out to find the level of entry of fertilizer remnants to ground water in potential sericulture clusters of Tamil Nadu.

MATERIAL AND METHODS

Description of study area: The studies were conducted in Erode district of Tamil Nadu, situated between 10°36' and 11°58' North Latitude and 76° 49' and 77° 58' East Longitude and 171.91 meters above mean sea level. The soil is mostly red sandy and gravel with moderate amounts of red-loamy and occasional black loamy tracts. Soil pH ranges from 8.0 - 9.0. The temperature ranging from 18.5°C in December to 32.2°C in May for the coldest and hottest periods respectively and the annual average precipitation is 823mm.

Survey on fertilizer usage in mulberry garden: Survey was conducted with the farmers who practicing sericulture more than five years, randomly selecting 40 each from Gobichettipalayam, Bhavani and Sathyamangalam sericulture clusters using a questionnaire and obtained information on fertilizer type and usage history in their mulberry garden. Based on the survey the farmers were

categorized in to five groups as detailed below.

T_1-Farmers using chemical fertilizers following recommended doses of N (ammonium sulphate), P (single super phosphate) and K (muriate of potash) @ 28:11:11 kg per crop and a FYM @ 8-10 MT / ha/year (Dandin et al 2003).

T_2 -50 per cent reduced application of recommended doses of N & P, application of *Azospirillum* and phosphobacteria formulation @ 2 kg each / crop and FYM @ 8-10 MT / ha/year.

T_3-75 per cent reduced application of recommended doses of N, P & K apply *Azospirillum* & phosphobacteria formulation @ 2 kg each / crop, FYM @ 8-10 MT / ha/year and annual green manuring with dhaincha (*Sesbania aculeata*).

T_4 -Invariably apply different organic inputs (100% organic) *viz.* Azospirillum & phosphobacteria formulation @ 2 kg/crop, FYM @ 8-10 MT / ha/year and one time mulching of green manure dhaincha (*Sesbania aculeata*) and other organic inputs like poultry manure, pressmud .

T_5 -Farmers using only chemical fertilizers irrespective of recommendations (control farmers).

Collection of water samples and analysis: A total number of twenty five sites, at the rate of 5 sites per category were fixed for sample collections based on the survey interpretations. Water samples from any available source (bore well / open well) in the vicinity of the study cite at the rate of 5 samples per group were collected and were the analysed for traces of fertilizers such as pH, EC, TDS, nitrate, ammonia, sulphate, phosphate and potassium as per the standard procedure of APHA (2005). The studies were conducted after each harvest of mulberry at bimonthly interval covering 12 crops between January 2015 and December 2016.

RESULTS AND DISCUSSION

Survey on fertilizers usages in mulberry garden in potential sericulture clusters indicated that about 35.83 per cent of sericulture farmers applying chemical fertilizers as per the recommendations *i.e.* NPK @ 70:28:28 kg / crop ha^{-1} and 26.66 percent of farmers indiscriminately using chemical fertilizers. However, about 20.83 per cent of farmers applying 50 per cent of reduced doses of N and P by supplementing respective manures with biofertilizers *viz. Azospirillum* and phosphobacteria. Awareness on use of organic fertilizers was spelled with only 7.50 per cent, whereas, 9.16 per cent farmers using about 25 per cent of recommended doses of chemicals in addition to organic manures. The physicochemical properties of ground water samples collected around the selected mulberry fields with different manuring practices were influenced significantly by different manuring practices (Table 1).

pH: The pH was minimum (7.29) in the water samples collected in the vicinity of mulberry with organic inputs (T_4) whereas it was maximum 8.96 on repeated application of chemical fertilizers (T_5). The pH of water in T_1 was on par (8.72) with (T_5) and both are slightly above the WHO standard. However the pH of the samples of T_2, T_3 and T_4 was within the permissible limit of WHO. The alkalinity of water samples is due to presence of cations like calcium, magnesium and sodium (Azeez et al 2000).

Electrical conductivity (dS/m): Least electrical conductivity in T_3 and T_4 where 25 per cent of the recommended chemical fertilizers in combination with different organic inputs and purely with organic inputs and were the permissible limit of WHO. The EC was highest (0.423 and 0.416) in T_5 and T_1 because of repeated application of chemical fertilizers. The electrical conductivity is the capacity of water to carry electric current and it signifies the amount of total dissolved salts in the water. The highest EC may be due to leaching of fertilizers in large quantity because of repeated applications. The electrical conductivity is also influenced by ionic mobility, ionic valence and temperature (Mohamed and Zahir 2013).

Total dissolved solids (mg/L): Total dissolved salts in all samples were beyond the limit of WHO standards (500). However, highest TDS (3416) was with T_5 on repeated application of chemical fertilizers and it was on par (3329) with T_1. Lowest value (1053) was noticed with T_4 i.e. with the organic farming system and it was increased with increase in

quantity of chemical fertilizers recording 1317 and 2090 with T3 & T2. The total dissolved solids which are directly related with the salinity as well as electrical conductance of the water (Pradeep 1998).

Nitrate (mg/L): Least values in nitrite contents (41.05 & 33.29) were recorded with T3 and T4 and found to be within the permissible limits of WHO standards and rest of the samples exhibited the range above the permissible limit. Highest content of nitrite (103.20) was recorded with T_5 which was followed by T_1 (90.73). These range were observed exceeds the permissible limit because excessive use of nitrogenous Fertilizers in mulberry garden. The addition of organic manures increases nitrogen retention capacity and reduce nitrate loss by leaching. Therefore, crops can efficiently utilize the applied fertilizer and residual N will remain in the soil for next crop also (Premanandarajah et al 2003). Since nitrogen retention increases with organic fertilizers, this may be the reason for low nitrate-N concentration in the water samples collected from the sites of mulberry garden applied with less inorganic fertilizers and more organic inputs. Hence, one of the ways to reduce nitrate pollution of groundwater is by incorporating organic manures.

Ammonia (mg/L): Highest ammonia content 2.07 and 1.95 was recorded with T_1 and T_5, respectively which were approximately three folds above than the permissible limit of WHO standards. Presence of high traces of ammonia might have been attributed to more application of N fertilizer in the form of ammonium sulphate or diammonium phosphate (DAP) in the mulberry garden. However, the content of ammonia was least (0.08) in T_4 and it was closely followed by T_3 (0.11). Both samples were exhibited the content below the permissible limit. These results revealed that application of low doses N fertilizers or supplementing N in the form of organic manure reduces the ammonia contamination in ground water.

Sulphate (mg/L): There was wide variation in sulphate content in the water samples collected from mulberry fields applied with different types of manures, ranging from 25.97-198.36. Repeated application of N fertilizers as ammonium sulphate was adversely reflected in the water samples of T_5 and T_1. Sulphate content in permissible limit was in T_2, T_3 and T_4 on reduced application of 50, 75 percent of chemical fertilizers and complete organic farming system respectively.

Phosphate (mg/L): The phosphate content of the samples tested irrespective of manuring practices was more than the permissible limit of WHO standards (0.10) and ranged from 0.21-1.12. According to Rajmohan and Elango (2005) normal water contains only a minimum phosphorus level because of low solubility of native phosphate minerals and the ability of soil to retain phosphate. The highest phosphate content in the water samples collected around the mulberry field applied repeatedly with chemical fertilizers was because of application of single super phosphate and diammonium of phosphate as the source of P. Lowest value was noticed with T_4 (organic farming system).

Potassium (mg/L): The potassium content of the samples ranged from 6.54 to 30.13. Continuous application of muriate of potash in T_5 (30.13) and T_1 (31.47) might have attributed to the leaching into ground water and lead to high concentration of potassium. However it was within the permissible limit of WHO standards in T_3 and T_4.

The physiochemical properties of water samples collected in the vicinity of the mulberry garden applied repeatedly with chemical fertilizers exhibited higher values of pH, electrical conductivity, total dissolved salts, nitrate, ammonia, sulphate, phosphate, potassium which were higher than the permissible limit of WHO standards. The contamination of ground water might have attributed to the leaching of water soluble elements of chemical fertilizers after plant uptake through rain or irrigated water. Fertilization increases efficiency and obtains better quality of product recovery in agricultural activities. Non-organic fertilizers mainly contain phosphate, nitrate, ammonium and

Table 1. Physicochemical properties of ground water samples collected around the selected mulberry gardens with different manuring practices

Treatments	pH	EC ($dS\ m^{-1}$)	TDS ($mg\ L^{-1}$)	Nitrate (NO_3) ($mg\ L^{-1}$)	Ammonia (NH_3) (mg/L)	Sulphate ($SO_{4)}$) ($mg\ L^{-1}$)	Phosphate (PO_4) ($mg\ L^{-1}$)	Potassium (K) ($mg\ L^{-1}$)
WHO standards	7-8.5	0.250	500	50	0.5	500	0.10	12
T_1	8.72	0.416	3329	90.73	2.07	187.12	0.83	31.47
T_2	7.71	0.325	2090	65.67	1.10	82.33	0.37	17.66
T_3	7.33	0.243	1317	41.05	0.11	30.30	0.21	10.75
T_4	7.29	0.239	1053	33.29	0.08	25.97	0.28	6.54
T_5	8.96	0.423	3416	103.20	1.95	198.36	1.12	30.13
CD (p=0.05)	0.66	0.071	218.3	20.31	0.081	16.72	0.014	3.25

potassium salts. However, in recent years, fertilizer consumption increased exponentially throughout the world, causes serious environmental problems (Serpil 2012). Application of nitrogen based fertilizers such as NPK (Nitrogen, Phosphorous, Potassium in complex form), urea together with organic manure like cow dung, decomposed vegetative waste, in more than required quantities could lead to the percolation and contamination of groundwater (Jack and Sharma 1983). Nitrate and phosphate pollution has been reported as a major problem in agricultural ecosystems, especially under intensive use of nitrogen and phosphorous fertilizers. Higher concentration of nitrates as well as phosphates in the water samples due to intensive use of chemical fertilizers especially with urea, DAP, super phosphate was reported by Ganesh et al (2011).

Water contamination due to indiscriminate application of chemical fertilizers in agricultural land was reported by many workers. There is an increased emphasis on the impact on environmental quality due to continuous use of chemical fertilizers. The integrated nutrient management system is an alternative and is characterized by reducing the input of chemical fertilizers and combined use of chemical fertilizers with organic materials such as animal manures, crop residues, green manure and composts. For sustainable crop production, integrated use of chemical and organic fertilizers has proved to be highly beneficial. Several researchers have demonstrated the beneficial effect of combined use of chemical and organic fertilizers to mitigate the deficiency of many secondary and micronutrients in fields that continuously received the only N, P and K fertilizers for a few years, without any micronutrient or organic fertilizer. Studies conducted by Jayaraj (2003) on integrated nutrient management (INM) in farmers' fields with various organic inputs confirmed the possibility of reducing recommended doses of NPK application by 25 per cent after the first year and by 50 per cent after the second year in mulberry cultivation.

CONCLUSION

In sericulture, success of cocoon production and profit of farmers are basically depends upon the soil fertility as it influences the quality of mulberry leaf which is essential for growth and development of silkworms and silk yield. Present investigation indicated that repeated application of chemical fertilizers either indiscriminately or even as per the recommendations in mulberry ecosystem resulted with contamination of groundwater. The water samples collected from the chemical farming system exhibited high concentrations of traces of fertilizers more than the limit of WHO standard. The conventional farmers of the study area admitted the use of excessive fertilizers mainly N beyond recommendations and believe that it is necessary to have better leaf productivity. These fertilizers infiltrated with the irrigation and or rain water to recharge the aquifer. The organic amendment not only supplements the chemical fertilizers but also reduces the environment pollution. Thus it could be concluded that a holistic approach should be made for creating awareness among the sericulture farmers and popularizing organic farming strategies to prevent ground water pollution in mulberry ecosystem due to continuous application of chemical inputs.

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Nutrient and Organic Components Mobilization in leaves of *Excoecaria agallocha* L. during Senescence

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Abstract: *Excoecaria agallocha* is the true mangrove species exhibits senescence. The nutrients and organic constituents in the leaf show variations in green and senescent leaves. The chlorophyll a content in green leaves is more and chlorophyll b is less. Protein and proline is adversely correlated. Among the nutrients, N and Mg content is more in green leaves and the rest of the elements are increased in the senescent leaves. This may be because, the excess nutrients absorbed by the plants recycled back into the environments through the leaves.

Keywords: Mangrove*, E. agallocha,* Senescence, Minerals, Organic constituent

The mangroves are a group of salt tolerant plants in the tropical and subtropical region throughout the world. The species of mangroves exhibit marked temporal and spatial variation with response to various environmental factors, salinity plays a crucial role in the growth and survival of mangroves. Based on the physiological studies, researchers concluded that mangroves are not salt lovers, rather salt tolerant. Salinity affects several metabolic functions of the mangroves like morphological changes in the structure of the chloroplast, structure of the leaf and it also controls the rate of photosynthesis, transpiration and the conductance in stomata (Pal et al 2018). Leaf senescence is characterized by loss of chlorophyll and proteins. Heat stress has also been reported to accelerate the process of protein degradation. Under conditions of high temperature, protein loss is accelerated as a result of increased protease activity and this, in turn, leads to accelerated leaf senescence (Mahalaxmi et al 2007).

Mangrove species have very efficient mechanism for retaining and recycling nutrients, growth of plant is determined by the amount of nutrients they acquire, and the amount of stored nutrient that can be reused. Nutrient reabsorption is the process by which nutrients are withdrawn from senecening leaves (Wei et al 2015). Mangrove species shows common characteristic of tolerance high salinity with the adaptation in those species. They develop mechanism associated with anatomical or physiological characteristics to regulate salt absorption and exclusion such as ultra filtration; salt secretion and ion sequestration. Temperature greater than the optimal negatively affect plant and induces various physiological and metabolic changes including premature leaf senescence. Senescence in plants is a dynamic process that is coordinated by a complex regulatory network in response to endogenous developmental signals and environmental cues (Woo et al 2013). This process plays a primary role in nutrient conservation especially because nutrients following this pathway are not lost through litter fall (Duchesne et al 2001).

Excoecaria agallocha L. a true mangrove species belongs to family Euphorbiaceae generally occurred as backward mangroves. This species is dioceous with the distinct male and female plant. Senescence is not common in mangroves and *E. agallocha* exhibit senescence. In the present work attempt is made to identify the behaviour of this species towards the salt tolerance, in addition to various physiological mechanism in other mangrove species, this may be the adaptation in *Excoecaria* for salt tolerance.

MATERIAL AND METHODS

The leaves of *Excoecaria agallocha* L. in different developmental stages green leaves (early stage), green-radish (mature leaves), radish leaves (senescent initiation stage), radish-yellow leaves (senescence development stage) and yellow leaves (senescent stage) are collected from Aaravi of Raigad district of Maharashtra. The plant material collected in sealed polythene bags washed, blotted to dry and analysed for organic constituents and minerals. The mineral content was estimated using Kjeldahl distillation method for N, spectrophotometer for p, flame photometer for Na and K and atomic absorption spectrophotometer for the remaining minerals. The chlorophyll content, protein and proline were estimated following the standard protocols

(Arnon 1949, Lowery et al 1951, Bates et al 1973). The concentrations of nutrients and organic constituents in green and senesced leaves were used to calculate the changes (Teklay 2004). Relative Per cent Change (RPC) = (Cg - Cs)/Cg) 100, where Cg is the concentration of a particular nutrient or organic constituent in green leaves, and Cs is the concentration of that particular nutrient or organic constituent in senesced leaves. This per cent change is referred as resorption efficiency and some similar studies. The terms 'depletion' or 'enrichment' are used to show either a positive RPC or negative RPC values, respectively. Resorption efficiency ratio was calculated as green: senescent leaves.

RESULTS AND DISCUSSION

The organic constituents and chlorophyll content (Table 1) shows variations/decline in the successive stages. The chlorophyll a content is more in green leaves which reduces in the later developmental stages while chlorophyll b content shows more or less similar composition. It was comparatively less in green leaf and maximum was recorded in the later stages. Decline in chlorophyll is associated with senescence and breakdown of chlorophyll is the earliest symptom of senescence. Chlorophyll as photosynthetic pigment and their reduction is associated with reduced rate of photosynthesis. The chlorophyll a/b ratio also declined with advancement of senescence. Similar results recorded in present work. Massive degradation of chlorophyll resulting in yellowing of leaves is the most obvious visible sign of plant senescence (Khaket et al 2014, Hidema et al 1992, Ougham et al 2005).

The protein contents also shows similar trends i.e. decrease in content from green to senescent, while the proline content is adverse, more accumulation of proline in the senescent leaves than the green. Decrease in protein contents in senescent leaves, and more accumulation of proline may be correlated with stress tolerance. On the other hand increased concentration of proline with increase age up to maturity and is decreased in senescent leaves of *S. apetala*. Among the minerals the major elements i.e. sodium, potassium, calcium and magnesium, the sodium content increased from green (early stage) towards the senescent stage while other shows variation with different stages of developments (Table 2). The K and Ca contents are more in senescent stage while the magnesium content is reduced with the stage. Na concentration is senescent leaves is greater, due to common salt avoidance strategy of halophytes to load excess Na into senescing leaves. This excess Na is then lost from plant when the leaves fall. The foliar K content is greater in senescent leaves than green leaves (Kao et al 2002, Teklay 2004). Decreased K concentration with age was reported in in *R. mangle and L. racemosa*(Medina et al 2015). These species also shows

Table 1. Organic constituent's in different stages of *E. agallocha*

Stages of leaves	Chlorophyll (µg/gm)			Protein (µg/gm)	Proline (µg/gm)
	Chl a	Chl b	Chl a &b		
Early stage	7.62	2.44	0.96	15.09	7.62
Mature stage	6.97	1.33	0.82	14.60	8.03
Early senescent stage	1.91	3.0	0.49	13.11	8.85
Late senescent stage	1.43	3.08	0.45	9.35	10.57
Senescent stage	1.26	2.5	0.34	7.34	12.54
Resorption efficiency ratio (Green: Senescent)	1:0.16	1:1.024	1:0.35	1:0.48	1:1.64
Relative percent change	83.46	-2.45	64.58	51.37	-64.56

Table 2. Major elements composition in different stages of *E. agallocha* (percent)

Stages of leaves	Na	K	Ca	Mg	Cl	N	P	S
Early stage	1.30	2.55	1.67	0.62	4.26	1.40	0.33	0.55
Mature stage	1.90	3.40	0.99	0.47	4.62	1.40	0.53	0.63
Early senescent stage	2.30	2.50	0.70	0.67	7.5	1.06	0.30	0.61
Late senescent stage	3.60	2.35	1.74	0.67	8.9	0.73	0.35	0.57
Senescent stage	2.10	3.35	2.77	0.46	7.8	0.72	0.52	0.60
Resorption ratio (Green: Senescent)	1:1.61	1:1.31	1:1.65	1:0.74	1:1.83	1:0.51	1:1.57	1:1.09
Relative percentage change	-61.53	-31.37	-65.86	25.8	-83.09	48.57	-60.6	-20

accumulation of Na, Mg, and Ca and Ca increased with leaf age in *L. racemosa.* Yellow leaves do not have higher Na concentration than green leaves, increased Mg concentration in senescent leaves than K and Ca has been reported in *S. apetala* (Cram et al 2002, Gokhale et al 2012). Nitrogen, phosphorus and sulphur content also vary with age. Nitrogen content decreased from early stage to senescent stage, while P is more or less similar in mature and senescent leaf. But the content of sulphur is similar throughout the developmental stages.

The minor element does not show any specific trend (Table 3). The range for iron is comparatively larger. The minimum content was in early stage and the maximum in senescent developmental stage where the leaves are not fully senescent yellow. The Zn content is less and not specific with the developmental stages. Interestingly the copper content in initial senescent development is much more higher compared to other stages indicating more accumulation of Cu which later may decrease as it reabsorbed into the plant. Manganese also show similar pattern like iron.

The RPC (relative per cent change) in the concentration (Table 1 and 2) of the major and minor elements is positive for nitrogen and magnesium where the concentration is higher in green leaves (initial stage) and decreased during senescent stage while rest of the elements it is negative indicating enrichment of those element in senescent stage. Considerable reduction in N and P contents and net enrichment in K content in senescent leaves is a normal feature among plants (Teklay 2004). The higher RPC of P than N might indicate that P is more limiting to plant growth than N in traditional agro forestry system. Nutrient translocation from senescent leaves back in to shoot was an important nutrient conservation mechanism for N and P and was less important for K and did not occur in Ca, Mg, Na or Cl (Wang et al 2003). The nitrogen and magnesium percent is higher 51 and 74 percent in green leaves than senescent leaves, while in the rest element the major element i.e. Na, K and Ca are 61, 31 and 65 per cent, respectively more in senescent leaves. This indicates as the N and Mg are important elements for growth and development. They accumulate more in the green leaves while the remaining are leached in to the soil through the senescent leaves, and helps to secrete the excess salt load from the plant onto the environment/ in the soil. The mangrove has mechanism of salt accumulation, salt exclusion and salt excretion and they avoid heavy salt loads through a combination of these mechanisms (Kannappan et al 2012). In *E. agallocha* the release of excess salt may be through the senescence. This can also be supported with the results of Na and Cl percentages being 61 and 83 per cent, respectively. CL in

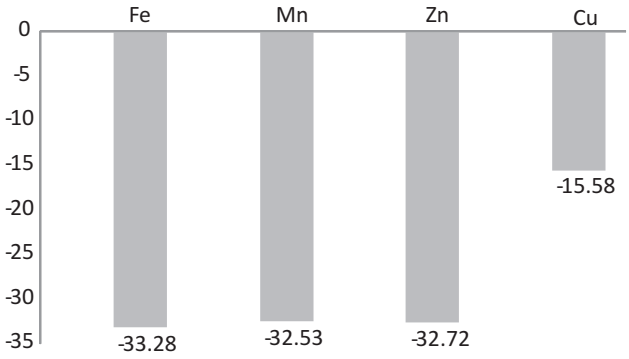

Fig. 1. Relative Percent Change (RPC in %) from green to senescent stages in Minor elements concentration in *E. agallocha*

Table 3. Minor elements composition in different stages of *E. agallocha**

Stages of leaves	Fe	Mn	Zn	Cu
Early stage	757	209	55	77
Mature stage	823	248	67	56
Early senescent stage	1206	257	78	1088
Late senescent stage	1979	404	55	205
Senescent stage	1009	277	73	89
Resorption efficiency ratio (Green: Senescent)	1:1.33	1:1.32	1:1.32	1:1.15

*All values are in ppm

senescent leaves is 83 per cent more than green leaves and it is the maximum in all other element. In *E. agallocha*, among the all absorbed minerals and organic constituents, the resorption of N and Mg is unique as these are essential elements for further growth and development of the plant while the other elements are washed away from the plants through senescence. The chlorophylls also resorb while in protein and proline, the proline remains accumulated in senescent leaves indicating adaptation for salt tolerance.

Among the mangroves, salt absorption and exclusion, salt secretion and salt accumulation are the common adaptations towards the salt tolerance. However, in *E. agallocha* mobilization of excess salts in the leaves during senescence may be the adaptation for the salt tolerance as it reflects from the results that the excess concentrations of some of the elements especially the calcium, sodium and chloride concentration is higher in the senescent leaves than the green. Therefore, the mobilization of excess salts through senescence may be a unique adaptation in*E. agallocha* for the salt tolerance.

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Effect of *Cladophora crispate* Extract on Potassium Release from Soil

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Abstract: Two soil samples were selected based on the difference in particle size distribution, included fine texture (clay loam) and coarse texture (sandy). Laboratory experiment was conducted by treating both the two samples by four concentrations of *Cladophora crispate* extract (0,1,2,3 g/l) to evaluate the ability to release soluble and exchangeable potassium. The tested soil samples varied in soluble and exchangeable potassium content which ranged between (0.2-1.12) and (0.1-0.79) Meq/l for fine texture and coarse texture, respectively and greater amount for released potassium was in the concentration of 3g/l for fine which was higher in fine than coarse texture. The results showed linear increment in potassium phases (soluble, exchangeable and available) with the increase of algae extract concentration

Keywords: Available potassium , *Cladophora crispate*, algae extract , soil texture

Iraqi soils characterize by high store of potassium content but is unavailable because its retention between layers of clay minerals such as mica and smectite (Alzubaidi 2003). The soil texture is important factor effecting on potassium availability (Anderson et al 2007). Fixation of potassium is major problem in Iraqi soils and that lead farmers to apply high quantities of potassium fertilizers to covering plant need from this macroelement but this undesired way because the risks of soil pollution and salinization (Aderhold et al 1996, Murphy et al 2005). The new trend of clean agriculture in the world requires reduce the use of potassium fertilizers by evolving technology which make the K available from soil to the crops (Safinaz and Ragaa 2013). Release of fixed K (unavailable) to the exchangeable and soluble forms(available) occurs when the amount of exchangeable and soluble K are reduced by plant uptake, leaching and perhaps by rises in microbial activities (Sparks 2000). Algae extract has been reported as a beneficial treatment as a soil conditioners which improve nutrients availability and this can reflect on the plant through increase of growth, yield and productivity (Norrie and Keathley 2006). Algae extract mixture consisted of wide range of active compounds including (organic acids amino acids, vitamins, hormones and enzymes) can react with minerals and rocks (Al-shakankerya 2014). The present study aimed to illustrate the role of different concentrations of algae extract on fixed potassium release from soil minerals in to the soil solution.

MATERIAL AND METHODS

Study area: The study was conducted at Misan University, Misan province/Ammarah city ,Iraq (N 31026- 56.62= - 310 27- 7.328= latitudes, E 470 43- 14.138=- 470 55- 3.961=longitudes). The climate of the area is hot and dry in summer and cold with moderately rainfall in winter. The mean annual precipitation less than 100mm.The parent material of soils is alluvium rich in calcium carbonates, soils in the study area are classified as Entisols. The soil moisture and thermal regimes are torric-Aridic (Fig. 1).

Physical and chemical properties of soils: The soil samples was collected from an agricultural field from depth of 0–15 cm**,** were air-dried, crushed, sieved with a 2 mm sieve and subjected to the physical and chemical analysis (Table1). The particles size distribution of the soil samples was performed according to Piper (1950) and organic matter of the soil samples by Walkely-Black method (Jackson 1973). Calcium carbonate was measured by the calcimeter method according to Nelson (1982). Soil pH was measured in 1:1 water: soil suspension using a glass electrode as reported by Mclean (1982). The electrical conductivity (EC) and soluble ions were estimated in the saturated soil paste extract using a conductivity meter (Jackson 1973). The cation exchange capacity (CEC) of the soil samples was calculated using NaOAC at pH 8.2 as a saturating solution and NH4OAC at pH 7.0 as a displacing solution, and then sodium was measured by flame photometer (Jackson 1973).

Algae isolation and identification: The classification of

algae was done according to Prescott (1975). The classification show that the sample be accustomed to green algae called *Cladophora crispate*. The enough quantity of sample spread on clean clothes cut to dry in laboratory temperature until complete dryness, grinding by electrical grinder and kept in clean container in the refrigerator until extract preparation.

Preparation of algae extract: Algae extract was prepared by solubilized 5g from algae powder in 100 ml of ethanol 70 percent. The extraction process conducted by using magnetic stirrer for 24 h followed by filtration process using 0.45µ opening diameter filter paper. The, filtrate was put in petri dishes exposed to air under natural conditions in the laboratory to allow alcohol to volatile and the residual extract collected which represent the algae extract which kept in refrigerator (Obaed 2015).

Experimental design and treatments: This experiment carried out with completely random design (CRD) with two factors first is soil type include clay loam and sandy texture and second factor is the four concentration of algae extract (0, 1 , 2 , 3 g/l). Each treatment was replicated thrice.

Addition of algae extract to soil samples: 10 g of air dried soil sample precisely weigh and placed in 25ml conical flask and then required concentration of algae extract was mixed with the soil and left for 24 hrs in incubator before determination of available potassium, soluble and exchangeable (Page et al 1982).

RESULTS AND DISCUSSION

The two soils belong to Entisols and were calcareous and alkaline. The particle size distribution of soil samples shown that ranged from 343–908 g/kg, 35–312 g/kg and 57-445 g/kg for sand, silt, and clay respectively, with $CaCO_3$ content and pH ranged from 110 to 230 g/kg and from 7.1 to 7.6 respectively (Table 1). Organic matter constituted 14–50 g/kg of the soils and highest was for fine texture**. T**these results agreed with many studies refers to the differences in soil texture impacts organic matter levels because of organic matter breaks down faster in sandy soils than in fine textured soils within given same environmental conditions and soil fertility, because of a higher percentage of oxygen available for decomposition in the coarse textured sandy soils. Cation exchange capacity ranged from 12 to 26 cmol/kg with the higher value in fine texture sample compared with coarse texture sample, the cation exchange capacity of the soil increases with percent clay and organic matter (Palm and Sanchez 1990, Marbet et al 2001). All soils were non saline according to its electrical conductivity (EC) values which ranges between 0.13 to 0.61 dc/m were the fine texture has higher value (Table 1)**.**

Table 1. Chemical and physical properties of soil samples

Property	Fine sample	Coarse sample
physical		
Clay (g/kg)	345	57
Silt (g/kg)	312	35
Sand (g/kg)	343	908
Texture class	Clay loam	Sand
chemical		
pH	7.6	7.1
EC (dS/m)	0.62	0.13
Soluble Ions (Meq/l)		
Ca	2.2	0.9
Mg	0.4	0.1
Na	0.6	0.3
K	0.2	0.1
Cl	0.9	0.4
CO_3	Nil	Nil
HCO_3	2.6	0.7
SO_4	0.6	0.2
Organic matter (g/kg)	50	14
$CaCO_3$ (g/kg)	230	110
CEC (Cmol/kg)	26	12

Effect of Algae Extract Concentration on Potassium Availability

Fine texture: The results showed that there is linear increase in available potassium (soluble, exchangeable and available) with the increasing of algae extract *Cladophora crispate* concentrations. The soluble potassium at 3 g/l of extract was 0.5 meq/l for fine texture with increase of 150 per cent over the control (Table 2, Fig. 2). This may be due to the effect of biochemical compounds in the extract that solubilize the potassium and resulted in more release of non-available potassium. Many researchers also obtained similar results (Rathore et al 2009, Sathya et al 2010, Kumar and Sahoo 2011, Chaiklahan et al 2013, Al-shakankerya et al 2014). Similar trend was registered for exchangeable potassium which increased to 0.62 Meq/l as compared with 0.35 Meq/l for control treatment. The exchangeable K was high as compared with soluble K. The available potassium have been estimated by sum of two phases (soluble and exchangeable) and the similar trend was observed with increase from 0.55 to 1.12 Meq/l at the higher concentration (3g/l). This is due to the ability of algae extract to solubilize of potassium from K- bearing minerals and release more quantity of both soluble and exchangeable K which represent total quantity of available potassium.

Coarse texture: Same trend was observed as fine texture

Table 2. Effect of algae extract concentration on potassium phases concentrations and percent increase

Soil samples	Potassium phases concentration (meq/l)											
	Soluble potassium				Exchangeable potassium				Available potassium			
	0	1	2	3	0	1	2	3	0	1	2	3
Algae extract concentration (mg/l)												
Fine texture	0.2	0.31	0.41	0.5	0.35	0.46	0.53	0.62	0.55	0.77	0.94	1.12
Coarse texture	0.1	0.13	0.21	0.36	0.13	0.15	0.24	0.43	0.2	0.3	0.5	0.8
Percent increase (%)												
Fine texture		55	105	150		31	51	77		40	71	104
Coarse texture		30	110	260		15	85	231		22	96	243

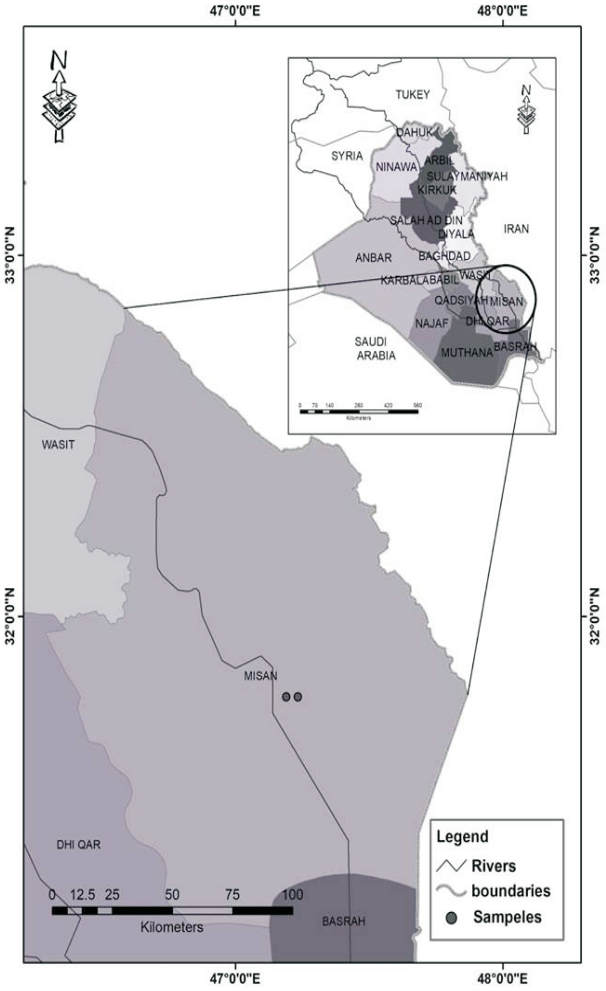

Fig. 1. Study area

but was lower because the difference in clay and silt fraction percentage which was lower in coarse texture (Table 1) and this results agree with Mengel and Kirkby (2001) and Al-Zubaidi (2001). The higher concentrations for potassium phases was registered in the higher level of algae extract (3g/l) being 0.36, 0.43 and 0.79 Meq/l for soluble, exchangeable and available potassium, respectively.

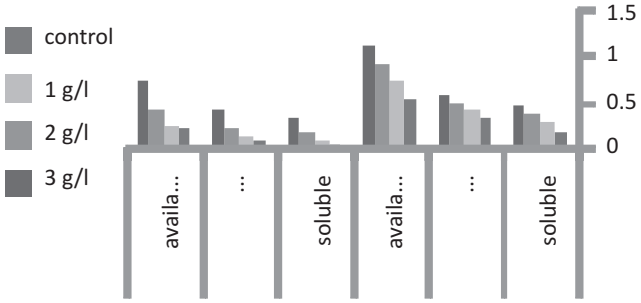

Figure 2. Effect algae extract concentrations on potassium phases concentration for studied soils

CONCLUSIONS

Algae extract concentration have precursor role on potassium availability by releasing it from the layers of clay minerals through some biochemical reactions between some active compounds including in algae extract and the element in mineral sheets. This effect more clearly in high concentrations where the results show linear increasing between extract concentration and quantity of soluble , exchangeable and available potassium. The texture of soil have a significant effect on the potassium phases concentration and more concentration of potassium release appear in clay texture and low in coarse texture.

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Impact of Penoxsulam Integrated with Stale Seedbed on Soil Health of Upland Rice Ecosystem

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Abstract: The present investigation was undertaken during *Kharif* season (June - October) of 2017 in Coconut Research Station (CRS), Balaramapuram, Kerala to assess the effect of penoxsulam integrated with stale seedbed on soil health of upland rice intercropped in coconut orchard by analyzing the microbial population (total count of bacteria, fungi and actinomycetes) and enzyme status (dehydrogenase and urease) in the experimental field. The treatments were combination of 2 levels of stale seedbed methods and 8 levels of weed management (combination of penoxsulam @ 20, 25 and 30 g ha^{-1} at 10-15 DAS with hand weeding at 35 and 40 DAS and with metsulfuron methyl + chlorimuronethyl @ 4 g ha^{-1} at 35-40 DAS, Hand weeding at 15and 35 DAS and weedy check) methods. The results revealed that no significant variation was observed between penoxsulam and non-herbicidal plots in microbial population. Compared to just before herbicide application an increase in microbial population as well as enzyme status of soil was observed at 15 and 30 DAHA. The weed management practices did not impart any harmful effect on the microorganisms and the enzyme status of soil indicating the safety of the herbicide penoxsulam on soil health.

Keywords: Microbial population, Penoxsulam, Stale seedbed, Soil enzyme

Soil health is presented as an integrative property that reflects the capacity of soil to respond to agricultural intervention, so that it continues to support both the agricultural production and the provision of other ecosystem services (Kibblewhite et al 2008). Soil microbial and soil enzyme activity are considered as important bio-indicators of soil health and are considered as indicators of soil quality and health as they are involved in various biochemical process resulting to the release of nutrients to the plants (Schloter et al 2003). Milosevic and Govedarica (2002) reported that soil microorgansims play vital role in the soil-plant-herbicide-fauna-man relationship as they are involved in the degradation process of herbicides. Soil enzymes act as catalyzers in several important reactions necessary for the life processes of microorganisms in soils and the stabilization of soil structure, decomposition of organic wastes, organic matter formation and nutrient cycling. Dehydrogenase activity is considered as indication of metabolic activity of the microbial population in soil. Raj and Syriac (2017) reported that microbial population and enzyme activity in soil are used as indicators of soil health because of their active role in soil organic matter production, decomposition of xenobiotics and cycling of nutrients, ease of measurement and rapid response to management practices.

Upland rice cultivation is evolved as a potential alternative to lowland rice cultivation. Weeds are the major pest that affect the upland rice yield to the greatest extent. Use of traditional high dose herbicides is effective for controlling weeds but continuous use has resulted in resistances and residue related problems. Integration of eco-friendly management option like stale seedbed method (SSB) with low dose high efficacy (LDHE), new generation herbicides is the need of the time. Penoxsulam is such a post emergence herbicide belonging to triazolopyrimidine sulfonamide group inhibiting acetolactate synthase (ALS) enzyme in susceptible species.

It is important to understand the behavior of herbicides in the soil to avoid their side effect on soil micro-organisms and enzyme activity. Hence, the current study was conducted to assess the effect of penoxsulam on soil microbial population *i.e.,* total count of bacteria, fungi and actinomycetes and enzyme status (dehydrogenase and urease) under upland rice ecosystem.

MATERIAL AND METHODS

Field experiment was undertaken during *Kharif* season (June - October) of 2017 in Coconut Research Station (CRS), Balaramapuram, Kerala, India. The experiment site is located at 8^0 23' 55.10328" North latitude and $77^0$1' 48.9774" East longitude, at an altitude of 9 m above mean sea level with a warm humid tropical climate. The experiment was laid out in randomised block design with 16 treatments replicated thrice. The treatments were combination of 2 levels of stale seedbed methods s_1 : Stale seedbed with mechanical

removal of weeds and s_2: No stale seedbed and 8 levels of weed management methods m_1:Penoxsulam @ 20 g ha^{-1} at 10-15 days after sowing (DAS) followed by hand weeding at 35-40 DAS; m_2 : Penoxsulam @ 25 g ha^{-1} at 10-15 DAS followed by hand weeding at 35-40 DAS; m_3: Penoxsulam @ 30 g ha^{-1} at 10-15 DAS followed by hand weeding at 35-40 DAS; m_4: Penoxsulam @ 20 g ha^{-1} at 10-15 DAS followed by metsulfuron methyl + chlorimuron ethyl @ 4 g ha^{-1} at 35-40 DAS; m_5: Penoxsulam @ 25 g ha^{-1} at 10-15 DAS followed by metsulfuron methyl + chlorimuron ethyl @ 4 g ha^{-1} at 35-40 DAS; m_6: Penoxsulam @ 30 g ha^{-1}at 10-15 DAS followed by metsulfuron methyl + chlorimuronethyl @ 4 g ha^{-1} at 35-40 DAS; m_7: Hand weeding twice (15 and 35 DAS) and m_8: unweeded control. The rice variety Prathyasa (MO-21), a short duration variety, released from Rice Research Station, Moncompu, Kerala was used for the experiment. The size of the experimental plot was 5 x 4 m (gross) and 3.6 x 3.8 m (net). The soil of the experiment site belongs to the textural class of red sandy loam. The organic manure source used for experiment was well decomposed dry cow dung containing 0.55 per cent N, 0.23 per cent P_2O_5 and 0.46 per cent K_2O. Dry cow dung powder was applied at the time of last ploughing. Recommended chemical fertilizers, N: P_2O_5: K_2O @ 60: 30: 30 kg/ha as per Packages of Practice Recommendations: crops (KAU, 2016) were applied . One third dose of nitrogen and potassium and full dose of phosphorus were applied as basal and remaining nitrogen and potassium were applied in equal splits at 40 and 60 DAS. Soil was acidic (pH 4.6) in reaction, high in organic carbon (0.81), medium in available nitrogen (282.8 kg/ha) and available phosphorus (36.04 kg/ha) and low in available potassium (105.6 kg/ha). The experiment plots were irrigated to field capacity during non-rainy period, once in a week.

In order to observe the microbial population of soil, samples were collected just before herbicide application and 15 and 30 days after herbicide application. The total count of bacteria, fungi and actinomycetes were assessed by serial dilution plate technique (Johnson and Curl 1972). Nutrient agar medium was used for growing bacteria, Kenknight's agar medium for actinomycetes and Martin's Rose Bengal agar Medium for fungi. The Microbes were grown in petridishes containing the respective media. Soil samples for enzyme studies were collected just before herbicide application and 15 days after herbicide application. Four samples were collected from each plot, mixed thoroughly to form a composite sample and stored in polythene bag at 4^0 C. The enzyme assay was completed within a week. Activity of dehydrogenase enzyme was determined by the method described by Casida et al (1964) and expressed as µg triphenyl formazon (TPF)/g of soil/day. The urease activity of soil was determined by the method described by Watts and Crisp (1954) and expressed as µg urea hydrolyzed/g of soil/h.

RESULTS AND DISCUSSION

Fungal population: The stale seedbed methods and weed management methods did not have any significant effect on the fungal population at 15 and 30 DAHA (Table 1). But compared to fungal population just before herbicide application (35 x 10^{-3} CFU g^{-1} wet soil), a substantial increase in fungal population was at 15 and 30 days after herbicide application (DAHA) (ranging from 58.67 to 72.17 x 10^{-3} CFU/g wet soil and 48.67 to 60.67 x 10^{-3} CFU/g wet soil, respectively) in weed control treatments. Corroboratory results were reported by Raj et al (2015). However, no significant difference was observed between herbicide applied and non-herbicidal plots implying that penoxsulam at 20, 25 and 30 g/ha do not have any adverse effect on fungal population. According to Bhatt et al (2017) after initial reduction (3 DAHA), population of fungi increased and was on par with unsprayed plots (HWT and unweeded control) by 23 DAHA with penoxsulam @ 22.5 g ha^{-1}. Sasna (2014) also reported an initial decline in the population of fungi (6 DAHA) due to the application of penoxsulam. Similar results on the inhibitory effect of herbicides on the growth of fungi in the initial stages and subsequent increase with passage of time were observed by Choudhary et al (2008).

Bacterial population: In the present study, compared to the count of bacteria just before herbicide application (JBHA) (172 x 10^{-6} CFU/g wet soil), a substantial increase in bacterial count was observed in the experimental field at 15 and 30 DAHA irrespective of weed management method used (Table 2). Findings of Raj et al (2015) also support this finding. However, no significant variation in total bacterial count was observed between herbicide applied and non-herbicidal (HWT and weedy check) plots implying that the herbicide penoxsulam is not having any adverse impact on soil bacterial population at the tested doses. These results are in agreement with the findings of Bhatt et al (2017) and Saranraj et al (2018), who observed no significant variation in total bacterial count in penoxsulam applied and control plots (HW and unweeded check). However, Sasna (2014) reported that there was a decline in the population of soil bacteria at 6 DAHA in penoxsulam (17.5 to 30.0 g ha^{-1}) treated plots compared to HWT and unweeded plots.

Actinomycetes population: The population of soil actinomycetes showed an increasing trend compared to pre-treatment population (5x 10^{-4} CFU/g wet soil) at 15 and 30 DAHA (Table 3). However, between penoxsulam plots and non-herbicidal plots no significant variation was observed in

actinomycetes population. This might be due to the fact that these micro-organisms are able to degrade herbicide and utilize them as a source of biogenic elements for their physiological processes. This results also implies that the delicate biological balance of the soil is very little affected by the application of post emergence herbicide penoxsulam, indicating very low environmental hazard. Dissipation kinetics of penoxsulam in soil of rice eco system revealed that half-life of penoxsulam ranged from 6.40 to 7.88 days in soil and from 3.40 to 5.12 days in water at 20, 25 and 30 g/ha (Kaur et al 2017). Bhatt et al (2017) reported an initial decline in actinomycetes population (3 DAHA) but the population

Table 1. Effect of weed management practices on the population of soil after herbicide application (population of fungi x 10^{-3} CFU/g wet soil)

Stale seedbed methods (S)	Weed management methods (M)								
	M_1	M_2	M_3	M_4	M_5	M_6	M_7	M_8	Mean
15 DAHA									
s_1	70.00	64.67	75.00	68.00	62.33	68.00	74.00	68.67	68.83
s_2	68.33	61.00	66.67	63.33	61.33	69.00	65.33	65.33	65.04
Mean	69.17	62.83	70.83	65.67	61.83	68.50	69.67	67.00	
30 DAHA									
S_1	53.67	56.33	57.33	59.33	57.67	54.67	59.67	57.67	57.04
S	54.67	52.00	56.33	59.00	54.33	55.67	55.33	54.33	55.21
Mean	54.17	54.17	56.83	59.17	56.00	55.17	57.50	56.00	

The difference in different treatments and interaction were non-significant

Table 2. Effect of weed management practices on the population of soil bacteria at after herbicide application (population of bacteria x 10^{-6} CFU/g wet soil)

Stale seedbed methods (S)	Weed management methods (M)								
	M_1	M_2	M_3	M_4	M_5	M_6	M_7	M_8	Mean
15 DAHA									
S_1	187.0	165.0	176.7	175.7	182.0	177.7	178.3	190.3	179.1
S	186.7	185.0	187.0	185.3	180.0	190.0	172.7	179.7	183.3
Mean	186.8	175.0	181.8	180.5	181.0	183.8	175.5	185.0	
30 DAHA									
S_1	167.3	188.7	196.7	166.0	173.7	172.7	172.7	175.0	176.6
S	183.0	178.3	173.3	171.3	173.0	180.0	190.0	174.3	177.9
Mean	175.2	183.5	185.0	168.7	173.3	176.3	181.3	174.7	

The difference in different treatments and interaction were non-significant

Table 3. Effect of weed management practices on the population of soil actinomycetes after herbicide application population of actinomycetes x 10^{-4} CFU/g wet soil)

Stale seedbed methods (S)	Weed management methods (M)								
	M_1	M_2	M_3	M_4	M_5	M_6	M_7	M_8	Mean
15 DAHA									
S_1	6.67	7.33	7.67	11.00	8.00	8.00	9.00	8.67	8.29
S	7.67	7.67	6.67	8.33	8.33	8.67	8.67	9.33	8.17
Mean	7.17	7.50	7.17	9.67	8.17	8.33	8.83	9.00	
30 DAHA									
S_1	7.00	6.67	6.33	8.33	6.67	7.33	6.33	7.67	7.04
S	8.00	6.33	8.33	7.67	7.00	7.67	7.33	7.00	7.42
Mean	7.50	6.50	7.33	8.00	6.83	7.50	6.83	7.33	

The difference in different treatments and interaction were non-significant

Table 4. Effect of weed management practices on dehydrogenase enzyme activity at 15 days after herbicide application, µg TPF/g soil/day

Stale seedbed methods (S)	Weed management methods (M)								
	M_1	M_2	M_3	M_4	M_5	M_6	M_7	M_8	Mean
s_1	13.57	16.97	10.93	11.41	15.83	13.20	10.26	5.28	12.18
s_2	9.99	13.57	14.51	16.58	8.153	10.56	4.93	7.08	10.67
Mean	11.78	15.27	12.72	14.00	11.99	11.88	7.60	6.18	

CD (p=0.05)- Stale seedbed methods (S)- 0.98; Weed management methods (M)-1.97;Interaction (SxM)-2.78

Table 5. Effect of weed management practices on urease enzyme activity at 15 days after herbicide application, (µg urea hydrolyzed/g soil/h)

Stale seedbed methods (S)	Weed management methods (M)								
	M_1	M_2	M_3	M_4	M_5	M_6	M_7	M_8	Mean
S_1	41.81	43.81	44.40	49.74	42.76	49.17	45.82	45.70	45.40
S_2	40.93	47.37	42.98	44.19	44.14	41.22	42.84	42.21	43.23
Mean	41.37	45.59	43.69	46.97	43.45	45.20	44.33	43.96	

The difference in different treatments and interaction were non-significant

increased subsequently. This could be because, before degradation, herbicides have toxic effects on micro-organism reducing their abundance, activity and consequently diversity of their communities. Later on, micro-organisms take part in the degradation process and then the degraded herbicide provide carbon rich substrate which in turn maximize the microbial population in the rhizosphere. Similar results are reported by Saranraj et al (2018).

Since there was no decline in the soil microbial population (bacteria, fungi and actinomycetes) at 15 and 30 DAHA compared to the pre-treatment values it can be inferred that the herbicide, penoxsulam is safe to the soil environment.

Effect of herbicide on enzyme activity: In the present study compared to pre-treatment values (12.01 µg TPF/g soil/day), herbicidal treatments recorded higher dehydrogenase activity (Table 4). Among the herbicidal treatments, penoxsulam @ 25 g ha^{-1} fb HW (m_2) recorded the highest activity of dehydrogenase in soil. Compared to the control treatments (HWT and unweeded control) all the herbicidal treatments, significantly higher dehydrogenase activity. This might be due to the greater availability of carbon source by the degradation and decomposition of herbicides and also by the decomposition of weeds. This result is in conformity with the findings of Sebiomo et al (2011) and Raj et al (2015).

The observation on urease enzyme activity revealed that at 15 DAHA, urease enzyme activity in soil was not significantly influenced by stale seedbed methods and weed management methods (Table 5). However, a drastic decline in the urease enzyme activity was observed in the experimental plots compared to the pre-treatment enzyme activity (77.03 µg urea hydrolyzed/g soil/day). Basal application of nitrogen in the form of urea might have caused the enhancement of urease activity in the experimental plot, as revealed by the higher, pre- treatment urease values compared to that recorded at 15 DAHA. Aparna (2000) reported that higher availability of substrate nitrogen and other nutrients promoted urease activity. Rasool et al (2014) observed that urease activity was stimulated by herbicides under flooded condition than unflooded condition. This explains the decrease in urease activity at 15 DAHA, in the present study, which was carried out in upland soil. When basal nitrogen application was done, copious irrigation was also given for better crop establishment. Contrary to this, application of butachlor, pyrazosulfuron, paraquat and glyphosate herbicides increased the activity of urease from 7th day to 28th day of incubation (Baboo et al 2013).

CONCLUSION

There was no decline in the soil microbial population (bacteria, fungi and actinomycetes) and enzyme status (dehydrogenase and urease) compared to that before herbicide application implying that the, penoxsulam is not having any adverse effect on the biological balance of soil.

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Qualitative Decline of Pollinator Spectrum in Sunflower Agro Ecosystem

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Abstract: Sunflower witnessed 30 per cent loss of floral visitors over 23 years. Majority (85%) of floral visitors in 1992 were pollinators than in 2015 (57.1%). Hymenoptera lost its dominant proportion from 60 per cent to mere 28.6 per cent and lost entire taxa of solitary and bumble bees. Despite increased density, *Apis mellifera* declined from 60.7 to 23.9 per cent followed by *A. dorsata.* Over this period, qualitative composition of floral visitors deteriorated, as non-pollinator species doubled from 3 to 6. Proportion of pestiferous fauna increased to 47.5 per cent from only 2.8 per cent in 1992. Weather conditions did not significantly varied during the period of 23 years to influence the decline in pollinators. One of the key factors in decline is the use of insecticides for management of new emerging pests.

Keywords: Sunflower, Floral visitors, Pollinators, Honey bees, Pollinator decline, Diversity, Abundance

Animal pollinators are proven providers of ecosystem services and increase food production through cross pollination besides greatly improving quality of fruits, nuts, oilseeds and vegetables. Such animal pollination benefits to Indian agriculture are estimated at US$ 22.52 billion annually (Chaudhary and Chand 2017). Millennium Ecosystem Assessment (2005) has identified pollination amongst the 15 ecosystem services under threat now, raising concern over global food security (Breeze et al 2014). The decline is not confined to honey bees alone but spreads to bumblebee and other wild pollinators that not only contribute to crop yield but provide insurance to farmers growing insect pollinated crops (Garibaldi et al 2014). The key global change drivers for present day problems include habitat loss, land use change, newer and severe invasive species and pesticide toxicity especially neonicotinoids that ultimately govern the decline in pollinators diversity, abundance and foraging behaviour and losses in pollinator species (Rader et al 2011). Escalated human activities lead climate change, global warming and pollinator decline are further expected to sharply decrease the agriculture output amidst rapidly growing world population, leaving humanity mostly with managed pollinators especially honey bees to perform this gigantic task.

Sunflower is copious source of nectar and pollen to the honey bees and one of the most important honey crops for the beekeepers in India. Being a highly cross pollinated crop, it attracts a large array of floral visitors predominated by honey that contribute greatly (40-90% reduction in yield in absence of pollinators) in production of seeds (Chaudhary and Chand 2017). Present studies were undertaken to assess the demographic complexion of floral visitors in chemically intensified and degraded sunflower agro-ecosystem of India, over two spatial time lines (23 years apart) at the same location, where pollination is being undertaken as an integral component of the national policy.

MATERIAL AND METHODS

Present studies compared the diversity and abundance of floral visitors of sunflower at CCS Haryana Agricultural University, Hisar (29°10'N, 75°46'E, 215.2 m AMSL) at two time spans of 1992 and as recent as 2015, an interval of 23 years.

Diversity and abundance of floral visitors (2015): The 2015 data on diversity and abundance of floral visitors was taken from our experiment (Rinku and Chaudhary 2017) conducted on spring planted (12th February 2015) eight sunflower cultivars comprising of two populations (HS-1 and Morden) and six hybrids (PSH-996, HSFH-848, HSFH-1183, SH-3322, DK-3849 and Pioneer 64A57). Crop was raised in three replications in complete randomization design at a spacing of 60 x 30 cm in a plot size of 10.0 m^2 following all the package of practices excluding the application of insecticides. From each plot, three capitulums were randomly selected and tagged for observations employing standard protocol (Delaplane et al 2013). Different floral visitors on the capitulum were collected using a cone type hand net at hourly intervals throughout the blooming period,

preserved and identified by comparing them with reference collection maintained at CCS HAU, Hisar (Haryana). From the marked capitulum (n=3), number of different floral visitors were visually recorded continuously for a period of two minutes at 2-hourly intervals from 0600 till 1800 h on ten clear, calm and sunny days at peak flowering. *A. mellifera* was visiting from 12 managed colonies kept at 550 meters from the experimental site while *A. cerana* visited from their feral nests in the foraging area. The two wild honey bees, *A. dorsata* and *A. florae* foraged from their wild nests in the foraging area.

Study conducted by Arya (1993) and Arya et al (1994) in the spring season of year 1992 at the same location was taken as the base year for comparison. Diversity and abundance, both temporal and spatial, was recorded on 10 marked plants/replication (n=30) at hourly intervals from sunrise to sunset on 5 alternate days. *A. mellifera* visited from 50 bee hives located near the experimental site. The data from absolute values was converted into unit values for comparison. The abundance of individual species of solitary and bumble bees, lepidopteran moths and dipteran flies was negligible and for evaluation, total values for the sub groups were taken.

Weather and climate parameters: The metrological data for both the periods of observation were obtained from the Department of Agricultural Meteorology, CCS HAU, Hisar for both the years. Long term climate change parameters (since 1970) were taken from the technical bulletin of the Department of Agricultural Meteorology (Singh et al 2014).

Pesticide application trends: To evaluate the kinds and doses of pesticides applied to control prevailing pests in the sunflower ecosystem, the information for respective intervals was obtained from the Package of Practices (Anonymous 1991, 2014) of the University, Oilseed Entomologist, farmers and pesticide dealers.

RESULTS AND DISCUSSION

Diversity of floral visitors: Spring planted sunflower recorded 20 species of floral visitors in the year 1992 that dwindled to 14 in year 2015 at the same location after 23 years of continuous chemically intensive cultivation, registering a loss of 30 per cent in species diversity (Table 1 and Fig. 1). Sunflower agro-ecosystem of Hisar (Haryana) recorded significantly lower diversity of floral visitors on both these referral periods compared to other locations in India and abroad. Significantly higher species diversity of 45 floral visitors was reported by Krishna (2014) from Latur, Maharashtra (India). Significant changes in floral visitor composition were also recorded. In 1992, 85.0 per cent of the total floral visitors (17 species) were pollinators, whereas, their proportion was 57.2 per cent (8 species) in 2015. Order Hymenoptera was the major taxa (60.0%) in 1992 representing 12 species comprising of 3 honey bees and 9 solitary bees and bumble bees. It was represented solely by four species of honey bees (28.6 per cent) in 2015 signifying 66.7 per cent loss of species diversity, representing entire taxa of the solitary bees and bumble bees. Eastern honey bee, *A. cerana* not recorded in 1992, registered its revival in 2015. Out of 30 species of floral visitors recorded, only 4 species were common during both these periods that included 3 species of honey bees namely, *A. mellifera*, *A. dorsata* and *A. florea* and a dipteran *M. domestica*. Commonality of mere 4 species indicated erosion of 16 and 10 species, respectively from the 1992 and 2015 list.

During this period, sharp decline (52.9%) in pollinator species (from 17 to 8) was recorded while the non-pollinator species doubled from 3 to 6 during the same period. Such a steep decline was further accompanied by a qualitative degradation in the composition of pollinator taxa. In 1992, 85.0 per cent of the total floral visitors were pollinators compared to only 57.1 per cent in 2015, a mega reduction of 27.9 per cent. Since 1992, nine hymenoptera species comprising the entire taxa of solitary and bumble bees were lost. The only gain was the revival of Eastern honey bee, *A. cerana*. Proportion of minor pollinators also dwindled significantly from 14 to 4 (71.4% reduction).

A qualitative decline in floral visitor composition was recorded in 2015. Although the number of lepidopteran species remained same (3) at both the time intervals but their relative proportion increased to 21.4 per cent in 2015 compared to 15.0 per cent in 1992. Pestiferous taxa comprised of four species and constituted a major chunk of

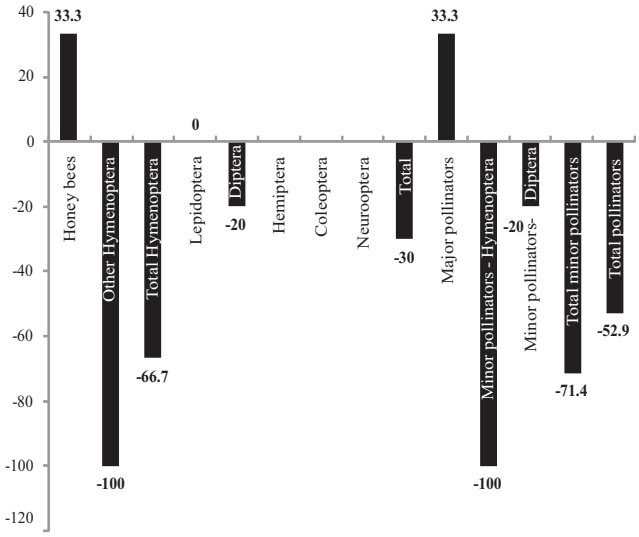

Fig. 1. Changes (%) in diversity of floral visitors in sunflower ecosystem during 2015 over 1992

Table 1. Diversity and abundance of floral visitors on sunflower bloom

Common name	Scientific name	Family	Mean population		Mean proportion (percent)	
			1992	2015	1992	2015
Hymenoptera						
European honey bee	*Apis mellifera* L.	Apidae	1.03	1.31	60.65	23.88
Eastern honey bee	*Apis cerana* F.	Apidae	0.00	0.61	0.00	11.08
Giant/rock bee	*Apis dorsata* F.	Apidae	0.39	0.02	22.94	0.38
Dwarf honey bee	*Apis florea* F.	Apidae	0.00	0.12	0.00	2.21
Total honey bees			1.42	2.06	83.59	37.55
Solitary and bumble bees						
	Pithtissm argdula F.	Anthophoridae	*	0.00	*	0.00
	Ceratina simillima Smith	Anthophoridae	*	0.00	*	0.00
	Xylocopa pubescens Spinola	Anthophoridae	*	0.00	*	0.00
	Xylocopa fenestrata F.	Anthophoridae	*	0.00	*	0.00
	Chalicodoma lanata F.	Megachilidae	*	0.00	*	0.00
	Chalicodoma cephalotes Smith	Megachilidae	*	0.00	*	0.00
	Megachile bicolor F.	Megachilidae	*	0.00	*	0.00
	Andrena ilarda Cam.	Halictidae	*	0.00	*	0.00
	Lasooglossum sp.	Halictidae	*	0.00	*	0.00
Total wild honey bees			0.39	0.75	22.94	13.67
Total other Hymenoptera			0.18	0.00	10.60	0.00
Total Hymenoptera			1.60	2.06	94.19	37.52
Lepidoptera						
African monarch	*Danais chrysippus* L.	Nymphalidae	*	0.00	*	0.00
Lemon butterfly	*Papilo demoleus* L.	Papilionidae	*	0.00	*	0.00
Paint-brush swift	*Baoris* sp.	Hesperidae	*	0.00	*	0.00
Head borer	*Helicoverpa armigera* Hubner	Noctuidae	0.00	0.84	0.00	15.3
Painted lady caterpillar	*Vanessa cardui* L.	Nymphalidae	0.00	0.76	0.00	13.8
Cabbage semilooper	*Trichoplusia ni* Hubner	Noctuidae	0.00	0.62	0.00	11.24
			0.05*	2.22	2.84*	40.34
Diptera						
Syrphid fly	*Megasyrphus* sp.	Syrphidae	*	0.00	*	0.00
Flesh fly	*Sarchophaga* sp.	Calliphoridae	*	0.00	*	0.00
Bot fly	*Gasterophilus* sp.	Gasterophilidae	*	0.00	*	0.00
House fly	*Musca domestica* L.	Muscidae	*	0.01	*	0.11
Hover/drone fly	*Eristalis tenax* L.	Syrphidae	*		*	
Blow fly	*Calliphora* sp. L.	Calliphoridae	0.00	0.5	0.00	9.13
Tachinid fly	*Spogossia bezziana* Baranov	Tachinidae	0.00	0.08	0.00	1.41
Syrphid fly	*Syrphus confrater* Wiedemann	Syrphidae	0.00	0.06	0.00	1.13
Total Diptera			0.05*	0.65	2.96*	11.77
Others						
Stink bug	*Nezara virudula* L.	Pentatomidae	0.00	0.39	0.00	7.19
Lady bird beetle	*Coccinella septumpunctata* L.	Coccinellidae	0.00	0.13	0.00	2.45
Green lacewing	*Chrysoperla carnea* Stephens	Chrysoperlidae	0.00	0.04	0.00	0.69
Total predators			0.00	0.17	0.00	3.1
Mean population/flower head			1.70	5.49		
Total species			20	14		

* Instead of individual value of the species, cumulative abundance value of the group is provided

28.6 percent. Proportion of non-pollinator species was further alleviated by the presence of two generalist predators (*C. septumpunctata* and *C. carnea*) bringing their proportion to a whopping 42.9 per cent (6 species) in 2015 compared to only 15.0 percent (3 species) in 1992.

Abundance of floral visitors: The floral visitor's diversity declined by 30 percent (14 species) in 2015 but their abundance increased by 322.2 per cent (5.49 floral visitors/capitulum) compared to 1992 base value (1.70 visitors) (Table 1). Amongst the proven pollinators of sunflower, domesticated *A. mellifera* visiting from managed bee hives was the most dominant species comprising 60.65 percent of the floral visitors in 1992 whereas its proportion declined to merely 23.88 percent in 2015. Their density on the contrary were lower in 1992 (1.03 bees/capitulum) than 2015 (1.31 bees) despite the presence of substantially higher number of bee hives (50) in the cropping area compared to merely 12 hives in 2015. Population of other two wild bees *A. florae* and *A. dorsata* (0.02) was alarmingly low. Proportion of these three honey bee species witnessed a sharp decline (from 83.59 to 37.55%) and during the same period, revival of *A. cerana* was also recorded (11.08%). Pestifeorus species comprising of 3 lepidopterans (*H. armigera, V. cardui* and *T. ni*) and a stink bug (*N. virudula*) became the most abundant taxa (47.5%) surpassing the population of pollinator species (37.6%). Their presence in such higher densities necessitate chemical intervention that may have deleterious effect on pollinators and other non-target organisms, partly explaining pollinator decline in sunflower ecosystem.

Weather conditions in 1992 and 2015: Weather conditions during both the years did not reflect any significant deviations from the long term median values for Hisar location (Table 2), indicating normal years. The only minor deviation was higher number of rainy days in March in the vegetative crop stage and June (at maturity) of 2015 that are unlikely to significantly influence diversity and abundance of floral visitors during bloom and the impact of local weather parameters on quantitative and qualitative composition of floral visitors on sunflower is unlikely to be drastic.

Impact of crop management practices on floral visitors: Cultural practices including tillage, seed rate, spacing, irrigation, fertilization and plant materials (hybrids and populations/composites) were similar during both the periods as per literature (Arya 1993, Anonymous. 1991, 2014, Rinku 2015) thus, could not have substantially influenced the diversity and abundance of pollinators. The three Lepidoptera species recorded in 1992 not being the designated pests, no insecticides were recommended or used by the farmers. However, with the emergence of various pests by 2014, many conventional insecticides have been recommended by the

Table 2. Weather conditions prevalent in years 1992 and 2015 in spring sunflower crop period

Months	Max Temp (°C)			Min Temp (°C)			Morning RH (percent)			Evening RH (percent)			Average wind speed (KM/H)			Bright sun shine hours			PAN evaporation (mm)			Rainfall (mm)		
	1992	2015	Normal*	1992	2015	Normal	1992	2015	Normal	1992	2015	Normal	1992	2015	Normal	1992	2015	Normal	1992	2015	Normal	1992	2015	Normal
February	21.1	23.5	22.8	7.0	9.6	7	90.9	89	0.1	54.1	46.0	6.8	4.9	5.0	4.6	4.6	6.2	7.4	2.7	2.1	74.7	22.9	12.2	17.2
March	27.5	25.2	28.6	10.4	11.5	11.4	92.3	84	-3.3	58.0	38.0	-1.2	5.2	4.4	5.1	5.9	6.8	8.1	4.2	2.8	138.1	3.6	47.0	13.6
April	34.5	33.7	36.1	15.5	17.0	17.2	73.2	65	5.7	35.3	26.0	12.5	4.8	5.2	6	8.7	9.3	9	7.2	5.6	241.4	8.1	16.4	11.7
May	38.6	40.5	40.2	21.4	23.4	22.8	57.5	54	0.3	27.5	24.0	-4.2	8.8	6.5	8.3	9.4	9.0	8.4	10.5	8.4	334.8	26.1	15.5	31.4
June	40.8	38.2	39.8	25.7	25.1	25.9	73.5	62	-0.8	48.5	35.0	-2.8	8.8	7.2	9.8	6.5	7.7	6.9	10.0	7.3	312.1	35.5	161.0	58.9

* Normal values are the mean of long-term values over last 45 years (since 1970)

Table 3. Status of pests and practices applied for their management during 1992 and 2015

Pest species	1992		2015		
	Pest status	Insecticides recommended (dose ha^{-1})	Pest status	Insecticides recommended (dose ha^{-1})	Insecticides applied by farmers ha^{-1}
H. armigera	-		Key	Carbaryl 50 WP 2.5 kg /Acephate 75 SP 2.0 kg /Chlorpyriphos 20 EC 2.5 L / Monocrotophos 36 SL 1.25 L / Chorpyriphos 50 EC + Cypermethrin 5EC 625 ml	Imidacloprid 17.8SL 250 ml /Actara (Thiamethoxam) 40G 250 ml /Bifenthrin 2.5EC 625 ml /Acephate 75 SP @ 2.0 kg
V. cardui	-		Minor	No recommendation but controlled by insecticides applied for *H. armigera*	Controlled by insecticides applied for *H. armigera*
Cutworms, *Agrotis ipsilon* Hufnagel, *A. flammatra*	Minor	BHC 10D 25 kg	Sporadic	Fenvalrate 0.4D 25 kg / Fenvalrate 20 EC 200 ml /Cypemethrin 25EC 125 ml /Decamethrin 2.8 EC 375 ml	Usually no insecticide applied
Hairy caterpillars, *Spilosoma obliqua*	Sporadic	BHC 10D 25 kg / Endosulfan 35EC 1250 ml / Monocrotophos 36 SL 500 ml / Dichlorvos 76 EC 500 ml / Quinalphos 25 EC 1250 ml	Sporadic	Monocrotophos 36 SL 500 ml/ Dichlorvos 76 EC 500 ml/ Quinalphos 25 EC 1250 ml	Controlled by insecticides applied for *H. armigera*
Weeds	Minor	2 hand hoeings	Minor	No recommendation	Pendimethalin 30EC 2.5 L
Alternaria blight	-		Minor	Dithane M-45 0.2 per cent	Carbendazim 50WP + Dithane M-45 1 kg
Root and stem rot	-		Minor	Seed treatment with Bavistin 50WP 2 g / Thiram 75DS 3 g/kg seed	Seed may be already treated by and at farmer's level, usually no treatment done

University (Anonymous 2014) but large gaps exist between the type and doses recommended and those actually applied by the farmers (Table 3). Chemically intensified sunflower agro-ecosystem of 2015 help further explain the massive loss of pollinator species' diversity (9 species) and abundance (from 97.16 to 49.32 per cent) from 1992 level. Climate change in Haryana over these periods (Ramnivas and Khicher 2016) may partly explain demographic changes in sunflower floral visitors as anthropogenic climate change has been documented to impact plant species directly through shift in timing of life history (IPCC 2014) that influences diversity by creating new competitive relationship among species (Yase 2005, Bartomeus et al 2010, Arora and Dhawan 2011).

CONCLUSIONS

Extremely narrow diversity of floral visitors (14 species) on sunflower indicated extremely degraded nature of the agro-ecosystem. The dominance of *A. mellifera* from managed bee hives to supplement the lost pollinators is essential and understandable but further indicates competition to the wild pollinators. Massive decline in pollinaotr's diversity and abundance in the present studies is attributed to multiple factors including changes in varietal scenario, weather factors, crop management practices, competition from introduced pollinators, use of pesticides and climate change. The loss of 9 pollinator species of bumble bees and solitory bees is ecologically grave as these wild bees complement planned bee pollination initiatives. Emergence of pests as the most dominant taxa (47.5%) indicated major demographic shift at the cost of pollinators, necessitating intensive chemical management, further damaging the fragile ecosystem and nullifying the very purpose of planned bee pollination. A thorough diagnosis of sunflower ecosystem and course correction is urgently required in chronically oilseed deficient India.

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Salinity Tolerance and Survival of Freshwater Carp, *Cyprinus carpio* Linn. in Inland Saline Water

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***Abstract*:** The present study was carried out to assess salinity tolerance and survival of freshwater carp, *Cyprinus carpio* (Linn.) in inland saline water. Fingerlings of *C. carpio* (10-12 cm) were exposed to different salinities viz., 0, 2, 4, 6, 8 and 10 g l^{-1} (ppt) for 10 days after gradual acclimatisation with salinity increase @ 1 ppt hr^{1}. Inland saline water (15 ppt) was lifted from salt affected water logged area in village Shajrana of district Fazilka (Punjab) and diluted with underground fresh water (0ppt) for preparation of different salinity treatments. Physico-chemical parameters of inland saline water and different salinity treatments were analysed with respect to pH, salinity, electric conductivity, total alkalinity, total hardness and concentration of different salts (sodium, potassium, calcium, magnesium, chloride and sulphate). No fish mortality was observed during the tolerance test up to 10 ppt salinity. The swimming movement of fish remained unaffected during first 8 days of tolerance test in all salinity levels, while fish became comparatively less active in 8 and 10 ppt treatments, after 8 days of exposure. However, no significant changes in food intake/appetite of fish were observed throughout the tolerance test. The present tolerance test reveals the possibility of rearing *C. carpio* in inland saline water.

***Keywords*:** Common carp, Salinity tolerance, Survival, Appetite

Salinization of inland areas in arid and semi arid regions along the Indus-Ganga plains of North- Western India, has affected agricultural output in the region. About 12 lakh hectare land in the non-coastal states (Punjab, Haryana, Uttar Pradesh, Bihar, Madhya Pradesh, Rajasthan and Jammu and Kashmir) of India is salt affected (Mandal et al 2010). Aquaculture has emerged as potential option for economic utilisation of such underproductive or zero earning lands. Further, aquaculture productivity depends on various abiotic as well as the biotic factors of the culture environment. Salinity of water is one of the most significant abiotic factors and its favourable range for survival and optimum growth of aquatic organisms is species-specific (Mubarik et al 2015). Although, the ideal choice to develop aquaculture in inland saline water is to culture brackish water species, but non availability of seed and climatic constraints in non-coastal northern states of India has triggered series of attempts of rearing freshwater species in these areas (Dhawan et al 2010, Ansal et al 2013, Pathak et al 2013, Kumar et al 2017). Salinity variations leads to osmoregulation stress in stenohaline freshwater species with significant effect on its physiology, which may lead to poor growth and even mortality, if salinity tolerance levels are crossed (Gholampoor et al 2011). Most of the available studies on salinity tolerance of freshwater fish have been conducted with either natural/ artificial sea water or salt solution prepared from different salts like sodium chloride (NaCl), calcium chloride ($CaCl_2$), rock salt etc. Very few studies have been conducted with inland saline water, which differs from sea water in respect to concentration of different salts. In the recent past, some attempts have been made to culture freshwater carps in inland saline areas of non-coastal states like Punjab and Haryana (Pathak et al 2013, Chandra and Joshi 2015, Dhawan et al 2016), having 1.51 and 2.32 lakh ha of salt affected areas, respectively (Mandal et al 2010). Further, salinity tolerance of fresh water carps in inland saline water has been found to be species specific (Ansal et al 2013, Islam et al 2014).

Hence, for optimising productivity of freshwater carps in inland saline water areas of the non-costal states, it is vital to study salinity tolerance of these species, so that best possible combinations of carps could be worked out for rearing under different salinity conditions. In view of above background, the present study was taken up to study salinity tolerance and stress response of one of the priced exotic major carp, *Cyprinus carpio* (Common carp) in inland saline water of district Fazilka, one of the salt affected south west districts of Punjab.

MATERIAL AND METHODS

The present study was carried out at Guru Angad Dev Veterinary and Animal Sciences University (GADVASU), Ludhiana (Punjab), India. Inland saline water (15 gl^{-1} or 15ppt) was lifted from the inland salt affected waterlogged

areas of village Shajrana in district Fazilka (Punjab) and diluted with underground fresh water for preparation of different salinity levels viz., 2, 4, 6, 8 and 10 ppt and were designated as S2, S4, S6, S8 and S10 treatments. Freshwater (0 ppt) served as control (S0). Fingerlings (10-12 cm) of *C. carpio* were conditioned for two days in a cemented pool. Conditioned fingerlings were acclimatized to different salinity levels gradually by increasing the salinity @ 1 ppt hr^{-1} and then transferred into 50L capacity glass aquaria (@ 10 $aquarium^{-1}$) holding 35L of water of different salinities in triplicate, for 10 days tolerance test. The fish were fed with pellet feed @ 0.5% of fish body weight, once a day as sustenance ration. Water in each aquarium was kept well aerated with the help of aerators. Salinity was maintained in each aquarium throughout the tolerance test by compensating evaporation loss with freshwater to keep water in the aquaria up to pre marked levels. Excreta and left over feed was removed from each aquarium every alternate day. Physico-chemical parameters of inland saline water (Table 1) and water in different salinity treatments were estimated with respect to pH, electrical conductivity (EC), total alkalinity (TA), total hardness (TH), ammonical-nitrogen (NH_3-N) and salt concentration, including calcium (Ca^{2+}), magnesium (Mg^{2+}) sodium (Na^{2+}) potassium (K^+), chloride (Cl^-) and sulphate (SO_4^{2}), as per standard methods (APHA 2005).

Survival of fish was recorded every 12 hours during the tolerance test. Swimming activity and appetite (feed intake) of fish was observed to record behavioural abnormalities in *C.carpio* under salinity stress. Swimming activity of fish was categorised as active and less active on the basis of daily visual observation, which included comparative opercular movement (ventilation rate) and horizontal/vertical movement of fish. Further, appetite or feed intake of fish in different treatments was also observed daily, on the basis of quantity of left over feed in each aquarium. Statistical analysis of the data was performed with the help of statistical package SPSS (Version. 16.0) for windows, SPSS Inc. Richmond, CA, USA.

RESULTS AND DISCUSSION

The mean water temperature varied from 25.33 to 26.66^{0}C in different treatments during the experimental period and the differences among treatments were insignificant (Table 2). Although, pH was significantly higher in S10 treatment but it was within the permissible limits (7.0-8.5) for freshwater carps, in all the salinity treatments (Boyd and Tucker 1998). The mean EC, TA, TH and concentration of various salts (Ca^{2+}, Mg^{2+}, Cl^-, Na^{2+},K^+ and SO_4^{2-}) in different treatments (S2- S10 ppt) were in accordance to the corresponding salinities (2-10 ppt). The NH_3- N (mgl^{-1}) levels recorded in all the treatments were within the permissible levels ($\leq$0.05 mgl^{-1}) for tropical fish (Boyd and Tucker 1998).

During the salinity tolerance test (10 days), no mortality of fish was observed in any of the salinity levels indicating that common carp can tolerate salinity levels up to 10 ppt. These results were in agreement with the study by Ansal et al (2013), where common carp was reported to tolerate salinity levels up to 12 ppt in inland saline water in Punjab. Salinity represents a critical environmental factor, which affects survival and growth of the fish. Stenohaline freshwater fish like carps inhabits hypotonic environments and salt concentration in their blood is reported to be equivalent to approximately 9.0 ppt (Kultz 1995). Hence, they have evolved to counter passive gain of water from and passive loss of salts to its hypotonic environments, through excretion of large volumes of urine and active absorption of salts across gills and kidney, respectively. Some of the species manages to adapt and grow in the saline environments, however, when the level of isotonic point is crossed, it forces the fish to make extensive physiological changes to compensate for the reverse osmoregulation in hypertonic environment (Mustafayev and Mekhtiev 2008, Kaltz 2015). Salinity tolerance in freshwater fish varies considerably with species (Ansal et al 2016), size (Gracia et al 1999) and genetic variations, even within the same species (Morgan and Iwama 1991).

Freshwater fishes have been reported to tolerate, survive and grow at low salinities (Chughtai and Mehmood 2012, Chandra and Joshi 2015, Ansal et al 2016, Dubey et al 2016, Kumari et al 2017). Earlier, Mangat and Hundal (2014)

Table 1. Physico-chemical parameters of inland saline water collected from salt affected water logged areas of village Shajrana, Fazilka, Punjab

Parameters	Value
Salinity (ppt)	15 ± 0.05
pH	7.28 ± 0.13
EC ($mScm^{-1}$)	19.78 ± 0.33
TA ($CaCO_3 mgl^{-1}$)	1254.7 ±6.76
TH ($CaCO_3 mgl^{-1}$)	2320.0 ±15.27
Ca Hardness ($CaCO_3 mgl^{-1}$)	1242.5 ±1.55
Ca^{2+}(mgl^{-1})	497.4 ±62.06
Mg^{2+}(mgl^{-1})	482.8 ±3.60
Cl^- (mgl^{-1})	1478.7±8.89
Na^{2+}(mgl^{-1})	1176.7 ±56.46
K^+(mgl^{-1})	85.26 ±2.24
SO_4^{2-} (mgl^{-1})	50.5 ±7.08
NH_3-N (mgl^{-1})	0.36 ±0.01

Values are mean ± SE

Table 2. Mean physico-chemical parameters of water in different salinity treatments during tolerance test

Parameters	0ppt (S0)	2ppt (S2)	4ppt (S4)	6ppt (S6)	8ppt (S8)	10ppt (S10)
Temperature (^{O}C)	25.66^{ab}	26.66^{a}	26.33^{ab}	26.00^{ab}	25.33^{b}	26.33^{ab}
pH	7.91^{b}	8.10^{b}	8.13^{b}	8.07^{b}	8.32^{ab}	8.65^{a}
EC (mScm^{-1})	5.71^{f}	25.06^{e}	35.93^{d}	95.10^{c}	113.33^{b}	151.23^{a}
TA ($CaCO_3$ mgl^{-1})	275.67^{c}	306.00^{bc}	344.00^{b}	341.33^{b}	404.00^{a}	397.00^{a}
TH ($CaCO_3$ mgl^{-1})	293.33^{e}	495.33^{d}	536.67^{d}	887.33^{c}	1235.3^{b}	1386.7^{a}
Ca-Hardness ($CaCO_3$ mgl^{-1})	124.17^{c}	140.00^{c}	231.0^{b}	290.67^{b}	290.50^{b}	441.33^{a}
Ca^{2+} (mgl^{-1})	46.37^{d}	56.06^{cd}	63.07^{cd}	92.51^{bc}	116.34^{ab}	156.68^{a}
Mg^{2+} (mgl^{-1})	74.27^{c}	86.38^{c}	139.00^{b}	255.05^{a}	229.59^{a}	262.11^{a}
Cl^{-} (mgl^{-1})	49.94^{f}	331.66^{e}	613.31^{d}	904.97^{c}	1171.6^{b}	1355.0^{a}
Na^{2+} (mgl^{-1})	46.76^{f}	150.63^{e}	273.20^{d}	502.17^{c}	830.20^{b}	930.17^{a}
K^{+} (mgl^{-1})	3.96^{c}	25.33^{bc}	32.26^{b}	34.40^{b}	43.49^{b}	122.18^{a}
SO_4^{2-} (mgl^{-1})	8.74^{c}	9.91^{c}	14.02^{b}	16.03^{b}	18.46^{a}	20.26^{a}
NH_3- N (mgl^{-1})	0.034^{a}	0.039^{a}	0.034^{a}	0.037^{a}	0.042^{a}	0.033^{a}

Values with different superscripts in a row differ significantly ($P \leq 0.05$)

reared fingerlings of *C. carpio* in salt water (prepared from commercial grade NaCl and $CaCl_2$) of different salinities (1.5, 3, 6 and 12 ppt) for 60 days and reported 100% survival up to 6 ppt salinity during different seasons (summer, autumn and winter). However, 100 and 20% mortality of fish occurred in 12 ppt within 1st week of rearing during summer/autumn and winters, respectively. Further, Mubarik et al (2015) exposed fingerlings of *C. carpio* in different salinities (0, 6, 8 and 10 ppt, prepared from rock salt) for 96 hours and recorded LC_{50} of 7.80, 8.31 and 6.88 ppt at 30, 32.5 and 35^{0}C, respectively. Lawson et al (2011) cultured another freshwater fish, *Carassius auratus* (comet goldfish) in different salinity treatments (2-10 ppt, prepared through dilution of seawater) for 7 days and recorded 100 per cent survival of the fish in 1 to 5 ppt salinities, while 90 and 94 per cent mortality was recorded in 8 and 10 ppt salinities, respectively. As compared to carps, freshwater stenohaline catfishes and murrels are better osmoregulators under salinity stress. Recently, Kumar et al (2017) reported pangas catfish, *Pangasianodon hypophthalmus* to tolerate salinity levels up to 15 ppt (inland saline water) for 60 days and observed 100% mortality at 20 ppt. Further, spotted snakehead (*Channa punctata*), has also been found to survive well up to 10 ppt salinity (Dubey et al 2016). Differences among various studies is attributed to experimental differences in respect to species, size of fish, genetic variations, temperature, salinity, saline water composition and duration of the salinity stress.

As compared to control (0 ppt), no significant changes in fish movement, including opercular movement (ventilation rate) and swimming activity (horizontal and vertical movements) were observed in any of the salinity treatments during first 8 days of the tolerance test. However, after 8 days of salinity exposure, fish became less active (slower ventilation rate and less vertical movement) in 8 and 10 ppt salinity treatments. Further, no significant changes in food intake/appetite of fish were observed throughout the tolerance test. Earlier, Wang et al (1997) reported reduced food consumption in *C. carpio* fingerlings reared in 6.5 ppt salinity (prepared from sea water) for 92 days. Later, Mangat and Hundal (2014), reported normal appetite in fingerlings of *C. carpio* up to 6 ppt salinity (NaCl and $CaCl_2$ solution) up to 14, 28 and 42 days of 60 days rearing in different salinities (1.5, 3, 6 and 12 ppt) during summer (28-37^{0}C), autumn (22.5-30.5^{0}C) and winter (14.5-19.5^{0}C) seasons, respectively. In 12 ppt fish survived only during winters with significant decline in feed intake, indicating significant role of temperature in salinity tolerance of freshwater fish.

Normal appetitive behaviour under salinity stress is an indication that fish body metabolism can still be maintained or regulated at a particular salinity, while low appetite is an indication of nearing a metabolic breakdown. In the present study at temperature range 25.33 to 26.66^{0}C, normal appetite of fish in all the salinity treatments reveals that *C. carpio* could tolerate salinity levels up to 10 ppt, without any major signs of distress during the short term exposure of 10 days.

CONCLUSION

The present short term salinity tolerance test suggests that *C. carpio* can tolerate salinity levels up to 10 ppt and hence, holds ample scope of rearing in inland saline water. However, behavioural changes in respect to swimming activity of fish, observed at salinity levels $\geq$6 ppt, further suggests that long term rearing of fish at different salinity levels need to be investigated to attain optimised growth of *C. carpio* in inland saline water under regional climatic conditions, with special reference to temperature.

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Development and Testing of Rotary Mechanism with Manual Feeding for Husking Coconut

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Abstract: Coconut husking is one of the major problems in this sector. A rotary mechanism having a single blade mounted on a segmented ring attached to a main shaft through three spokes was developed. A movable platform for supporting the coconut and feeding it to the rotating blade was also developed. The blade was rotated at a speed of 30 rev/min. The blade pierced the husk on one side of the coconut and ripped open a sector of the husk. Using the twin hand-levers, the movable platform, together with the coconut, were then moved backward. By repeating the operations, the entire husk was removed. The mean husking durations for green and dry coconuts were respectively 24.5 and 26.1 s and maximum durations for husking were respectively 51 and 50 s and the minimum 7 and 12 s, respectively. The number of pieces into which the whole husk of a coconut was split was 4-6 for the green coconuts and 4-7 for the dry ones. During the experiments, none of the green coconuts got mechanically .

Keywords: Coconut husking, Rotary mechanism, Tools, Dehusker, Movable platform

Coconut palm *(Cocosnu cifera*) is the most significant of all cultivable palms and Kerala is the major producer of coconut with a share of 33.51 per cent in India. Coconut husking is one of the major problems in this sector and is more of a problem, especially for women as it involves great drudgery. A skilled person husks about 3000 coconuts in a day in spite of the great drudgery involved in it. No efficient mechanical device for husking coconuts on a large-scale is known to be in existence despite its great need. Some small tools are available for husking. Even the traditional crowbar is based on principle of the wedge and lever. Some other tools which make use of these principles are coconut husking machine and coconut husk removing tool (Aneesh et al 2009). Central Plantation Crop Research Institute, Kasaragod, has developed and improved a manually operated dehusker. The husking tool developed in the Kerala Agricultural University is simple in construction and is widely used. All the tools are either fully hand-operated, foot-operated or a combination of both. Muhammad (2002, 2005) developed a rotary coconut dehusker for large-scale application in which the coconuts were completely husked and the nuts emerge out at the outlet while in few cases whole coconuts got punctured and softened husk emerged out. They require secondary operations to remove the husk. This was one of the major drawbacks. The dehusker was bulky and costly and not of convenience for small-scale applications. In case of large scale, it was time consuming and required high skill (Abi and Jippu 2014). The present study is undertaken to develop a rotary mechanism for husking coconut and evolve a mechanism to manually feed the coconut to the husking mechanism.

MATERIAL AND METHODS

To achieve the objectives, an experimental set-up was designed which consisted of mainly a rotary mechanism for husking and a hand-lever-assisted mechanism for feeding of coconut one at a time. The rotary mechanism developed for husking was mounted on a machine lathe for the sake of regulation of speed, and convenience of feeding and testing. Figure 1 shows the major parts of the rotary husking mechanism are (1) main shaft, (2) segmented ring, (3) blade. Similarly, the hand-lever-assisted feeding mechanism, also mounted on the same machine lathe, comprised the following main parts (1) main platform, (2) auxiliary platform, (3) movable platform, (4) hand-lever.A machine lathe was used for mounting the experimental husking and feeding mechanisms. This facilitated as the test bed. Its relevant specifications are given below in Table 1.

The rotary mechanism for husking was provided by lathe machine with the support of a main shaft. One end of this shaft was held with the lathe chuck. The other end of this shaft was mounted on the dead centre fixed on the tail stock. This arrangement facilitated rotation of the husking mechanism at the designated speed of the lathe. However, in

Table 1. Details of machine lathe

Name	Specifications
Brand	New Bharat
Model/Type	HGN/4
Horsepower	3 hp
Speed (rpm)	30, 75, 110, 160, 240, 400, 575, 1235
Swing diameter over carriage (mm)	220
Length between centres(mm)	2370

order to match with the speed of manual feeding, the head stock spindle rotated the husking mechanism at its lowest speed of 30 rpm. The higher available speed of 75 rpm was quite detrimental as it caused severe damage to the nuts. For the same reason, the other available higher speeds of the lathe were also not considered in this study. Since the lathe was being used as the test bed, speeds other than that of the lathe could also not be used in this study.

Main shaft: A mild steel (M.S.) shaft of length 600 mm and diameter 25 mm was selected. As stated above, it was rotated with the lathe chuck at 30 rpm. This shaft carried a segmented ring frame and the blade.

Segmented ring: A 229^0-segment of a ring of outer diameter 120 mm was fabricated from a mild steel (M.S.) rod of diameter 12 mm and firmly fixed to the main shaft through three spokes placed 90^0 apart. One pair of diametrically opposite spokes was made of M.S. flat of 45 x 5 mm. The other spoke was made with M.S. flat, 25 x 5 mm in size. Two bases made from M.S. flat, 45 x 5 mm, and carrying two holes of diameter 12 mm, which provided the base for fixing the blade, were welded radial to the shaft.

Blade: A blade of length 100 mm was made from M.S. flat of size 100 x 35 x 5 mm. One end of it was sharpened like a pointed spear. It was provided with a curvature of radius 145 mm lengthwise. Two M.S. square rods of size 100 x 12 mm were welded perpendicular to the blade. These were welded parallel to each other lengthwise but 12 mm apart. This arrangement provided a slot for varying the radial distance of the blade from the shaft and the segmented ring. This provided the facility for varying the depth of penetration of the blade into the husk.

Main platform: This is a platform so designed to accommodate on the carriage of the lathe an auxiliary platform and a pair of hand-levers. It was made from pieces of M.S. angle. The fore - end of it rested on the rear end of the V-bed way to the cross-slide. It was then firmly secured to the carriage through a pair of screws. A circular rod, together with a small sleeve and its set screw, was fixed on top and across this platform and positioned at its centre. This sleeve served as the pivots for the twin hand-levers. By fixing the sleeve at different locations on the rod, it was possible to relocate the pivot position according to the size ranges of coconuts.

Auxiliary platform: This is a platform mounted directly on the main platform. It is so designed as to facilitate the varying of (i) height, (ii) angle of inclination, and (iii) closeness of this platform to the main shaft. This is made possible by providing slots on the supporting pedestals and the sides of this platform. This platform carried at its centre, but across and at its top, a circular rod together with two sleeves and its set screws to facilitate sliding of the movable frame towards or away from the shaft when respectively feeding coconut to the blade or withdrawing it whenever required, but generally after the separation of each sector of the husk.

Movable platform: The removal of husk from the coconut, sector by sector, was with a rotating blade upon feeding the coconut to the said blade. But, after the removal of a sector of the husk or due to the reasons like jamming of husk, improper husking the coconut was to be drawn away from its earlier position to manually reorient the coconut and feed again. This was required also on termination of the husking of a coconut. This to and fro motion was made possible with the movable platform made to slide on the auxiliary platform. This platform rested on the auxiliary platform. The said rod positioned on top of the auxiliary platform passed through the movable platform and restrained the latter's to and fro sliding to a fixed trajectory. The two sleeves fixed at selected positions on the said rod decided the terminal position of the movable platform when sliding to and fro. Its movement was effected basically with the twin hand-levers. Two limiting rods positioned in front of the movable platform with a clearance of 30 mm over the blade width limited the forward movement of the coconut with respect to the movable platform. These limit rods were provided an inverted 'U' shape to facilitate the husk removal.

Twin hand-lever: A pair of hand-levers which could be operated together manually was provided to press the coconut against the rotating blade. The twin hand-levers provided the mechanical advantage required to feed the coconut to the rotating blade. The bottom ends of these two levers were pivoted to the sleeve on the rod of the main platform. The levers oriented upwards, passed through the auxiliary platform and the movable platform. The rod and sleeve arrangement on the main platform assisted in relocating the hinges of these levers at different locations. These levers were made from M.S. rods of 12 mm diameter and 400 mm long.

The sample consisted of 30 coconuts; green coconuts 15 in number and dry coconuts constituted the rest. Experiments were carried out separately for the green and

dry coconuts. Major dimensions of the coconuts were also measured and recorded. Observations recorded in respect of each coconut were husking duration, number of husk-bits, mean time for separating each husk-bit, damage, frequency of occurrence of certain number of husk-bits; viz. from 3 to 8.

RESULTS AND DISCUSSION

Husking rate: The mean time required for completely husking a coconut is 24.5 s and the mean time for separating one bit is 5.2 s. These are by all means too long. In comparison, large-scale husking of coconuts using a crowbar carried out by skilled labourers required a mean duration of only 8 s. Similarly, the mean duration required by a man for husking coconuts using the KAU coconut husking tool named Keramithra is 12 s. The problem observed in the case of the system developed under the study is slipping of the blade from the loosened husk-bit even before total detachment of that bit from the coconut. This required feeding of the same husk-bit to the blade a second time or even more times and hence resulted in more time requirement. The factors responsible for this problem have already been identified and the same are being incorporated under the suggestions for future work.

In one case, the green coconut got husked in even 7 s. Therefore, the system developed in this study has the potential to do the husking in such a short time, which is even comparable to the manual methods mentioned above. The maximum time required for the complete husking of green coconut was 51 s. This is too long a duration and unjustifiable too. This was mostly due to the stickiness of the husk and also the reasons cited above. The mean husking time for a dry coconut was 26.10 s and the mean time for separating one bit is 5.30s. In respect of the dry coconuts, the minimum and maximum durations taken for complete husking were 12 and 50 s respectively. It requires further improvement of the assembly and durations have to be reduced by modifying the system.

Husking effectiveness: The minimum number of bits into which the husk has to be split for complete husking is three (Table 2). Hence, this is considered the most effective husking. None of the green coconuts got completely husked by splitting into three bits. This was observed to be due to the small sweeping angle of the blade and use of a large sweeping angle damaged the nut. The minimum number of bits required in the present study was four. In respect of green coconuts, 46.7 per cent of them could be husked by splitting the husk into four bits. This was due to traversing of the blade through only small segments of the husk. The sweeping through wider segments became detrimental as the blade, in the process, more often impinged upon the coconut shell and damaged it. Therefore, in the present study, splitting of the husk into four bits was considered the best option next to three bits, for the husking effectiveness. The 53.3 per cent of the green coconuts had to have their husk split into bits in excess of four. This too is due to the reasons cited in the section just preceding this. In addition, when coconut is fed a second time, sometimes the husk gets split along another plane and results in smaller bits. The fact that 46.7 per cent of the green coconuts could be completely husked by splitting into just four bits is quite encouraging. Further modification of the mechanism is likely to improve the husking effectiveness. In respect of dry coconuts too, none got completely husked by splitting into three bits (Table 3). As with the green coconuts, these too required splitting into a minimum of four

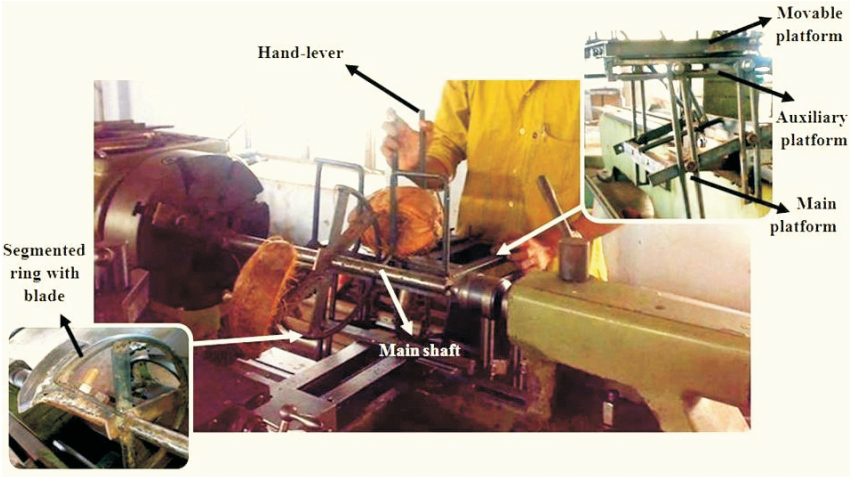

Fig. 1. Laboratory experiment set-up of developed mechanism, which is mounted on lathe machine

bits (53.3%). Those required splitting into pieces in excess of four were 46.7 per cent. Therefore, whether the coconuts are green or dry, husking effectiveness was nearly similar for both. However, the percentage of coconuts husked by splitting into three bits using this mechanism has to be enhanced considerably and made 100 per cent or closer to it. It appears that this can be achieved by modifying the blade assembly. Concerted efforts are required along these lines.

Mechanical damage: Mechanical damage is indicated by either crack(s) on the shell extending into the meat or severe rupture or puncturing of the shell to expose a portion of the meat. None of the green coconuts were damaged during husking. However, in husking dry coconuts, two of the fifteen coconuts were punctured by the blade. An examination of the damaged nuts showed that one of the nuts was already a rotten nut and hence did not have the strength to withstand the compressive stress induced by the blade through even its spongy husk. This was, therefore, considered a matter of no concern. In any case, even if undamaged, that nut would not have been normally traded. Rupturing of the other nut was due to carelessness of the operator. The timely withdrawal of the coconut, instead of re-feeding it when encountered with a light seizing of a husk-bit by the blade, possibly no damage would have been caused to nut. The damage was often due to inaction of the operator in timely withdrawing the nut. After the removal of a bit of the husk, the nut remains exposed and

Table 2. Husking duration, number of husk-bits, and mean time for removing

One husk-bit of green coconuts					One husk-bit of dry coconuts				
Size		Husking time (sec)	Husk-bit (No.)	Mean time for removing one husk-bit (sec)	Size		Husking time (sec)	Husk-bit (No.)	Mean time for removing one husk-bit (sec)
Length (mm)	Diameter (mm)				Length (mm)	Diameter (mm)			
187	137	35	4	8.8	225	150	26	4	6.5
197	156	51*	6	8.5	200	145	20	4	5.0
196	140	25	5	5.0	210	155	41	5	8.2
200	162	23	5	4.6	215	140	19	6	3.2
200	155	11	5	2.2	220	145	36	6	6.0
185	145	28	6	4.7	200	150	19	5	3.8
205	115	28	5	5.6	180	135	16	4	4.0
190	130	14	4	3.5	205	130	13	4	3.3
190	145	25	5	5.0	200	160	33	5	6.6
185	135	11	4	2.8	170	127	12**	4	3.0
200	140	12	4	3.0	235	145	46	6	7.7
210	145	40	4	10.0	205	150	21	4	5.3
175	140	43	5	8.6	205	145	15	4	3.8
170	140	15	4	3.8	205	145	25	4	6.3
165	110	7**	4	1.8	235	150	50*	7	7.1
190	140	24.5	4.7	5.2	207	145	26.1	4.8	5.3

*Maximum husking time, ** minimum husking time

Table 3. Number of husk-bits detached and its frequency of occurrence

Green coconuts				Dry coconuts		
Sl. No.	Husk-bit (No.)	Frequency of occurrence		Husk-bit (No.)	Frequency of occurrence	
		No.	%		No.	%
1	3	0	0.0	3	0	0.0
2	4	7	46.7	4	8	53.3
3	5	6	40.0	5	3	20.0
4	6	2	13.3	6	3	20.0
5	7	0	0.0	7	1	6.7
6	8	0	0.0	8	0	0.0
Total	33	15	100.0	33	15	100.0

feeding of that part again to the blade caused the blade to impinge upon the exposed nut and puncture it. So, by exercising caution, it is possible to eliminate or minimize the extent of damage caused in this manner. However, it is also essential to incorporate a fool-proof method in the husking mechanism to prevent the operator from feeding the exposed shell a second time to the blade.

CONCLUSION

A rotary mechanism having a single blade mounted on a segmented ring attached to a main shaft through three spokes along movable platform for supporting the coconut and feeding it to the rotating blade was developed. The movable platform rested on an auxiliary platform for regulating its motion. Both the mechanisms were mounted on a machine lathe which formed the test bed and tested with 30 coconuts. The mean husking durations for 15 each green and dry coconuts were respectively 24.5 and 26.1 s. The number of pieces into which the whole husk of a coconut was split came to 4-6 for the green coconuts and 4-7 for the dry ones. None of the green coconuts got mechanically damaged. Therefore, the results indicated that the husking and feeding mechanisms developed under the study have the potential to be incorporated in a powered husking machine with manual feeding of the coconuts.

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Impact of Drip Irrigation Scheduling and Water Use Efficiency on Tomato *(Lycopersicon esculentum)* In Western Uttar Pradesh, India

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Abstract: The present study entitled Impact of drip irrigation scheduling and water use efficiency on tomato *(Lycopersicon Esculentum)* was carried out at Department of Agricultural Sciences and Engineering, IFTM University, Moradabad in 2016-17. The effect different irrigation schedules *viz*. one hour in one-day interval , two hours in two-day interval , three hours in three-day interval and four hours in four-day interval was observed to assess the drip irrigation scheduling on growth and fruit quality of tomato, and determine the benefit-cost (B-C) ratio. The three hours in three-day interval was significantly superior on the basis of plant height, fruit weight, yield and water use efficiency.

Keywords: Drip irrigation method, Treatments, Irrigation scheduling

Water is a most limiting factor and main source of crop production in irrigation sector. Efficient management of available water resources is very essential to meet the increasing competition of water between agricultural and non-agricultural sectors both. Hence, proper utilization of water is prime requirement for ensuring the food security of the country. India has largest irrigation network but still now irrigation efficiency is estimated less than 60 per cent due to improper utilization of available water resources (Imamsaheb et al 2011). Therefore, judicious use of the available water resources through modern drip irrigation method becomes essential to enhance the water use efficiency and yield to get maximum crop production per unit of water application (Dunage et al 2009).

In India, most of the rainfall occurred during the monsoon season (June to October). Therefore, adoption of modern irrigation method such as pressurized irrigation method (drip and sprinkler) will be very helpful for fulfilling the food demands of growing population. Now days, drip irrigation method can be used effectively for crop production under water stress situation. Hence, it is needed that the available water resources should be utilized effectively through adoption of advanced irrigation technology. Many scientists previously done lots of work related to application of drip irrigation method to show its impact on various parameters for higher crop production of tomato crop by efficient and accurate application of water. In recent time, various studies on drip irrigation parameters based modern irrigation (Alaoui et al 2014, Reddy et al 2014, Khalel et al 2015), and they suggested that drip irrigation method has provided high yield and maximum water use efficiency, and studied the relationship between irrigation amount, yield and quality. Keeping above reviews study was conducted on tomato crop with objectives to assess the effect of drip irrigation scheduling on growth, productivity and economics under different treatments.

MATERIAL AND METHODS

The experiment was carried out at IFTM University, Moradabad, India. The research farm is geographically situated at 28°21´ to 28°16´ N latitude and 78°4´ to 79° E longitudes at an altitude of 193.23 m above the mean sea level during 2016-2017 (October to March). Land topography of the Moradabad district in almost flat. The experimental setup consists of screen filter, main, sub mains, laterals, drippers and other accessories required for drip irrigation and fitted in the experimental plot of 0.006 ha land. The main and sub main pipelines used for drip irrigation were made of PVC pipes of 50 mm and 25 mm diameter respectively. Linear Low Density Poly Ethylene (LLDPE) pipes of 12 mm diameter were used for laterals in the treatment. Drippers having flow rate, 1.46 l/h were fitted on the laterals at a spacing of 70 cm and the end plug fixed on each lateral of the plot to control the flow rate of all taps. Switching was allowed through small valves placed in the beginning of each treatment. Layout of drip irrigation system is shown in Figure 1. The experiment

has been analyzed using the completely randomized block design with three replications and plot size of 60 m^2. The experiment was conducted on "Hybrid NS-524" variety of tomato (*Lycopersicon esculentum Mill.)* and details of crop specification are given Table 1. There were five treatments 1, 2, 3 and 4 h/day at 1, 2, 3 and 4-days interval along with control. The treatments comprised of five drip irrigation levels at 50, 65, 80, 95 and 100 per cent with three replications. Harvesting was started 55-60 days after sowing. As practiced by commercial growers, curved or deformed fruits were removed from the plant during pruning operations and marketable immature fruits were harvested in 8–10 days and then weighed. The numbers of fruits were also counted. Field water use efficiency of each treatment was conducted.

Soil samples were collected from the different location of the field by physical properties was judged as sandy soil. The detailed physical properties of the soils are given in Table 2. The meteorological data (average temp, humidity, sunshine duration, wind velocity, rainfall, and evaporation) of year 2016 were collected from the website (www.accuweather.com) which is used for the analysis shown in (Fig. 2). The average maximum temperature exceeds 32ºC during hot summer in May and June and minimum temperature occasionally falls below 1ºC during winter in December and January were 16°C. The mean annual rainfall is 904 mm. The total rainfall during the crop season was 285 mm out of which the maximum was received in the month of July. The relative humidity ranged from 87 to 80% in July and December, respectively during the crop growing period.

Water use efficiency

$$WUE = \frac{\text{Yield of crop (kg ha}^{-1})}{\text{Total water used (cm)}} \quad (1)$$

$$WUE = \frac{Y}{WR} \quad (2)$$

where, Y is the weight of marketable produce of the crop (kg ha^{-1}), and WR is the Depth of water used (cm).

The expenditure incurred from field preparation to harvest was worked out total income based on the prevailed minimum market rate of Rs. 5.0 Kg^{-1}. The cost of drip system for one hectare was worked out based on current market rates. The life of the drip system was assumed to be 5 years. The cost : benefit ratio was worked out.

RESULTS AND DISCUSSION

Yield and related parameters: The yield of tomato varid significantly among different treatments and was significantly high in T_3 (644.8 q ha^{-1}) when irrigation is done for three-hour time interval in three days during whole crop period than in

Table 1. Experimental details of drip irrigation system

Description	Unit	Details
Crop	-	Tomato
Net irrigation area	ha	0.006
Row to row Spacing (spacing between laterals)	m	0.70
Plant to plant spacing (spacing between emitters)	m	0.50
Row direction	-	East-West
No. of emitters in each row	-	16
Total no. of plants	-	192
Type of irrigation system	-	Drip irrigation system
Emitter type	-	online Emitter
Emitter per Plant	-	1 Emitter
Emitter discharge	l/h	1.46
No. of lateral per row	-	1 Lateral
Water source	-	Tube well
Water source depth	m	30

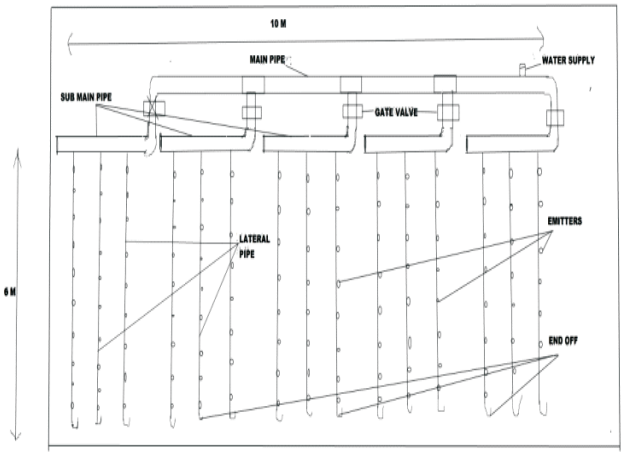

Fig. 1. Layout of designed drip irrigation system

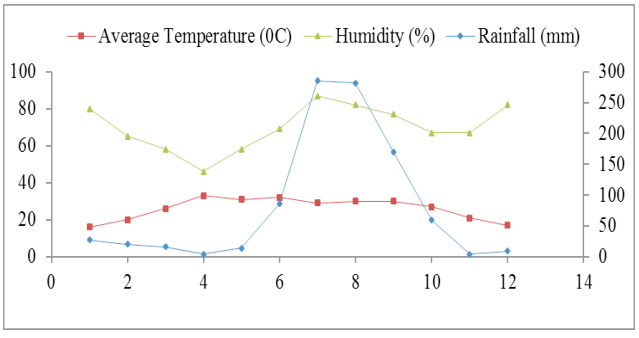

Fig. 2. Climatic data of Moradabad district

other treatments and was followed by T_2 and T_1 (Table 3). The plant height also varied significantly among different treatments, being maximum in T_3 followed by T_4, T_2 and T_1. The drip irrigation gave significantly higher yield over surface irrigation. There applied drip irrigation scheduling significantly affected the fruit weight. But there was no significant difference in T_4, T_3 and T_1 and were significantly better than T_2 and T_5. The fruit weight/plant differed significantly among different treatments being significantly high in T_3 (7.49 kg) and minimum in T5 (4.82 kg). The high values of uniformity coefficients indicated that drip irrigation system gave excellent performance in terms of uniformly supply of water throughout the lateral lines in the experiment. The water use efficiency (WUE) 3.15 q^{-1}ha-cm was maximum T_3 followed by T_2 and T_1. The various yield parameters in the treatment T_3 ensured that more water is saved and will support the sustainable crop production. The irrigation water is supplied through drippers by a network of drip irrigation system in which three-hour water is supplied to the root zone of the crop in every three days during whole crop grown period for achieving higher productivity.

Economics: The life of drip system varies from 5 to 10 years based on quality and maintenance of drip system. Hence a normal life of drip system of 6 years was considered for computation. Though the initial capital investment was high due to drip irrigation system, the cumulative benefit would be greater, considering the longer life of the system. The fixed cost towards installation of drip system was worked out to be

Table 2. Soil physical characteristics of experiment

Soil depth (cm)	Size distribution of soil			Texture class	Saturated point (%)	F.C. (%)	W.P. (%)	EC (dSm^{-1})
	Coarse sand	Fine sand	Clay silt					
0-20	46.72	48.76	2.85	Sandy	23.0	10.5	5.6	0.35
20-40	57.73	39.55	3.60	Sandy	20.0	14.4	6.5	0.30
40-60	39.62	9.42	3.50	Sandy	22.0	12.8	4.2	0.50

Table 3. Effect of irrigation scheduling on yield parameters of tomato

Treatments	Avg. plant height (cm)	Avg. fruit weight (gm)	Fruit weight (kg $plant^{-1}$)	Yield (q ha^{-1})	Water use efficiency (q/ha-cm)
T_1 -One hour in one-day interval	16.26	5.33	5.38	548.09	2.75
T_2 -Two hours in two-day interval	16.54	4.83	5.96	580.50	2.92
T_3 -Three hours in three-day interval	17.61	5.17	7.49	630.08	3.15
T_4 -Four hours in four-day interval	17.29	5.33	4.96	526.83	2.64
T_5 -Control	16.13	4.67	4.82	512.25	2.48
CD (p=0.05)	0.07	0.17	1.36	7.43	

Table 4. Economics of scheduling ofdrip irrigation

Description	T1	T2	T3	T4	T5
Fixed cost (Rs)	80000	80000	80000	80000	80000
Life (Years)	5	5	5	5	5
Annual cost (Rs)	16000	16000	16000	16000	16000
Interest @ 8% (Rs)	6400	6400	6400	6400	6400
Repair and maintenance (Rs)	512	512	512	512	512
Total Cost (Rs) (A)	20812	20812	20812	20812	20812
Cost of cultivation, (Rs ha^{-1}) (B)	60050	60105	62450	60650	59650
Seasonal total cost (Rs) (C = A+B)	80862	80917	83262	81462	80462
Maximum production (q ha^{-1})	561.41	597.33	644.75	538.83	508.25
Selling price (Rs q^{-1})	500	500	500	500	500
Income from produce (Rs) (D)	280780	298665	332375	269415	254125
Total Net seasonal benefit (Rs) E = (D – C)	199918	217748	249113	187953	173663
Benefit – Cost ratio F = (D/C)	3.47	3.69	3.99	3.30	3.15

Rs. 80000 ha^{-1} taking into the prevailing rate. For maximum highest seasonal net income was recorded (Rs. 249113) in T_3. The lowest net seasonal income was for the treatment with alternate day drip irrigation in (Rs. 173663) in T_5. The maximum benefit – cost ratio (BCR) was in T_3 (3.99) .

CONCLUSION

The drip irrigation system should be used as a benchmark for planning and management of available water resource by reducing water losses in large extent. For dry land area drip irrigation method will be very helpful for obtaining more food production by efficient use of water to fulfill the demand of growing population. Indian agriculture today faces the challenge of meeting demand for safe and quality food.

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Quantification of the Pine Processionary Caterpillar *Thaumetopoea pityocampa* (Notodontidae) Haemocytes

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Abstract **:** *Thaumetopoea pityocampa* is an important pine pest in the Mediterranean basin and central Europe and larvae are called pine processionary caterpillars. To understand the resistance mehcanism for management, a study on the immune system and reactions of the larva in different stage was conduced. The aim of our work is to identify the hemocytes of the caterpillar during the larval stages L_2, L_3 and L_4, as well as the quantification of the different cells during each stage. After extraction of the hemolymph by centrifugation, the cells were placed in culture medium and then incubated. Microscopic observation has shown that prohemocytes population appear early in hemolymph, they differentiate into plasmatocytes and granulocytes during the advanced stages. The quantification process has shown that granulocytes are the most abundant cell population in the hemolymph of the insect larvae. To investigate the role of hemocytes in immune responses, cells of *T. pityocampa* were co-incubated with bacteria, entomopathogenic nematodes and synthetic beads. Both humoral and cellular encapsulation processes was observed early in larval stages, all hemocytes seem to be involved in the formation of nodules and capsules against bacteria and microbeads. The entomopathogenic nematodes(*Steinernema feltiae*) were not recognized and encapsulated, but their presence can strongly damages host hemocytes.

Keywords: *Thaumetopoea pityocampa,* Prohemocytes, Plasmatocytes, Granulocytes, Entomopathogenic, *Steinernema feltiae,* Encapsulation

Insect's immunity consists of both, humoral and cellular reactions (Blandin and Levashina 2004). Humoral reactions include the production of antibacterial, peptides and enzymatic complex of coagulation or melanization in hemolumph (Meister 2000, Lowenberger 2001). In contrast, cellular reactions consist of hemocytes-mediated immune responses, representing by the activity of circulating cells in different forms such as phagocytosis, nodule formation and encapsulation (Strand and Pech 1995). The phagocytosis is a process aimed to eliminate foreign particles, usually single cells, as bacteria or protozoa, the process follows few steps, recognition, attachement, pseudopodia formation, engulfing and finally intracellular lysis of foreign body (Bayne 1990). If not-self invasions carried out by larger organisms, encapsulation takes place, thus the formation of a multilayered capsule of hemocytes that surround the foreign organism occasionally. Host hemocytes can also form nodules to entrap groups of bacteria; this reaction is conventionally named nodulation (Herbiniere 2006).

Thaumetopoea pityocampa, also known as pine processionary, is a an important pine forest pest in Europe and in all Mediterranean area (Martin 2007). The Lepidopteran insect are also characterized by the presence of different populations of hemocytes freely circulating in the hemolymph, they mediate all the cellular reactions, comprising phagocytosis of small microorganisms and formation of nodules and capsule around foreign particles. Considering the remarkable development of experimental methods to collect cells and to classify the different hemocytes types (Gardiner and Strand 1999) and in order to understand the immune system of *T. pityocampas*, an accurate identification of hemocytes sub-populations is an essential starting point to study of immune processes. The main goal of présent experimentation is the quantification of haemocytes of the pine processionary caterpillar .

MATERIAL AND METHODS

Hemolymph collection: The healthy and grown up 10 to 15 larvae of each instar of processionary moth were selected, and washed with ethanol extensively (several times) to sterilize them. Small larvae injured, by cutting the lower and the tail regions were placed inside a double Eppendorf system built with two different Eppendorf tubes (the big outside and the small inside). The small larvae were perforated at the bottom to allow the hemolymph to flow out in the bigger tube, but retaining the fragments of the larvae body. Centrifugations were done at 1200 rpm in a refrigerated eppendorf centrifuge model (5804R centrifuge,

for 10 minutes at 10°C). In late instar larvae, the haemolymph was extracted by puncturing the ventral side of the larvae. After centrifugation, hemocytes from 2nd, 3rd and 4th instars, were been collected and separated from the humoral fraction of the haemolymph. Hemocytes were cultured in Grace Medium, and observed by phase contrast light microscopy.

Culture medium conditions: After centrifugation, humoral fraction was collected, pelletted cells were washed with grace insect medium. The procedure was repeated twice to avoid contamination of tissues or cells debris. Hemocytes were suspended in a complete culture medium (10% fetal calf serum, 1% antimycotic antibiotic, 1% glutamine in Grace Medium). The cells were cultured in 96 Micro well plates (cluster cell cultures, flat bottom, Iwaki) and kept at 25-26 °C in a moistened incubator (Cellstar) without CO_2. The most common populations of insects hemocytes are pro-hemocytes, granulocytes, plasmatocytes, spherulocytes, and oenocytoids (Lavine and Strand 2002).

Immune reactions and light microscopy: An inverted phase contrast light microscopy (Olympus IX51, Olympus INC) was used to investigate the cell-mediated responses and immunity reactions of *T. pityocmapa* hemocytes against not-self reactions. Different responses were monitored such as, the ability to encapsulate insects parasite, the bacteria nodulation focusing on the ability of the cells to recognize and encapsulate abiotic material (synthetic microbeads).

Total haemocytes count: The total haemocytes count (THC) is a measure of the concentration and abundance of haemocytes inside the hemolymph (cells/ml). For observation, light microscopy was used to identify and quantify the cells in hemolymph. An estimation of cells number from 2nd, 3rd and 4th larval instar, was calculated. The granulocytes cell number (THCg) can be estimated from the THC (cells/ml). Aliquots of hemocytes were used to determinate the granulocytes percentage in larval hemolymph. The observation was realised on counting grids by adding a small quantity of hemolymph to hemacytometer slider (Malassez). The cell formular in the 2nd instar was less abundante, this is why the dilluation of the hemocytes was not necessary. The number of cells from the three instars was estimated in about 100 cubics. The percentage of hemocytes types were calculated, the (THC) was estimated for all cells and for each hemocyte. A comparison between the (THC) of different stages was assessed.

Statistical analysis: The XLStat was used to investigate the differences between the cells quantification in each stage in order to identify the rhythm of their development along the larval stage. A comparison of the (THC) of different cells in each *Thaumetopoea pityocampa* instar was also estimated.

RESULTS AND DISCUSSION

Identification and quantification of cells : The total count of haemocytes in haemolymph of L_2 stage larvae was $75x10^2$ cells/ml, the number increased constantly to ($250x10^3$cells/ml) in L_3 and ($63x10^4$ cells/ml) in L_4. *Granulatocytes* were the most abundant hemocytes observed in *T. pityocampa* hemolymph, from the 2nd to the 4th instar (Fig. 1). In the last instar, the most abundant cells are granulocytes, their HTC was about $208x10^3$ t cells / ml of hemolymph, followed by plasmatocytes (113x 10cells / ml). The cells that were less abundance in the last development larval stage of *T. pityocampa* are prohemtocytes with an HTC estimated at 130 x10 cells / ml of hemolumph. The most important cells identified are pro-hemocytes, plasmatocytes and granulocytes. Oenocytoids were observed in 2nd instar, (Fig.1), their form was large, round and often contain granules. Their number was instable in the first instars. They were observed only in the first instars, they completely disappeared in the last instars. Cells evolution is estimated along the larval stage and compared between each one. The variance analyse of each value showed that all cells quantification increase significantly along the larval stage development.

Pro-hemocytes were the smallest cells in hemolymph of *T. pityocampa*. They are described as precursor of all the immuno-competent cells in the early developmental stages (Fig. 3) and develop to plasmatocytes orgranulocytes in late instars and their shape varied between oval or elongated profiles. Prohemocytes represent the 10 percent of all the Hemocytes of the first larval instar of *T. pityocampa,* and their number decrease in the last instars (Fig.1)

Granulocytes were round or irregularly shaped cells. The nucleus was also generally central position in the cytoplasm (Fig. 2). The plasma emitted pseudopodia and filopodia in order to encapsulate foreign bodies. Granulocytes were the main cells in haemolymph of *T. pityocampa*, they represented 80-90 perent of total hemocytes population. *Plasmatocytes* were large spindle-shaped cells, which when adherent in culture plates, showed cell protrusions, such as pseudopodia and filopodia (Fig. 2).

Encapsulation and phagocytosis: Plasmatocytes, followed by pro-hemocytes were the most common cells in this insect. Pro-hemocytes were identified by their small size (Fig. 2a). When in culture medium, most of cell population identified participated with granulocytes in encapsulation processes (Fig. 3b), forming a multilayered capsule around foreign bodies. Plasmatocytes were also involved in phagocytosis of bacteria. In *T. Pityocampa*, plasmatocytes represented 10-20 percent of total hemocytes. In the assays with bacterial cells, used as not-self target, granulocytes

contacted rapidly the microorganisms then they participated to phagocytosis processus in the medium (Fig. 3) To investigate in deep the cellular encapsulation responses, parasites and free living nematodes were added at various times to cells medium culture of *T. pityocampa*. The ability of hemocytes populations to recognize and encapsulate worms was investigated. A considerable number of granulocytes reach the body- surface of free-living nematodes and bacteria, plasmatocytes also participate and completed the capsule. The profile of pro- hemocytes and plasmatocytes significantly changed after immune challenges (Fig. 4c). Humoral melanisation is a humoral immune response, which, in this case, cooperates with immuno-competent cells, by

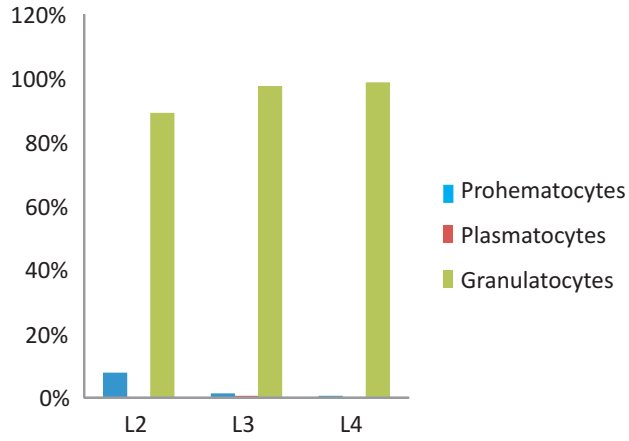

Fig. 1. Proportional counts ratio of *Plasmatocyte*, *Granulocyte* and *Prohemocyte*and comparaison of each instar level of each hemocyte in hemolymph of *Thaumetopoea pityocampa* larvae ($P < 0.05$)

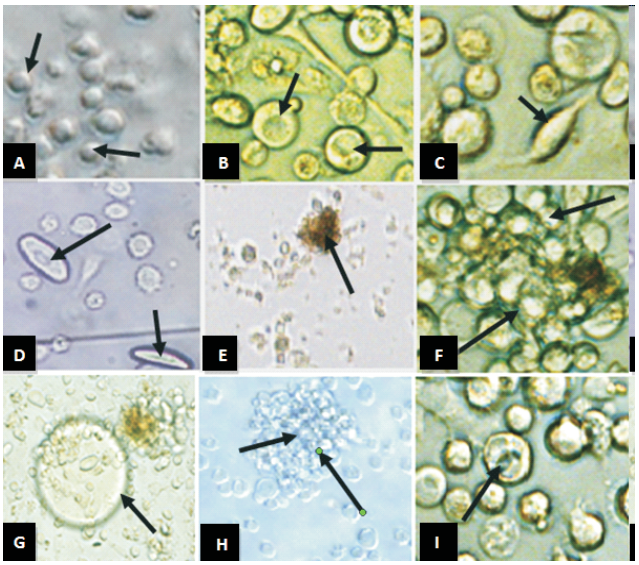

Fig. 2. Morphology of different types of Hemocytes, extracted from *T. pityocampa* larvae
Insect immune competent cells were purified from larvae hemolymph. (A) *Prohematocytes* (B) *Granulocytes,* (C) Plasmatocyte, (D) *Oenocytoids,* (E) cellular debris, (F) *cellular aggregation* (G: 40x10). (G) Microbeaud, (H) Nodulation forms (G: 10x10) (I) Cell in mitotic features (G: 40x10)

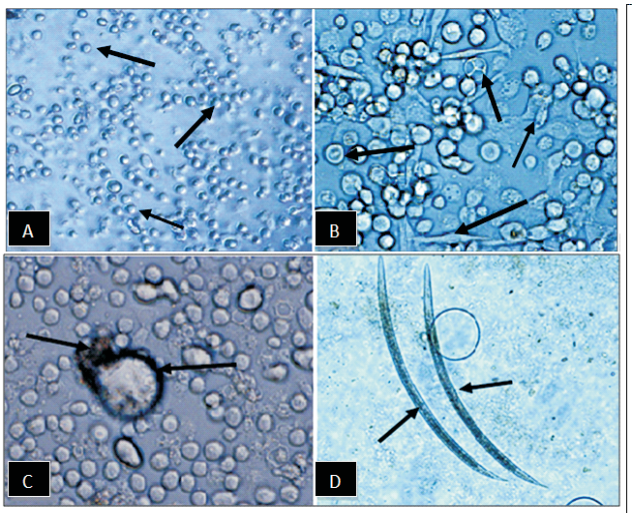

Fig. 3. Phase-contrast microscopy showing different immunity reactions of cells of *Thaumetopoea pityocampa*. (A)Hemocytes morphology before being adding to the culture medium (G: 10x10); (B) Cells morphology in grace medium(C) Nodulation: Hemocytes forming nodules and encapsulation around Bacteria Incubation (G: 40x10) (D) Parasites "*Steinernima carpocapsae"* added to the medium, (G: 10x10)

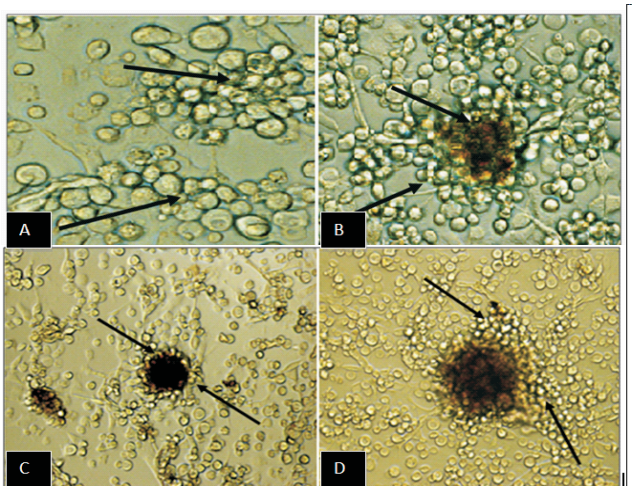

Fig. 4. Phase-contrast microscopy showing different encapsulation reactions of in hemolymphe of *Thaumetopoea pityocampa*. (A) Cells aggregation (B) start of debris aggregation forming a simple humoral encapsulation (G:40x10). (C) humoral encapsulation (D)Different cells aggregate around humoral fraction forming cellular encapsulation. (G: 10x10)

melanin synthesis and deposition, in the isolation of foreign elements from the host body. The microscopic observation of cells challenged with either bacteria or latex microbeads demonstrated that mainly plasmatocytes were able to phagocytise both beads and bacteria (Fig. 3). Aggregation of latex particles were not observed at any experimental time. Humoral encapsulation was the usually observed before cellular encapsulation, the debris in the hemolymph surround the nematode and the bacteria, cellular encapsulation appears later.

Hemocytes are the main elements of cell-mediated immunity in insects (Rolffand and Siva-Jothy 2003). They are able to phagocyte and eliminate both biotic particles, such as bacteria, and abiotic targets, such as synthetic beads (Lavine and Strand 2002). In literature, hemolymph in many insects' species such coleopteran andlepidopteran are characterised by the presence of several cell types: prohemocytes, plasmatocytes, granulocytes, oenocytoids and adipo-hemocytes (Strand and Pech 1995). Many of these cells types have been also identified in *T. pityocampa* haemolymph. The most represented cells identified are prohemocytes plasmatocytes and granulocytes. The observation from 2nd to the 4th larval instar showed that pro-hemocytes and granulocytes were the most abundant cells. The plasmatocytes were present in the later stages. In the 2nd instar, pro-haemocytes were recognized by their small round shape; they represented only 8 percent of the cells observed, their number increased remarkably in the 3rd instar and was unchanged in the last larval instar; which confirms that the pro-haemocytes differentiated to plasmatocytes and granulatocytes after 2 days of incubation. The regular microscopic observation demonstrated that most of pro-haemocytes of the larvae, developed and transformed into plasmatocytes and granulatocytes .

In *T. pityocampa*, plasmatocytes were recognizable by their elongated shape and pseudopodia, and the cell number increasesduring the larval stages. These cells represent the main cells in hematopoietic tissues in larvae and adults of *Carabus lefebvre* (*Coleoptera, Carabidae)* (Giglio et al 2008). In *T. pityocampa*, plasmatocytes were recognizable by their elongated shape and pseudopodia and the cell number increases during the larval stages. These cells represent the main cells in hematopoietic tissues in larvae and adults of *Carabus lefebvre* (Giglio et al 2008). In our study, granulocytes were detected by their round shape . In the 4th instar, the haemocytes retained their ability to react and encapsulated either synthetic microbeads or free-living nematodes. At this stage the larva reached immunity maturity. Humoral and cellular encapsulation, phagocytosis and nodules, have been observed in the presence of target. In other insects, different types of haemocytes could also perform phagocytosis, such as pro-haemocytes of *B. mori larvae* (Ling et al 2005) and oenocytoids of the grub *Cetonischema aeruginosa* (Giulianini et al 2003). The granulocytes of *P. Xylostella* are the only cells responsible of encapsulation.

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CONCLUSION

Knowledge of the cell population in *T. pityocampa* is important for analyzing immune processes and to develop strategies for fight this pest that causes both damage to plants and for human health. The most cells identified participated in all immunity reactions.

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Morphological Study of Genetic Variability of Banana Genotypes for Crop Improvement

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Abstract: Sixteen germplasms of *Musa* sp. (sub group- AAB) were assessed with an aim to describe the phenotypic diversity and the heterogeneity within morphological parameters, yield and quality attributes. A close relation between selection and uses of cultivars with the morphological, physico-chemical quality attributes and rheological specificities were highlighted for these germplasms and a significant variation among them was highlighted through Cluster analysis, Proximity Matrix for characterization of variables to identify major characters responsible for grouping of homogeneous cultivars. Dudhsagar genotype was the best for its high economic yield, high TSS and good sugar: acid ratio. The Sobri and Manohar had short crop duration, but late bunch harvesting at Manohar while, early at Amritpani, Martaman and Sobri. Nendran, Rasthali, Sobri, Martaman, Dudhsagar, Amritpani, Krishna Vazai, Malbhog and Kalibhog were found good in respect of plant height, petiole margin colour, empty nodes on peduncle, finger weight, pulp weight, pulp:peel ratio, TSS, total sugars, reducing sugar, non-reducing sugar and sugar-acid ratio. On the other hand Alapan, Champa, Poovan, Kanai Bansi and Chang Monua dominated by position of sucker, petiole length, bract base shape, colour of mid-rib dorsal surface, number of hands per bunch, number of fingers per bunch, fruit shape, fruit apex, flesh texture and acidity. Thus, it may be concluded that Dudhsagar may be taken as promising banana genotype for future breeding programme in respect of high economic yield, good TSS and sugar: acid ratio.

Keywords: Banana, Morphological study, Chemical characteristics, Cluster analysis

Banana (Family- *Musaceae*) is cultivated extensively in humid agro-ecological zones of the tropics while, many banana cultivars cannot be grown in non-tropical regions. As a result, most banana breeding takes place in tropical regions. Some banana types can be cultivated in subtropical regions also between 20° and 30° North and South of the equator. The main goals of banana improvement programmes in these sub-tropical regions are the development of genotypes that are better adapted to cooler climates and that have resistance to pests and diseases with higher fruit yield and quality. The main climatic factors affecting banana production in the subtropics are the greater diurnal temperature fluctuations, lower night temperatures, higher rainfall and stronger winds in the summer. Furthermore, winter leaf sunburn, under peel discolouration and growth cessations are typical physiological problems associated with banana production in the subtropics. Local intra-varietal selection remains an important means of overcoming these environmental constraints. In these areas, Cavendish bananas (AAB genome) are among the most commercial groups. Commercial banana cultivars within the Cavendish sub-group are triploid, seedless, sterile and parthenocarpic and therefore, banana production has been improved in many countries by either importing promising cultivars or selections from other geographical areas or *via* identification of superior and stable local selections. Bananas were classified under 6 genomic groups (AA, AAA, AAB, AB, ABB, and ABBB) by Simmonds and Shepherds (1955) and Stover and Simmonds (1987), however, later Singh and Uma (1996) classified as 6 separate groups namely- AA/AAA, AAB, AB, ABB, ABBB and BB/BBB. However, banana breeding programmes have been rather slow in developing new clones with these characteristics due to the complex and polyploidy nature of the *Musa* genome that results in sterility barriers and other obstacles to conventional breeding approaches and only a few cultivars have been developed during the past few decades. As a result, the selection of improved 'dessert' banana types adapted to specific environmental conditions continues to be important in the local improvement of this crop. Selection of off-types under marginal growing conditions has resulted in clones with improved bunch weight and fruit quality. An alternative to conventional breeding methods involving mutation and recombinant DNA technologies has been suggested but, these techniques facilitate small genetic changes as opposed to large-scale recombination (Khayat et al 1998).

Consequently, local selection efforts remain an important potential for banana improvement. Until recently, morphology-based methods had been used for the characterization of *Musa* germplasm, however, influenced by the environment. Some differences in growth and physiology between germplasms have been noticed during developmental stages. In the present experiment morphological, yield and quality evaluation was done for AAB sub-group taking 16 genotypes collected from different parts of the country.

MATERIAL AND METHODS

Sixteen germplasms of banana were collected from various sources (Table 1) and ordered multistage characters were coded as series of discrete states. For example if there were three flower colours: red, pink and white, individuals could be scored 1 for white, 2 for pink and 3 for red. Five variant plants were selected from each plot and the mean value was worked out for taking observations from the plants grown at Bidhan Chandra Krishi Viswavidyalaya, Mohanpur, Nadia, West Bengal, India. The observations were taken as per Characterization Descriptor (IPGRI/INIBAP-CIRAD 1996). Statistical analysis regarding mean, range of variation, standard error of mean and critical difference for each quantitative character in terms of vegetative growth, yield and quality parameters was worked out by the standard method. The different characters then further statistically analysed to study the genetic variability concerning with genotypic and phenotypic variance (Burton and Devane 1953) and correlation coefficient of difficult pairs of characters (Jiboure et al 1958, Dewey and Lu 1959). Difference between genotypes for different characters were tested for significance using analysis of variance on the basis of the following method complied by Singh and Chowdhury (1985) with model- $Y_{ij} = \mu + t_i + \beta j + e_{ij}$; (i = 1, 2, …….. v; j = 1, 2, ……...r). [Where, Y_{ij} = Yeild corresponding to i^{th} treatment in j^{th} replication; μ = General effect; t_i = Additional effect due to i^{th} treatment; $\Sigma t_i = 0$; β_i = Additional effect due to j^{th} replication, $\Sigma\beta_j = 0$; e_{ij} = Random error component assumed to independently, normally distributed with mean zero and constant variance.]

Genetic diversity was determined by D^2 Statistics as derived by Mahalanobis (1936) to measure the genetic divergence existing within a population. The generalized distance between any two genotypes was measured by the method proposed by Majumder and Rao (1958).

Contribution of individual character toward divergence: The different component characters contribute variedly to the D^2 values between each pair of genotypes. The relative

Table 1. Source of various germplasms collection

Germplasm	Place of collection
West Bengal	
Sobri	Horticulture Research Farm, Kalyani, B.C.K.V. (introduced from Bangladesh Agricultural Research Institute)
Krishna Vazai	Horticultu al Research and Developmental Farm, Chunchura
Malbhog	Pundibari,Uttar Banga Krishi Viswa Vidyalaya
Champa	Horticulture Research Farm, Kalyani, B.C.K.V. (introduced from Bangladesh Agricultural Research Institute)
Kalibhog	Horticulture Research Farm, Kalyani, B.C.K.V.
Martaman	Horticulture Research Farm, Kalyani, B.C.K.V.
Kanai Bashi	Horticulture Research Farm, Chakdaha, B.C.K.V.
Chang Manua	Pundibari, Uttar Banga Krishi Viswa Vidyalaya
Baman Deshi	Pundibari, Uttar Banga Krishi Viswa Vidyalaya
Bihar	
Alapan	Rajendra Agriculture University, Pusa
Kerala	
Nendran	Banana Research Station, Kannara
Tamil Nadu	
Rasthali	Tamil Nadu Agricultural University
Poovan	Tamil Nadu Agricultural University
Andhra Pradesh	
Amritpani	Agriculture Research Station, Kovvur
Assam	
Dudhsagar	Assam Agriculture University, Jorhat
Manohar	Assam Agriculture University, Jorhat

contribution of each character was ranked with scores 1 to 9 (as in the present study number of characters taken were 9) according to this magnitude of contribution to the D^2 values. Rank 1 represented the highest contributor and Rank 9 the lowest one. The number of times each character ranked first was counted and thus the percentage contribution towards total divergence was calculated.

Grouping of genotypes into clusters: Cluster analysis was performed to identify a smaller number of groups such that the elements (genotypes) residing in a particular group were more similar to each other than to elements (genotypes) belonging to other groups. Grouping in the present study was done by Tocher method (Rao 1952). The process was continued till all the genotypes were included into one or other cluster (Singh and Chowdhury 1985). Multivariate analysis of characterization, parameters were made following nearest neighborhood method of hierarchical cluster analysis of the Square Euclidean distance and Co-phenetic Correlation distance matrix on the basis of characters measured which is either cardinal or ordinal in nature (Dillon and Goldstein 1984).

RESULTS AND DISCUSSION

Crop duration, days of shooting and days for harvesting: The crop duration (Table 2) was maximum in Nendran (492 days) with maximum days from planting to shooting (387.2 days). The number of days required for harvesting from shooting was maximum in Kanai Bansi (119.6 days). Further, genotype Sobri registered the minimum crop duration followed by Malbhog and lowest days for shooting was also in Sobri followed by Malbhog and Manohar and lowest days for harvesting in Amritpani. Aravindakshan et al (2002) observed that Myndoll had longest crop cycle and Manjery Nendran had average crop cycle. Sarkar et al (2004) documented early harvesting in Malbhog (335 days) close to Poovan and Krishna Vazai.

Variation in vegetative growth characters: The plant height was maximum in Chang Monua (3.22 m), whereas, minimum in Krishna Vazai. Similar to the present investigation Lenka et al (2004) and Sarkar et al (2005) also observed maximum pseudostem girth in this group. The total number of functional leaves at shooting time in different cultivars was not differed among themselves very widely. However, it was maximum in Amritpani, Manohar and lowest in Nendran.

Relationship among morpho-physical characters of fruits: The cultivar Champa, registered the highest number of hands bunch^{-1} (15.78) while, lowest (7.38) was in Kanai Bansi (Table 3) and that was at par with Nendran. However, Kanthali was reported to produce maximum hands in each bunch by Sarkar et al (2004). Similarly, number of fingers bunch^{-1} was highest in Champa (213.68) and lowest in Nendran (52.74). Other cultivars, Poovan, Alapan, Dudhsagar and Manohar also produced good number of fingers. The number of fingers did not correlate with bunch weight and finger weight. Dudhsagar recorded the maximum

Table 2. Variation in plant morphological characters in different germplasms of banana

Germplasm	Crop duration (days)	Days to shooting	Days to bunch harvest	Plant height (m)	Pseudostem girth (cm)	Functional leaves at the time of shooting
Sobri	348.4	258.6	89.8	2.66	64.95	12.6
Nendran	492.0	387.2	104.8	2.60	60.73	10.4
Krishna Vazai	411.4	306.2	105.2	2.50	63.03	13.6
Malbhog	364.4	268.6	95.8	2.97	69.84	12.6
Rasthali	388.0	289.4	98.6	2.85	67.65	13.0
Amritpani	390.4	303.4	87.0	2.59	59.31	14.4
Champa	422.8	322.6	100.2	2.57	58.39	11.8
Kalibhog	422.2	311.8	110.4	3.01	69.56	12.4
Dudhsagar	384.8	287.6	97.2	2.82	69.44	12.2
Martaman	383.0	294.6	88.4	2.79	70.66	13.6
Kanai Bansi	426.4	306.8	119.6	2.81	67.86	11.8
Chang Monua	450.0	341.2	108.8	3.22	82.82	11.4
Poovan	379.0	262.6	116.4	2.76	69.48	13.6
Manohar	434.0	316.2	117.8	2.60	70.51	14.4
Bamandeshi	445.8	354.4	91.4	3.03	62.90	13.6
Alapan	442.4	333.6	108.8	3.00	80.15	11.6
CD (p=0.05)	9.64	8.09	5.46	0.10	2.76	1.76

bunch weight (23.1 Kg) having good finger weight of 158.14 g, however, the minimum finger weight in Champa reduced the bunch weight of banana, though finger weight was maximum in Krishna Vazai (163.38 g) and minimum bunch weight was in Nendran. In Krishna Vazai, the bunch weight was maximum, pulp weight was maximum in Dudhsagar (131.8 g) while, Champa registered the minimum pulp weight. However, De Langhe (2000) concluded that Pakte showed much higher weight of single finger (186.0 g) followed by Robusta and Bor Jahaji as compared to the present study. Dudhsagar had the maximum pulp : peel ratio (5.52) while the lowest ratio was in cultivar Alapan, although, peel weight was minimum in Champa and highest in Krishna Vazai. Sarkar et al (2005) observed that cultivar Malbhog had the highest pulp: peel ratio.

Variations in fruit bio-chemical characters: The highest total soluble solids was noted in Dudhsagar (26.44 ^{0}B) and lowest in Poovan, which was statistically at par with Champa and Alapan (Table 4). Similarly, Sarkar et al (2005) also reported the highest TSS in Dudhsagar and Malbhog. The reducing sugar content in different cultivars was in the order of Sobri > Rasthali > Martaman > Dudhsagar > Krishnavatai > Manohar > Malbhog > Kanai Bansi. Non-reducing sugar content was maximum (15.94%) in Martaman followed by Rasthali, Nendran and the lowest in Champa. The total sugars content (21.08%) was higher in Rasthali and Martaman whereas, minimum in Champa but, at par with Poovan and Alapan. Ascorbic acid content in different cultivars varied between 2.28 and 15.08 mg 100g^{-1} of edible pulp. Ascorbic acid content was highest in Amritpani followed by Chang Monua and the lowest in Dudhsagar. Champa recorded the highest total titratable acidity (0.486%) affecting the taste of Champa followed by Alapan and lowest in Sobri, Rasthali and Martaman. But, maximum sugar: acid ratio was calculated in Martaman and Rasthali (89.02) followed by Sobri whereas, lowest ratio in Champa.

Leaf nutrient: Leaf nutrient content in terms of nitrogen, phosphorus and potassium was estimated maximum in Champa while, Dudhsagar showed the maximum sulphur content followed by Amritpani and Champa (Table 5). In most cases, Krishna Vazai reported the minimum content of nitrogen, phosphorus, potassium and sulphur. High leaf nitrogen content might influence to increase acidity in Champa as discussed by Maji et al (2015), which showed increase in acidity with increase in nitrogen content.

Proximity matrix: Proximity matrix study revealed the maximum similarity between Amritpani and Martaman followed by Manohar and Dudhsagar (Table 6). The highest value 234.24 denoted the lowest similarity between Krishna Vazai and Poovan followed by the next maximum dissimilarity between Krishna Vazai and Champa. The next pairs of germplasms illustrated similarity between Nendran and Malbhog, Dudh Sagar and Monohar and Champa and Martaman, Krishnavazi and Kalibhog, Malbhog and Rasthali, Kalibhog and Kanai Bansi which showed the similarity group as based on proximity matrix.

Table 3. Variation in bunch and fruit physical characters in different cultivars of banana

Germplasm	No. of hands per bunch	No. of fingers per bunch	Bunch weight (Kg)	Finger weight (g)	Pulp weight (g)	Peel weight (g)	Pulp: peel ratio
Sobri	9.28	114.60	15.02	116.72	87.54	27.08	3.24
Nendran	7.64	52.74	8.50	141.40	113.86	25.40	4.52
Krishna Vazai	8.26	86.48	15.74	163.38	125.52	35.98	3.49
Malbhog	9.20	106.44	14.54	123.02	97.08	23.64	4.13
Rasthali	9.04	118.18	13.64	109.90	86.32	21.62	4.01
Amritpani	8.14	107.16	12.80	110.40	86.58	22.02	3.93
Champa	15.78	213.68	13.30	57.50	41.0	14.84	2.76
Kalibhog	9.20	95.38	13.56	130.16	102.62	25.52	4.04
Dudhsagar	10.42	132.88	23.10	158.14	131.80	23.92	5.52
Martaman	8.76	120.24	15.46	117.60	94.64	21.04	4.51
Kanai Bansi	7.38	92.56	10.04	101.32	73.88	25.22	2.93
Chang Monua	11.12	77.20	15.84	156.26	120.58	35.86	3.38
Poovan	14.08	183.72	16.38	74.92	55.66	19.26	2.92
Manohar	10.32	128.22	18.46	133.68	105.94	25.60	4.16
Bamandeshi	8.96	123.14	14.70	111.84	87.20	22.34	3.91
Alapan	12.08	181.22	15.18	74.10	53.02	21.08	2.52
CD (p=0.05)	0.56	3.13	1.13	8.21	6.70	2.49	0.30

Table 4. Variation in biochemical characters of fruits in different cultivars of banana

Germplasm	TSS (^{0}Brix)	Reducing sugar (%)	Non-reducing sugar (%)	Ascorbic acid (mg/100g of edible pulp)	Total sugars (%)	Titratable acidity (%)	Sugar: Acid ratio
Sobri	22.68	5.52	13.60	8.50	19.41	0.237	81.99
Nendran	24.08	2.82	15.30	6.25	18.28	0.269	67.98
Krishna Vazai	26.0	4.38	12.29	11.15	16.91	0.256	66.04
Malbhog	21.76	3.99	13.84	6.08	17.69	0.282	62.80
Rasthali	23.96	5.25	15.55	4.23	21.08	0.237	89.02
Amritpani	22.56	3.64	14.43	15.08	18.28	0.320	57.10
Champa	20.24	2.51	9.72	5.86	12.25	0.486	25.18
Kalibhog	22.16	3.68	11.72	11.63	15.58	0.269	57.93
Dudhsagar	26.44	4.38	14.80	2.28	19.41	0.275	70.55
Martaman	23.48	4.88	15.94	7.43	21.08	0.237	89.02
Kanai Bansi	23.88	3.95	12.74	5.63	16.91	0.416	40.64
Chang Monua	24.68	3.35	11.10	14.08	14.63	0.288	50.79
Poovan	20.08	2.39	10.81	5.32	13.32	0.397	33.58
Manohar	22.88	4.12	14.50	8.23	18.79	0.320	58.73
Bamandeshi	23.44	2.	11.98	11.48	14.99	0.320	46.86
Alapan	20.8	2.53	10.43	8.55	13.10	0.467	28.04
CD (p=0.05)	1.80	2.93	0.74	2.12	2.86	NS	11.67

Table 5. Variation in leaf nutrient composition in different banana genotypes

Cultivars	Nitrogen (%)	Phosphorus (%)	Potassium (%)	Sulphur (%)
Sobri	1.137	0.321	1.316	0.417
Nendran	0.931	0.291	0.973	0.380
Krishna Vazai	0.897	0.289	0.960	0.263
Malbhog	1.038	0.305	1.217	0.337
Rasthali	1.004	0.336	1.103	0.396
Amritpani	0.989	0.398	1.307	0.539
Champa	1.486	0.567	1.367	0.529
Kalibhog	0.970	0.401	1.212	0.391
Dudhsagar	1.267	0.349	1.130	0.613
Martaman	1.161	0.376	1.319	0.409
Kanai Bansi	0.973	0.357	1.219	0.410
Chang Monua	1.349	0.229	1.097	0.345
Poovan	1.401	0.428	1.243	0.445
Manohar	1.195	0.333	1.183	0.329
Bamandeshi	0.967	0.319	1.129	0.385
Alapan	1.376	0.412	0.997	0.445
CD (p=0.05)	0.261	0.063	0.281	0.155

Single and complete linkage clustering: Single and complete linkage clustering formed five to ten clusters of collected genotypes according to Squared Euclidean distance matrix and Co-phenetic correlation distance matrix under various allowed disytance co-efficient (0.246, 18.18 and -0.025). There were several cluster groups which content same genotypes in different allowed distance co-efficient and under different method of clustering as presented in Figure 1 to 4.

Cluster-I consisted Malbhog, Kalibhog, Bamandeshi, Sobri, Martaman, Amritpani (Fig. 1) and Dudhsagar and

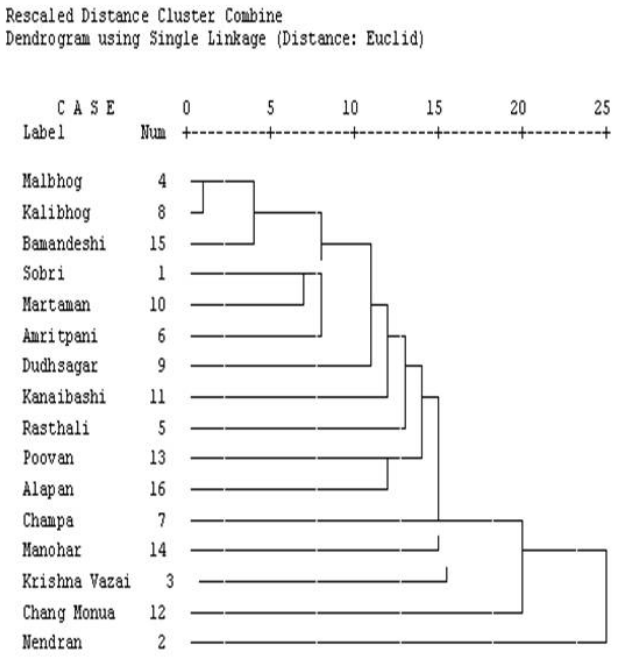

Fig. 1. Dendogram using single linkage hierarchical clustering of Squared Euclidean distance matrix for characterization variables of banana cultivars

Table 6. Proximity matrix by squared euclidean distance between banana genotypes

Cultivars	Nendran	Krishna Vazai	Malbhog	Rasthali	Amritpani	Champa	Kalibhog	Dudh sagar	Martaman	Kanai Bansi	Chang Monua	Poovan	Manohar	Baman deshi	Alapan
Nendran	206.88														
Krishna Vazai	106.06	122.64													
Malbhog	31.73	184.66	82.51												
Rasthali	52.64	164.35	84.37	46.32											
Amritpani	67.90	150.26	76.57	49.70	41.01										
Champa	169.66	222.17	193.02	164.34	143.63	138.22									
Kalibhog	100.58	113.68	46.10	75.45	64.02	50.66	157.17								
Dudhsagar	80.74	169.79	60.83	63.99	71.31	77.18	173.51	74.74							
Martaman	52.06	163.87	79.22	44.96	17.69*	40.62	148.96	64.95	61.39						
Kanai Bansi	109.43	128.81	88.57	87.18	74.19	57.39	137.38	46.41	109.20	83.09					
Chang Monua	151.67	76.26	59.54	125.85	117.06	102.25	194.15	57.73	106.95	114.24	88.66				
Poovan	108.28	234.24**	163.51	107.76	103.92	107.66	86.19	134.54	133.78	111.42	117.30	185.25			
Manohar	113.29	121.27	63.51	91.15	72.44	67.82	139.05	37.10	71.92	73.09	62.71	68.51	125.37		
Baman deshi	141.65	102.43	98.66	121.89	97.76	78.11	124.73	65.26	115.12	97.67	69.29	79.43	140.91	58.39	
Alapan	159.74	179.48	161.13	147.58	124.09	115.85	50.99	122.13	152.68	129.40	102.68	151.80	96.44	103.68	86.04

Fig. 2. Dendogram using single linkage hierarchical clustering of Co-phenetic Correlation distance matrix for characterization variables of banana cultivars

Fig. 3. Dendogram using complete linkage clustering of Squared Euclidean distance matrix for characterization variables of banana cultivars

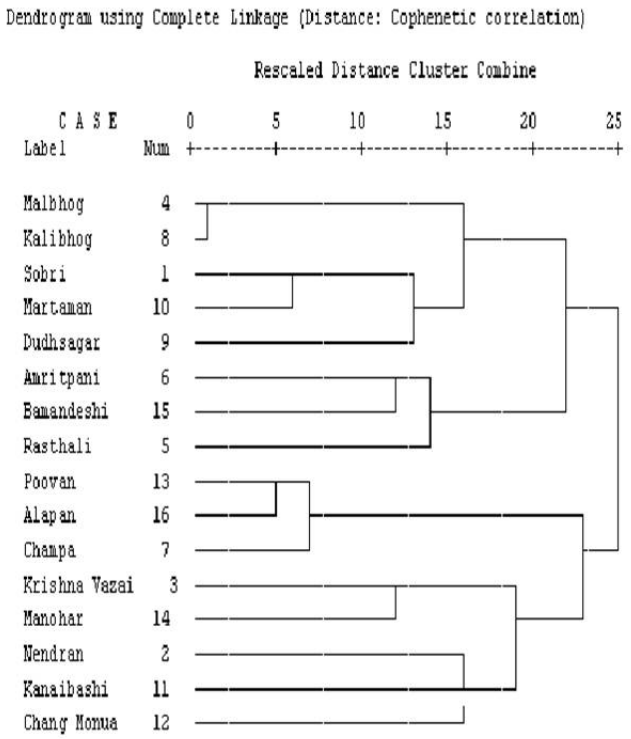

Fig. 4. Dendogram using complete linkage clustering of Cophenetic correlation distance matrix for characterization variables of banana cultivars

Table 7. Combined cluster members of selected germplasms of banana

Cluster members
Malbhog, Kalibhog, Bamandeshi, Sobri, Martaman, Amritpani, Krishna Vazai, Manohar, Dudhsagar
Dudhsagar, Rasthali, Poovan, Alapan, Champa, Amritpani, Bamandeshi
Poovan, Alapan, Champa, Rasthali
Kanai Bansi, Krishna Vazai, Nendran
Alapan, Bamandeshi, Chang Monua, Manohar, Kanai Bansi
Champa, Krishna Vazai, Nendran
Manohar
Krishna Vazai, Nendran
Chang Monua, Kanai Bansi
Nendran, Chang Monua

Rasthali came in the cluster-II in case of single linkage clustering using squared Euclidean distance matrix. On the other hand, clusters III to X consisting single germplasm namely Poovan, Kanai Bansi, Alapan, Champa, Manohar, Krishna Vazai, Chang Monua and Nendran, respectively. Again Malbhog, Kalibhog, Sobri, Martaman and Amritpani were similar in characters by considering co-phenetic correlation distance matrix and came under cluster- I (Fig. 2). Poovan, Alapan and Champa were nearest to each other to make cluster-II. Rasthali, Dudhsagar, Bamandeshi, Krishna Vazai, Manohar, Nendran, Kanai Bansi and Chang Monua remained in distant to each other to form separate single cluster from III to X, respectively.

In case of complete clustering (squared Euclidean distance matrix) Cluster-I consist of Malbhog, Kalibhog, Sobri, Martaman and Amritpani whereas Krishna Vazai, Bamandeshi and Manohar came in cluster II. Dudhsagar and Rasthali were in cluster III. Similarly, Poovan, Alapan and Champa formed cluster IV due to similarity in characterization variables. Kanai Bansi, Chang Monua and Nendran were distant to each other and formed separate cluster *i.e.* V, VI and VII (Fig. 3, 4). Co-phenetic correlation distance matrix formed 5 homogeneous clusters.

From the study of all clustering (Table 7) it was observed that Malbhog, Kalibhog, Martaman, Amritpani, Sobri were very close and came under Cluster I of linkage study. Dudhsagar and Rasthali were close to each other along with Poovan, Alapan. Champa also made a relation with Krishna Vazai and Nendran. Manohar as well as Chang Monua created a long distance cluster among the selected genotypes of banana.

CONCLUSION

Among the collected germplasms, Sobri was the short duration banana germplasm while, early harvesting can be done in Amritpani. The germplasms like Sobri, Martaman, Malbhog, Bamandeshi also showed similar type of plant characters. From the cluster analysis it can be inferred that Sobri, Martaman, Amritpani, Malbhog, Kalibhog, Bamandeshi came under the similar cluster. The same status was in Dudhsagar and Rasthali especially for plant characters. Chang Monua had maximum plan height and Krishna Vazai was the dwarf. Dudhsagar had the highest yield potential with high bunch weight, maximum pulp: peel ratio, highest TSS and highest sugar : acid ratio etc. In case of yield attributing characters Nendran was low yielding germplasm.

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Effect of Pre Seed Treatment and Growing Media on Germination Parameters of *Gmelina arborea* Roxb.

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Abstract: The ccomparative performance of pre-sowing treatments and growing media to improve the seed germination of *Gmelina arborea* Roxb. by soaking seeds in water and gibberellic acid ($GA_{3)}$ solutions (100 and 200 ppm) for varying periods (12 and 36 hours) followed by sowing in different media (standard nursery media [(soil : sand : vermicompost :: 2:1:1], coco peat and white sand) for a period of 30 days on germination parameters. *T*he germination was initiated early in P_4 (seeds treated with GA_3 solution @ 200 ppm) from 6.5 day, reached peak at 12.17 days and ceased within 25.75 days. Further, maximum germination percent (73.13%), mean daily germination (2.85), peak value of germination (0.979), germination value (2.8) and high germination energy (35.83) was in pre-treatment P_4. Similarly, germination was initiated early in standard nursery. The higher values of germination percent mean daily germination, peak value, germination value, germination energy and germination rate index and minimum mean germination time (13.91 days) was with standard nursery media. The estimates of the seed germination indicated higher values of all observed germination parameters by recorded seeds with GA_3 solutions and then sowing treated seeds in standard nursery media for production of quality seedlings.

Keywords: *Gmelina arborea,* Germination, Pre-sowing treatments, Growing media,GA_3

Gamhar (*Gmelina arborea* Roxb.) belongs to the family Lamiaceae and is native to India, Bangladesh, Sri Lanka, Myanmar, Thailand, southern China, Laos, Cambodia, Sumatra and Indonesia. In India, it is found throughout greater part in eastern sub-Himalayan tract, Indo-Gangetic plains, Aravali Hills, central India, western Peninsula and western Himalayas. Characteristically, it is found scattered in dry deciduous and moist deciduous forests but occurs occasionally in evergreen forests. *G. arborea* is a commercial fast growing multipurpose tree species that grows up to 30 m in height and over 80 cm Diameter at Breast Height (DBH). It is widely grown as a component of agroforestry system in humid tropics (Pooja et al 2017). It performs best on fresh, well-drained, fertile alluvial soils where rainfall annually varies from 1200 to 4500 mm, temperature ranges from 20 to 45°C, and elevation ranges from sea level to 1000 m. This species also grows on dry sandy or poor soils having a stunted growth. It is a light demander, moderately frost hardy and has good power of recovering but doesn't withstand excessive drought and bad drainage. Flowering takes place during February to April and fruiting starts from May onwards up to June. Seeds are ex-albuminous and orthodox in nature, generally dispersed by animals. Seeds weigh average 1,250 per kg to 2,750 per kg (Kijkar 2010). *G. arborea* wood is relatively light with a density of 420 to 640 kg per m^3 and has calorific value of about 4800 kcal per kg. It is an important agroforestry species, for which production of quality planting material in the nursery is essential for better establishment of seedlings in the agroforestry field**.** The species is mostly propagated by seeds. The fruit maturity or ripening period is an important aspect as it determines the viability and vigour of seeds. The mature fruits have considerably higher germination rate provided the dormancy is less significant. Various pre sowing treatment methods can be adopted to enhance seed germination and reduce the time of germination (germination period) by soaking seeds in cold water for various time period and the application of growth hormones GA_3 at different levels. The present study was intended to investigate the comparative performance of *Gmelina arborea* seed germination as influence by different pre-sowing treatments and growing media.

MATERIAL AND METHODS

The present investigation was conducted during the year 2017-18, at the Navsari Agricultural University, Navsari, Gujarat, India. The mature/ripe fruits (greenish yellow to yellow) of *Gmelina arborea* were collected from the randomly selected good fruit bearing middle aged trees of 10-15m height and 30 cm DBH (OB). Seeds were extracted from fruits by de-pulping manually and weighed for the fresh

weight and dry weight (after 2-3 days of air drying in shade). Fruit length, fruit diameter, seed length, seed diameter, fresh weight as well as dry weight of fruit, pulp and seed, and 100 seed weight were measured and recorded (Table 1).

The seeds were subjected to different pre-sowing treatments such as soaking in tap water for 12 hours (P_1) and 36 hours (P_2), soaking in gibberellic acid (GA_3) solution at different concentrations GA_3, 100 ppm (P_3) and 200 ppm (P_4) for 12 hours as per the treatment objectives. The GA_3 solution was prepared by thoroughly mixing 100 mg powder in ethanol and then adding distilled water to it as per concentration. The experiment was carried out in germination trays and three types of trays were prepared filled with different media *i.e.,* standard nursery media (M_1), coco peat (M_2) and white sand (M_3), separately (each media in 8 trays). The standard nursery media was prepared by mixing soil, sand and vermicompost in the ratio of 2:1:1. A total of four replications of 160 (40 seeds in each replication) were sown per treatment. The number of germinated seeds was counted and recorded on daily basis up to 30 days from sowing and the germination parameters were estimated and data was subjected to statistical analysis using OPSTAT software in experimental design factorial complete randomized Design (FCRD) .

Methods for calculation of germination parameters

1. Germination percentage (GP) = (Total number of normal seeds germinated/Total number of seeds sown initially) x 100
2. Mean daily germination (MDG**)**= Cumulative germination per cent/Total number of days taken for germination (Czabator 1962)
3. Peak Value of germination (PV) = Maximum germination (%) achieved on daily count/day at which peak (maximum) germination achieved (Czabator 1962)
4. Germination value (GV)= MDG x PV (Czabator 1962)
5. Mean germination time (MGT) =Σ (n x d)/ Σ n
   where, n =newly germinated seeds on day d and d = number of days counted from the beginning of germination test (Edmond & Drapala 1958 and Ellis and Roberts 1981)
6. Mean germination rate (MGR) = CVG/100 = 1/T; where T is mean germination time and CVG is the coefficient of velocity.(Labouriau1970)
7. Coefficient of velocity of germination (CVG) = $\Sigma_{Ni}/\Sigma_{NiTi}$) x 100
8. where N is the number of seeds germinated on i^{th} days and T_i is the number of days from sowing corresponding to N. (Nichols & Heydecker1968 and AOSA 1983)
9. Germination Energy (GE) **=** (Total number of seeds germinated up to peak germination / Total number of seeds sown) X 100
10. The time taken to reach 50% germination (T_{50})= t_i +[(N/2 – n_i)($t_i – t_j$)/ ($n_i – n_j$)]
11. where N is the final number of germination and n_i, $n_j$are cumulative number of seeds germinated by adjacent counts at times t_i and t_j when n_i< N/2 < nj (Coolbear et al 1980)
12. Germination rate index (GRI) = $G_1/T_1+G_2/T_2$ + ...+ G_n/T_n
13. where G_1 is the germination percentage on day 1, G_2 is the germination parentage at day 2; and so on.(Throneberry and Smith 1955, Maguire 1962)
14. Germination index (GI) = $(30xN_1)+(29xN_2)$+ ... +$(1xN_0)$
15. where N_1, N_2 ...N_{20} is the number of germinated seeds on the first, second and subsequent days until 31st day and the multipliers (e.g. 30, 29 ...etc.) are weights given to the days of the germination. (Ranal et al 2006)
16. Timson's germination index (TGI) = ΣG/T, where G is the percentage of seed germinated per day, and T is the germination period (Timson 1965).

Table 1. Fruit and seed attributes of *Gmelina arborea* used in experiment

Fruit and seed attributes	Values	Fruit and seed attributes	Values
Fresh weight of fruit (g)	10.83	100 seed weight (g)	127.92
Fresh weight of pulp (g)	9.53	Fruit length (mm)	26.80
Fresh weight of seed (g)	1.30	Fruit diameter (mm)	22.50
Dry weight of fruit (g)	2.72	Seed length (mm)	19.22
Dry weight of pulp (g)	1.48	Seed diameter	12.12
Dry weight of seed (g)	1.24		

* Per fruit and seed attributes are average of 100 seeds

RESULTS AND DISCUSSION

The growing media and seed pre-sowing treatments significantly influenced the initiation of germination, peak germination day, cessation of germination, germination percent, mean daily germination, days to 50 per cent germination of the total seeds germinated, peak value, germination value, mean germination time, mean germination rate, coefficient of velocity of germination, germination energy, germination rate index, germination index and Timson's rate index (TRI) in *Gmelina arborea* seeds (Table 2). The germination was initiated within 6-8 days after sowing which was early when the seeds were treated with GA_3 solution (100 ppm) for 12 hrs *i.e.,* 6.5 days after sowing, reached peak at 12.17 days (GA_3 solution at 200ppm) and ceased within 25.75 days. Further, maximum germination percent (73.13%) mean daily germination, peak value of germination, germination value (2.8), germination

energy (35.83), and Timson's rate index (2.44) was observed with seeds in GA_3 solution (200 ppm) (P_4) while the highest mean germination rate, coefficient of velocity of germination, germination rate index and germination index were in GA_3 solution (100 ppm) (P_3). The reduced D_{50} and mean germination time was in pre-sowing treatment P_3. Similarly, germination was initiated early in M_1 (standard nursery media) from 6.5 day, reached peak at 11.31 days and ceased within 24.38 days followed by Coco peat and delayed in white sand. The higher values of germination per cent mean daily germination peak value (germination value), mean germination rate, coefficient of velocity of germination, germination energy, germination rate index (germination index) and Timson's rate index lower D_{50} and mean germination time was recorded with M_1. Many times the interaction of factors has a cumulative effect on the performance of growth parameters (Table 3). The significant interaction effect among the two factors (growing media and seed pre sowing treatment) were observed for the parameters like germination value and germination energy), which was maximum in M_1P_4 (standard nursery media and 12 hours soaking seeds in GA_3 solution @ 200 ppm), while the maximum germination rate index) and germination index (7) in the combination M_1P_3 (standard nursery media and soaking seeds in GA_3 solution @ 100 ppm for 12 hours).

The results shown higher values of above parameters and reduced time of germination when seeds were in GA_3 solution (100 ppm and 200 ppm) for 12 hours (P_2 and P_3) followed by sowing in standard nursery media soil : sand : vermicompost :: 2:1:1) (M_1). The germination initiated early when the seeds were treated with GA_3 solution for 12 hrs as compared to soaking seeds in normal tap water and it speeded up by sowing the treated seeds in standard nursery media. The GA_3 has promoted the germination by breaking physical dormancy by softening the seed coat through some chemical reactions at the surface of stone. The improved results in standard nursery media might be due to its high water holding capacity and maintenance of soil temperature with less fluctuation as compared to others. Similar results were also reported by Sondarva (2017) in *Khaya*

Table 3. Interaction of pre-sowing treatments and growing media on the germination parameters of *Gmelina arborea* Roxb. at 30 DAS

Treatment combinations	Seed germination parameters			
	GV	GE	GRI	GI
$M_1 P_1$	2.62	25.63	0.180	1121
M_1P_2	2.96	23.75	0.185	3144
$M_1 P_3$	3.76	36.50	0.270	1587
$M_1 P_4$	4.40	46.88	0.235	1418
$M_2 P_1$	1.58	19.63	0.120	740
M_2P_2	1.77	22.50	0.118	693
$M_2 P_3$	2.19	35.38	0.160	973
$M_2 P_4$	2.66	40.00	0.143	856
$M_3 P_1$	0.68	18.13	0.063	374
M_3P_2	0.82	21.75	0.078	478
$M_3 P_3$	1.07	22.50	0.113	767
$M_3 P_4$	1.34	20.63	0.128	671
CD (p=0.05)	0.28	2.86	0.017	91.51
CV (%)	8.86	7.14	7.92	7.02

Table 2. Influence of pre-sowing treatments and growing media on the germination parameters of *Gmelina arborea* Roxb. at 30 DAS

Treatments	IG (Days)	PGD (Days)	CG (Days)	MDG	PV	GV	MGT	MGR	CVG	GE	GRI	GI	TGI
Growing Media													
M_1	6.50	11.31	24.38	3.29	1.117	3.43	13.91	0.073	7.31	33.19	0.218	1317.81	2.70
M_2	7.19	14.38	26.44	2.31	0.738	2.05	16.33	0.062	6.20	29.38	0.135	815.47	1.98
M_3	8.00	16.31	27.75	1.71	0.424	0.98	17.69	0.057	5.70	20.75	0.095	572.5	1.53
CD (0.05)	0.43	0.74	1.35	0.13	0.037	0.14	0.99	0.004	0.37	1.43	0.009	45.58	0.11
Pre-sowing treatments													
P_1	8.25	16.08	27.42	2.01	0.588	1.63	16.77	0.061	6.07	21.13	0.121	745.63	1.80
P_2	7.58	14.67	26.92	2.15	0.635	1.85	16.25	0.062	6.25	22.67	0.127	771.46	1.85
P_3	6.50	13.08	24.67	2.73	0.836	2.34	14.35	0.071	7.13	31.46	0.181	1108.96	2.19
P_4	6.58	12.17	25.75	2.85	0.979	2.80	16.45	0.070	7.06	35.83	0.168	981.67	2.44
CD (p=0.05)	0.50	0.85	1.56	0.15	0.043	0.16	1.15	0.005	0.43	1.65	0.010	52.63	0.13
CV %	8.23	7.29	7.18	7.35	7.21	8.86	8.63	8.24	7.96	7.14	7.92	7.02	7.49

IG=germination, PGD=peak germination, CG=cessation of germination, GP=germination percent, MDG=mean daily germination, days to 50% germination of the total seeds germinated peak value (PV), germination value (GV), MGT=mean germination time, MGR=mean germination rate , CVG=coefficient of velocity of germination, GE=germination energy, GRI=germination rate index , GI=germination index (GI),TRI= Timson's rate index; DAS=Days after sowing

senegalensis, Kumar (2016) in *Terminalia bellerica,* and Sahoo and Thangjam (2017) in *Parkia timoriana*. The mean daily germination, peak value of germination and germination value was obtained higher in pre-sowing treatment GA_3 (100 ppm) and also increased by sowing the seeds in standard nursery media. This indicates greater speed and completeness/totality of germination from normal rate by applying the above treatments and also higher seedling vigour (Ranal and Santana 2006). Many researchers also confirmed that if the differential performance of seeds is affected by dormancy, a gibberellic acid treatment may improve germination and vigour, expressed as germination speed index (GSI). Collateral findings were also reported by Pandey et al (2002) and Adebisi et al (2011).

Further, for parameters like GE and Timson's rate index,the main effect of pre-sowing treatment was highest with soaking in GA_3 solution (200 ppm) whereas the MGT, MGR, CVG, GRI and GI was highest in GA_3 solution (100 ppm). The lower the value of MGT, the faster a population of seeds has germinated (Vidyasagaran et al 2017). Moreover, the effect of GA_3 was more pronounced in synchronizing germination and emergence as depicted by lower T_{50} and MGT, and higher GI, GE in treated seeds compared with untreated seeds. This relates the daily germination to the maximum germination value, where the lower the value of GI, the slower and less uniform germination. MGT is significantly related to seed vigour and field performance. Timson germination index also showed high values for all treated seeds. Seed pre-sowing treatment and growing media is important for the enhancement of germination. In our study on *G. arborea* nursery practices suggests that the seed pre-sowing treatment with GA_3 solution increased the germination percent and other seed germination attributes that aids in improving seed vigour and completeness of germination. Further the growing media as standard nursery media also proved to be better for seed germination.

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Biometric Characteristics of Giant River-Catfish *Aorichthys seenghala* (Sykes, 1839) from Harike Wetland – A Ramsar site

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Abstract: The study was carried out to evaluate the morphometric characteristics and biology of Giant river-catfish *Aorichthys seenghala* from Harike wetland – a Ramsar site from September 2016 - February 2017. Among different morphometric characteristics of *A. seenghala* average weight of fish, total length, standard length, fork length was 1197 g , 59.93 g, 47.57 cm, 51.01 cm, anal fin rays, caudal fin rays ranged from 8-9, 19-21 whereas, dorsal fin rays, ventral fin rays, pectoral fin rays was 7, 5, 9, respectively. *A. Seenghala* established negative algometric growth with respect to length weight relationship, thus species became slender as it increased in length. Highest Gonado Somatic Index (%) in male and female was in September (0.996 and 3.127) and lowest in November whereas, Hepato Somatic Index (%) of male and female fish recorded highest in November (1.158 and 2.208) and lowest in September. Hepato Somatic Index varied seasonally and inversely correlated with Gastro Somatic Index. Highest Gastro Somatic Index (%) in male and female was in September (1.277 and 2.278) and lowest in January. Relative Length of Gut value recorded < 1 indicating fish is carnivore in feeding habit. The fish is predominantly a carnivore fish and preferably lives in the bottom (as significantly detritus material found in the stomach). The Harike wetland is still supporting a good numbers of matured giant river catfish *A. seenghala* despite of different natural and anthropogenic disturbances which is required to be conserved.

Keywords: Harike wetland, *Aorichthys seenghala,* Gonadosomatic index, Gut content analysis, Cat fish

Harike wetland one of the largest wetlands of Northern India is situated 31°13'N and 75°12'E in the State of Punjab. This man-made, riverine and lacustrine wetland covers the land area of Tarn Taran, Ferozepur and Kapurthala districts in Punjab State. The river Beas rises in the Himalayas in central Himachal Pradesh and flows to river Sutlej in western Punjab at Harike Pattan. The headworks is located downstream of the confluence of the Beas and Sutlej rivers. The rich biodiversity of the wetland which plays a vital role in maintaining the precious hydrological balance in the catchment with its vast concentration of migratory fauna of waterfowls, including a number of globally threatened species. These are responsible for the recognition accorded to this wetland in 1990, by the Ramsar Convention, as one of the Ramasar sites in India, for conservation, development and preservation of the ecosystem (Baker et al 2007, Carreno et al 2008, Chander et al 2009). In Punjab, most of the wetlands are undergoing general ecological degradation and the attitude of the public is minimal with respect to ecological restoration (Ladhar 2002). The most serious problem to Harike wetlands is siltation due to erosion from highly degraded catchment areas. The ecology of this wetland is also threatened due to excessive growth of exotic weed-water hyacinth, accidental outflows of pollutants from industries ,water quality, inflow of pesticides and fertilizers as run off from agricultural fields and sewage from towns. The polluted water and declining water table in Harike wetland is affecting biodiversity and fish growth (Jain et al 2008, Brraich and Jangu 2015).

Catfish possess high nutritive value and has great market demand in Punjab due to absence of intramuscular spines. Among catfish, order Siluriformes is a diverse group with more than 3,000 valid living species in 37 families. Bagridae is the seventh most diverse catfish family currently recognized, and it includes more than 210 valid species in 17 genera (Ng and Kottelat 2013). The biology, biometric characteristics and diversity of family Bagridae has not been evaluated in detail, in Punjab. To fill the gap, the present study was carried out to evaluate the biology, biometric characteristics of commercially important fish species *Aorichthys seenghala* under Bagridae family of Harike wetland.

MATERIAL AND METHODS

Present study was conducted during September, 2016 – February, 2017 comprising post monsson and winter seasons at Harike wetland. Fish samples were collected from landing sites situated adjacent to Harike wetland (31°08'N to

31°23'N latitudes and 74°90'E to 75°12'E longitudes) for biology whereas, morphometric characters meristic counts were measured on landing site and identified up to species level with the help of standard key given by Jayaram (1999) and Talwar and Jhingram (1991). Per month ten fishes were considered for biometric analysis. A total of 25 morphometric characters were recorded (Table 1). Fish samples were brought under iced conditions in insulated corrugated boxes and stored at -20°C till further analysis. The following biological parameters were considered for the present study.

Length-weight relationship: The relationship between length and weight of fish was analysed by measuring length and weight of fish specimens collected from landing centre. The statistical relationship between two parameters of fishes were established by using the parabolic equation by Forese (2006)

$W = aL^b$

Where, W= weight of fish (g), L = length of fish (mm), a = constant, b = an exponential expressing relationship between length-weight.

The relationship ($W = aL^b$) when converted into the logarithmic form gives a straight line relationship graphically:

Log W = Log a + b Log L

Where, b represents the slope of the line, Log a is a constant

Condition factor (K): Fulton's condition factor (K) was calculated according to Htun-Han (1978)

$K = W X 100 / L^3$

Where, W = weight of fish (g), L= Length of fish (cm).

Gonadosomatic index (GSI): Calculated as follows (Barber and Blake 2008).

$$\text{Gonado - somatic Index} = \frac{\text{Weight of gonado}}{\text{Weight of fish}} \times 100$$

Hepatosomatic index (HSI): The Hepatosomatic index (HSI) of the fish was determined by the use of equation cited by Parmeswaran (1974)

$$\text{Hepatosomatic Index} = \frac{\text{Weight of Liver}}{\text{Weight of fish}} \times 100$$

Gastrosomatic index (GaSI): Gastrosomatic index (GaSI) of the fish was determined by the following formula

$$\text{Gastrosomatic Index} = \frac{\text{Weight of stomach content}}{\text{Weight of fish}} \times 100$$

Statistical analysis of the collected data was performed by using SPSS -16 software package.

Relative length of gut (RLG): The relative length of the gut (RLG) was calculated using the equation derived by Yamagishi et al (2005)

$$\text{Relative length of gut} = \frac{\text{Gut length (cm)}}{\text{Fork length (cm)}} \times 100$$

Gut content analysis: Gut contents were analysed both qualitatively and quantitatively. The qualitative analysis was performed based on complete identification of the organisms in the gut contents and the quantitative analysis were performed based on frequency of occurrence method (Hynes 1950)

$$\text{Frequency of Occurrence} = \frac{Ji}{P}$$

Where, J_i is number of fish containing prey i and P is the number of fish with food in their stomach.

RESULTS AND DISCUSSION

In *Aorichthys seenghala,* average length and weight was maximum in January (65.50 cm and 1540 g) and minimum in November. Among different morphometric characteristics of *A. seenghala* average weight of fish, total length, standard length, fork length were 1197 g, 59.93, 47.57 and 51.01 cm, respectively. Anal fin rays caudal fin rays ranged from 8-9, 19-21 whereas, dorsal fin rays, ventral fin rays and pectoral fin rays recorded 7, 5, and 9, respectively. Hafiz (2008) also reported similar observation in *Sperata sarwari* from Mangla Lake, Pakistan. The 'b' was 2.524 indicating negative allometric growth. When TL was regressed with Wt, the slope value was significantly lower than critical isometric value i.e. 3. In present study negative algometric growth values explains the proper fit of the model for growth. Co-efficient of determination (r^2) wass 0.86 indicating more than 86 per cent variability by the model and good fitness. Jatoi et al (2013) reported allometric growth pattern (b= 2.97) in *A. seenghala* with r^2 value of 0.940 from Indus river, Pakistan whereas, Akhtar et al (2015) reported r^2 value between 0.897 to 0.983 from Baran Dam, Pakistan in same species.

Gonado Somatic Index (GSI %) in September for both male and female fish (0.996 and 3.127) revealed spent phase. Clinical observations of gametes also confirmed the presence of unspawned eggs and sperms in female and male fish, respectively. In November GSI of both male and female fish was lowest (0.171 and 0.781) and increased subsequently from December (0.224 and 0.884) to February (0.524 and 1.524). Lower GSI in November denoted resting phase followed by increasing GSI in February revealed preparatory phase. The mean values differed significantly during different months within the species. In *A. seenghala* highest Hepato Somatic Index (HIS %) of male and female fish recorded in November (1.158 and 2.208) and lowest in September (Table 2). The mean values differed significantly during different months within the species. During the

breeding season major portion of lipid transferred from the liver towards the gonad during the process of vitellogenesis, hence immediate after breeding lowest HSI was observed both in male and female (Arukwe and Goksøyr 2003). HSI varied seasonally and inversely correlated with GSI. Highest Gastro Somatic Index (GaSI%) in male and female was in September (1.277 and 2.278), whereas, it was lowest in the January (Table 2). The mean values differed significantly during different months within the species. The feeding intensity was reduced as the onset of winter thus GaSI value was also decreased in winter months as compared with post-monsoon months. The average relative length of gut (RLG) in male and female fish was 0.563 and 0.571, respectively. RLG less than 1 indicate fish is carnivore in feeding habit. Yadav (2006) and Babare et al (2013) also observed that in carnivorous fishes, the gut length ratio is less or equal to the body length.

The gut contents analysis revealed highest amount of small fish and fish body parts (57.06%) comprised of *Puntius spp., Gudusia chapra, Chanda* spp., *Nandus nadus* as major food item. The second dominant group was zooplanktons (16.2%) dominated by copepod and Cladocerans followed by

Table 1. Biometric characters of *A. seenghala* during study period

Biometric characters	September	October	November	December	January	February	Average
Morphometric characters							
Weight of fish (g)	1333^{d}	1355^{c}	979^{e}	1066^{f}	1540^{a}	1412^{b}	1197
Total length (cm)	63.70^{b}	61.42^{d}	48.85^{f}	56.20^{e}	65.50^{a}	62.50^{c}	59.93
Standard length (cm)	47.83^{d}	50.64^{c}	41.22^{f}	42.60^{e}	52.75^{a}	52.00^{b}	47.57
Fork length (cm)	50.75^{c}	53.64^{d}	45.77^{e}	46.50^{d}	54.35^{a}	54.00^{ab}	51.01
Head length (cm)	13.33^{c}	14.50^{a}	10.60^{5}	13.00^{d}	13.60^{b}	13.27^{c}	13.27
Head depth (cm)	5.41^{e}	5.78^{b}	5.21^{f}	5.71^{c}	5.84^{a}	5.6^{d}	5.40
Snout length (cm)	5.08^{b}	5.14^{b}	4.60^{d}	4.78^{c}	5.50^{a}	4.66^{c}	5.05
Eye diameter (cm)	1.16^{a}	0.95^{b}	1.04^{a}	1.02^{a}	1.09^{a}	1.00^{a}	1.05
Inter-orbital length(cm)	3.93^{c}	3.92^{c}	3.80^{d}	4.02^{a}	4.93^{a}	4.00^{b}	0.40
Pre-dorsal length (cm)	21.08^{f}	22.28^{b}	19.21^{e}	19.40^{e}	23.40^{a}	21.66^{c}	21.39
Pre-pectoral length (cm)	13.25^{d}	13.90^{b}	10.35^{f}	11.40^{e}	14.42^{a}	13.50^{c}	12.89
Pre-pelvic length (cm)	26.50^{c}	26.78^{b}	23.10^{f}	25.85^{d}	28.80^{a}	24.33^{e}	25.21
Pre-adipose length (cm)	33.00^{ab}	33.14^{b}	27.60^{e}	31.57^{d}	33.70^{a}	29.50^{c}	31.42
Pre-anal length (cm)	37.16^{c}	39.21^{b}	33.10^{e}	33.38^{d}	40.16^{a}	39.30^{b}	37.11
Adipose fin length (cm)	5.83^{d}	7.35^{a}	6.30^{c}	6.52^{c}	6.75^{b}	5.33^{e}	6.34
Height of dorsal fin (cm)	6.50^{d}	6.72^{c}	6.60^{cd}	6.64^{c}	7.65^{a}	7.33^{b}	7.14
Anal fin length (cm)	6.75^{c}	7.07^{b}	5.90^{e}	5.92^{e}	7.15^{a}	6.50^{d}	6.54
Body depth (cm)	8.66^{c}	8.83^{b}	8.10^{d}	8.92^{b}	9.10^{a}	7.50^{e}	8.58
Caudal depth (cm)	6.08^{c}	6.00^{c}	6.00^{c}	6.07^{c}	6.96^{a}	6.16^{b}	6.76
Caudal length (cm)	12.50^{d}	9.35^{c}	8.60^{f}	8.85^{e}	14.33^{a}	14.10^{b}	12.06
Caudal fin surface (cm)	6.75^{e}	9.07^{c}	6.70^{e}	9.78^{b}	9.90^{a}	8.50^{d}	8.45
Mandibular barbell (cm)	19.91^{b}	19.00^{b}	17.50^{b}	17.60^{b}	22.05^{a}	17.66^{b}	20.30
Outer mandibular barbel length (cm)	8.83^{a}	8.00^{a}	7.90^{b}	6.85^{b}	9.00^{a}	8.50^{a}	8.27
Inner mandibular length (cm)	6.00^{a}	5.90^{a}	5.64^{a}	5.92^{a}	6.10^{a}	6.00^{a}	5.75
Nasal barbel length(cm)	2.58^{a}	2.08^{a}	1.82^{a}	1.82^{a}	2.95^{a}	2.66^{a}	2.40
Meristic characters							
Dorsal fin rays (nos.)	7.00^{a}	7.00^{a}	7.00^{a}	7.00^{a}	7.00^{a}	7.00^{a}	7.00
Ventral fin rays (nos.)	5.00^{a}	5.00^{a}	5.00^{a}	5.00^{a}	5.00^{a}	5.00^{a}	5.00
Pectoral fin rays (nos.)	9.00^{a}	9.00^{a}	9.00^{a}	9.00^{a}	9.00^{a}	9.00^{a}	9.00
Anal fin rays (nos.)	9.00^{a}	8.00^{a}	9.00^{a}	9.00^{a}	8.00^{a}	9.00^{a}	9.00
Caudal fin rays (nos.)	20.00^{a}	20.00^{a}	19.00^{b}	20.00^{a}	21.00^{a}	20.00^{a}	20.00
Number of barbels (nos.)	4.00^{a}	4.00^{a}	4.00^{a}	4.00^{a}	4.00^{a}	4.00^{a}	4.00

Values with different alphabetical superscripts (a, b, c...) in a row differ significantly

Table 2. GSI, HSI, GaSI and RGL of *A. seenghala* from Harike wetland

Months	September	October	November	December	January	February
Male						
GSI	0.996[a]	0.490[c]	0.171[f]	0.224[e]	0.285[d]	0.524[b]
HSI	0.442[e]	0.452[d]	1.158[a]	0.822[b]	0.801[bd]	0.785[c]
GaSI	1.277[a]	1.236[b]	0.918[c]	0.782[d]	0.508[e]	0.520[e]
RGL	0.552[a]	0.556[a]	0.566[a]	0.558[a]	0.576[a]	0.568[a]
Female						
GSI	3.127[a]	2.096[b]	0.781[f]	0.884[e]	1.085[d]	1.524[c]
HSI	0.946[f]	1.242[e]	2.208[a]	2.150[b]	1.822[c]	1.406[d]
GaSI	2.288[a]	2.256[b]	1.978[c]	1.783[d]	1.608[f]	1.720[e]
RGL	0.568[a]	0.572[a]	0.568[a]	0.570[a]	0.572[a]	0.574[a]

GSI=Gonadosomatic Index), HSI=Hepatosomatic Index; GaSI =Gastrosomatic Index, GaSI= Gastrosomatic Index , RGL= Relative Length of Gut

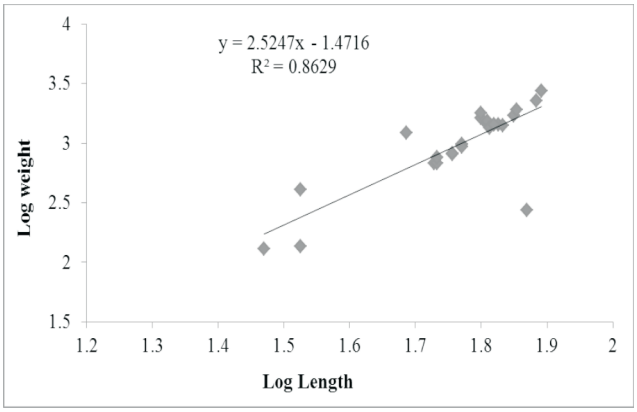

Fig. 1. Log length and log weight relationship of *A. seenghala* in Harike wetland

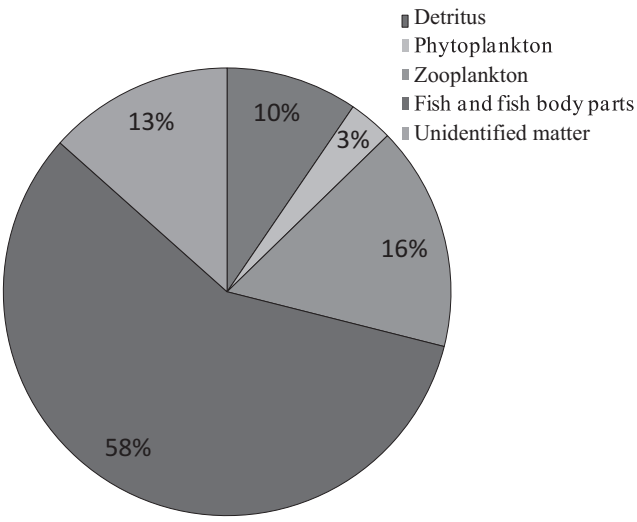

Fig. 2. Analysis of food and feeding habit of *A. seenghala* during the study period

detritus matter with sand and mud. Phytoplankton constituted around 3.2% (Chlorophyceae and Bacillariophyceae were predominant group). Unidentified matter comprised only 13.41 % of the gut content (Fig. 2). The fish is predominantly a carnivore fish and preferably lives in the bottom (as significantly detritus material found in the stomach). The results of the present study also confirmed the predatory habit of *A. seenghala*. According to Babare et al (2003), this fish is a bottom feeder and highly predaceous in nature. The wetland is also maintaining a healthy food chain where plenty of small sized fish are available to which these predatory carnivore fish like *A. seenghala* can prey upon.

CONCLUSIONS

Based on biometric characteristics it can be concluded that despite of different natural and anthropogenic disturbances the Harike wetland is still supporting a good numbers of matured giant river catfish *A. seenghala* which is to be conserved. Findings pertaining to present study may be useful as valuable time series data w.r.t. future study and policy making of this internationally important Ramsar site.

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Effect of Pretreatments on Shelf life and Nutritional Quality of Moth Bean (*Phaseolus aconitiflius* Jacq.) Sprouts

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Abstract: The present investigation was conducted with the objective to study the effects of various treatments and storage conditions on nutritional (ascorbic acid, antioxidant activity, total sugars, reducing sugars, phytic acid, polyphenol content) and keeping quality of moth bean sprouts. Moth bean (*Phaseolus aconitiflius* Jacq.) seeds after germination were subjected to various treatments viz., hot water dip (50^{0}C for 2 min), ethanol vapours (30 min) and UV-Irradiation (10 kJm^{-2} in laminar flow chamber for 1 h). Ascorbic acid and antioxidant activity were highest in ethanol vapours treated sprouts. There was decrease in polyphenols and phytic acid of sprouts by various treatments with maximum reduction in UV- irradiation treatment. Similar trend was observed at room and low temperature storage conditions. The sprouts were acceptable upto 24 h at room temperature and 96 h at low temperature storage conditions, except in hot water treatment, where the quality of moth bean sprouts was maintained upto 72 h at room temperature and 120 h at low temperature.

Keywords: Antioxidant activity, Ethanol vapours, Hot water dip, Moth bean sprouts, UV-irradiation

Moth bean (*Phaseolus aconitifolius* Jacq.), being one of the most drought resistant pulses, is widely grown under rainfed condition in semi-arid and arid zones of India. It contains 24.1, 0.8,1.3 and 3 per cent protein, crude fibre, fat and 3 ash (Bhattacharya 2010). Sprouting has been identified as an effective method for improving the nutritional quality of legumes (Khattak et al 2008) coupled with reduction in anti-nutritional factors (Ghavidel and Prakash 2007). Due to high moisture content and high metabolic activity, sprouts are highly perishable. The rapid quality loss at moderate temperature emphasizes the critical need to augment shelf life and maintain the keeping quality of sprouts during storage. Ethanol vapour treatment and hot water dip treatment improved the nutritional quality and shelf life (by inhibition of enzymatic browning) of mung bean sprouts (Goyal and Siddiqui 2014). The shelf life of sprouts is very limited, restricted to two days. Keeping in view the nutritional importance of moth bean and its sprouts, the present investigation was undertaken to study the effect of various pre-treatments on nutritional quality of moth bean sprouts during storage.

MATERIAL AND METHODS

Plant material: Moth beans variety HM-61 was procured from, Department of Genetics and Plant Breeding, CCS HAU, Hisar, India. Moth bean seeds were cleaned, washed and soaked 4 to 5 volumes of water (22–25^{0}C) for 10 h under ambient laboratory conditions. At the end of the period, the water was drained and the seed samples were allowed to germinate in sprout maker (NovellePlast, Delhi) for 24 h at 30±1^{0}C.

Treatments and storage conditions: Moth bean sprouts were separated into 4 lots of equal amount and subjected to hot water dip (HWD) (50 °C for 2 min), ethanol vapours (in a glass chamber saturated with ethanol vapours for 30 min.) and UV irradiation (10 kJm-2 in laminar flow chamber for 1 h). Untreated sprouts were used as control. The sprouts from each treatment were packaged in disposable plastic cups (~200 ml volume) and wrapped with 2 percent perforated cling films. Water soaked filter paper was placed along the inner sides of plastic cup to maintain high humidity inside. There was ~100 g sprouts per pack and the packs were stored in dark at room (30±3^{0}C) and low (7±0.5^{0}C) temperature conditions. The sampling for various parameters was done regularly at 24 and 48 h at room, and 120 h at low temperature conditions.

Proximate analysis: The raw and sprouted moth bean (without any treatments) were analyzed for carbohydrate, crude protein, crude fat, ash, crude fibre, moisture and total dietary fibre was estimated by the methods suggested by AOAC (1995).

Chemical analysis: The ascorbic acid was analyzed as per the procedure suggested by Ranganna (2014). The antioxidant activity was assessed as per the procedure described by Shimada et al (1992). Then estimation of total sugar, phytic acid and polyphenol was done by the method described by Hulme and Narain (1931), Haug and Lantzsch

(1983) and Swain and Hills (1959), respectively.

Overall acceptability:-Sensory evaluation was carried out using 9-point hedonic scale. In order to take care of the variation in individual preferences for various organoleptic characteristics, a panel of 10 trained judges was constituted. Sprouted mung beans were evaluated for colour, appearance, texture and taste. Overall acceptability (OA) of sample was calculated as mean score given to it by a judge for these parameters.

RESULTS AND DISCUSSION

Physico-chemical Changes of Moth Bean during Sprouting

Carbohydrates: In the present investigation, due to respiration and other metabolic activities, carbohydrates were decreased from 68.5 to 63.5 percent in moth bean after 48 h of germination. Khattak et al (2008) observed decrease in carbohydrates from 64.26 to 61.88 percent with germination time of 120h in chickpea seeds.

Crude protein: The moth bean sprouts were showing an apparent increase of 9.13 per cent in crude protein. This increase probably may be a virtual increase, as the results have been expressed on dry matter basis. The results of present study are in conformity with the findings of Khattak et al (2008) also reported increased level of protein from 19.84 to 21.97 per cent after 96 h germination of chickpea seeds. Similarly increase in protein content was also observed by Ghavidel and Prakash (2007) in some legumes (cowpea, green gram, lentil and chickpea), which could be due to biosynthesis during germination.

Fat content: The, fat content was decreased from 1.6 to 1.2 percent in moth bean after 48 h of germination. The results of the present study are in agreement with the findings of Shah et al (2011) observed percent fat content was decreased from 1.79 to 1.4 t and 1.71 to 1.39 in mung bean varieties Ramzan and NM-98, respectively.

Ash content: Ash content increased from 3.4 to 3.6 percent in raw moth bean and after 48 h of germination. Devi et al (2015) also reported increase in ash content from 3.78 to 3.94 g after 24 h of germination at 25^0C

Crude fibre: The crude fibres content decreased in raw moth beans from 3.5to 2.8% after 48 h of germination. Khattak et al (2008) also reported a significant decrease in fibre content from 7.9 to 5.55% with germination time of 120h in chickpea seeds. Similarly, Mankotia and Modgil (2003) also reported a significant decrease in crude fibre content from 3.83 to 3.52% with germination of 72 h in moth bean sprouts.

Dietary fibre: The total dietary fibre content increased slightly from 15.3 in raw moth bean to 15.6 in germinated after 48 h. Martin et al (2008) also observed that germination results in increase in total dietary fibre content of cowpea (14%) than in raw seeds.

Physico-chemical Characteristics of Sprouted Moth Bean during Storage

Ascorbic acid: Ascorbic acid content of sprouts first increased (18.1 to 30.1 mg/100 g sprouts) up to 24 h and thereafter decreased to 20.5 mg/100 g sprouts (Table 2). At low temperature storage condition, ascorbic acid content increased upto 72 h and thereafter decreased during storage. All the treatments resulted in significant decrease in ascorbic acid content at 0-day, however, helped in retention of higher ascorbic acid during storage over to untreated sprouts. Among the various treatments and at both the storage temperatures, maximum ascorbic acid was maintained by ethanol vapour treatment followed by hot water dip treatment, while it was minimum for UV treated sprouts.

Ascorbic acid content augmented in hot water treated sprouts due to elevated rate of metabolic activity than control. The possible reason could be synthesis of ascorbic acid during initial period of storage. In ethanol treated sprouts, it could be due to inhibition of metabolic activity by ethanol vapours, so initially formed ascorbic acid did not get utilized during storage and it was maintained at higher levels in treated sprouts. Goyal et al (2014) reported that hot water dip and ethanol treatments increased the ascorbic acid content of mung bean sprouts and attributed it to inhibition of metabolic activity by ethanol vapours, so initially formed ascorbic acid did not get utilized during storage and was maintained at higher levels in treated sprouts.

Total antioxidant activity: Antioxidant activity of sprouts first increased from 25.8 to 62 mg/100 g sprouts up to 24 h and thereafter, it decreased to 42 mg/100 g sprouts at room storage (Table 3). At low temperature storage condition antioxidant activity increased from 25.1 to 76.1 mg/100 g sprouts up to 72 h and thereafter decreased to 50.2 mg/100 g sprouts. At both the storage temperatures, a significant increase in antioxidant activity over control was observed in all the treatments except in HWD treatment showing significantly lower antioxidant activity. Throughout the

Table 1. Proximate composition of raw and sprouted (48h) moth beans

Nutrients	Raw moth bean	Sprouted moth bean
Moisture (%)	9.1±0.16	70.0±0.25
Proteins (% DM)	23.0±0.17	25.1±0.21
Fats (% DM)	1.6±0.05	1.2±0.07
Crude fibre (% DM)	3.5±0.07	2.8±0.08
Ash (% DM)	3.4±0.08	3.6±0.07
Carbohydrate (% DM)	68.5±0.23	67.3±0.27
Total dietary fibre (%DM)	15.3±0.18	15.6±0.12

storage period, maximum activity was observed under ethanol vapour treatment followed by UV treatment. Similar decrease in antioxidant activity by heat treatment and increase in antioxidant activity by ethanol vapours in mung bean sprouts was attributed to higher amounts of phenols and ascorbic acid content in ethanol treated sprouts in mung bean sprouts (Goyal et al 2014).

Total and reducing sugars: Total and reducing sugar first increased up to 48 h and 96 h at room temperature and low temperature storage conditions, respectively and thereafter decreased (Table 4). All the treatments resulted in slight but significantly higher total and reducing sugars in sprouts with respect to control, however, no significant differences were observed amongst various treatments. This increase in sugar could be attributed to breakdown of starch into water soluble sugars.

Polyphenols and phytic acid: Polyphenols and phytic acid contents of sprouts decreased progressively with the increase in storage duration both at room and low temperature storage (Table 5, 6). All the treatments resulted in significant reduction in antinutritional content with respect to control. The reduction in polyphenols and phytic acid was

Table 2. Effect of different treatments on ascorbic acid (mg/ 100 g) of moth bean sprouts during storage

Treatments	Storage period (h)						
	0	24	48	72	96	120	Mean
Room temperature							
Control	20.7	22.6	20.5	-	-	-	21.3
HWD	18.1	29.9	28.3	-	-	-	25.5
Ethanol	19.0	30.1	29.4	-	-	-	26.1
UV	20.0	29.3	28.1	-	-	-	25.8
Mean	19.4	28.0	26.6	-	-	-	
CD (p=0.05)		Treatments (T) = 0.48;		Storage (S) = 0.41;		TxS = 0.82	
Low temperature							
Control	21.8	22.2	22.6	24.6	23.3	21.5	22.7
HWD	19.2	25.4	29.7	31.5	28.4	24.8	26.5
Ethanol	20.5	26.0	30.5	32.5	29.7	25.7	27.5
UV	20.5	25.0	29.5	30.3	28.0	23.3	26.1
Mean	20.5	24.7	28.1	29.7	26.8	23.8	
CD (p=0.05)		Treatments (T) = 0.32;		Storage (S) = 0.40;		TxS = 0.51	

HWD= Hot water dip; - = Observations were not recorded due to spoilage of samples

Table 3. Effect of different treatments on antioxidant activity (% scavenging of DPPH) of moth bean sprouts during storage

Treatments	Storage period (h)						
	0	24	48	72	96	120	Mean
Room temperature							
Control	38.3	51.6	44.7	-	-	-	44.9
HWD	25.8	38.4	42.0	-	-	-	35.4
Ethanol	45.8	62.0	51.8	-	-	-	53.2
UV	41.8	53.9	49.4	-	-	-	48.4
Mean	37.9	51.5	47.0	-	-	-	
CD (p=0.05)		Treatments (T) = 0.64;		Storage (S) = 0.56;		TxS = 1.11	
Low temperature							
Control	40.9	54.0	61.3	62.4	59.1	55.2	55.5
HWD	25.1	34.8	49.0	53.4	52.7	50.2	44.2
Ethanol	46.1	65.5	74.1	76.1	71.8	67.2	66.8
UV	41.9	54.0	70.0	68.6	62.4	60.4	59.6
Mean	38.5	52.1	63.6	65.1	61.5	58.3	
CD (p=0.05)		Treatments (T) = 0.38;		Storage (S) = 0.47;		TxS = 0.93	

HWD= Hot water dip; - = Observations were not recorded due to spoilage of samples

Table 4. Effect of different treatments on total and reducing* sugars (g/100 g) of moth bean sprouts during storage

Treatments	Storage period (h)						
	0	24	48	72	96	120	Mean
Room temperature							
Control	0.65 (0.45)	0.87 (0.56)	1.09 (0.70)	-	-	-	0.87 (0.57)
HWD	0.62 (0.48)	1.06 (0.70)	1.22 (0.78)	-	-	-	0.97 (0.65)
Ethanol	0.71 (0.53)	0.97 (0.66)	1.14 (0.75)	-	-	-	0.94 (0.63)
UV	0.69 (0.53)	1.04 (0.64)	1.11 (0.74)	-	-	-	0.94 (0.63)
Mean	0.66 (0.49)	0.98 (0.63)	1.14 (0.74)	-	-	-	
CD (p=0.05)	Treatments (T) = 0.04(0.03)*; Storage (S) = 0.02(0.03)*; TxS = 0.06(0.07)*						
Low temperature							
Control	0.64 (0.48)	0.77 (0.53)	0.95 (0.62)	1.09 (0.77)	1.30 (0.93)	1.21 (0.91)	0.99 (0.71)
HWD	0.58 (0.42)	0.85 (0.67)	1.02 (0.77)	1.21 (0.90)	1.36 (1.04)	1.30 (0.99)	1.05 (0.80)
Ethanol	0.65 (0.54)	0.81 (0.67)	1.00 (0.72)	1.17 (0.86)	1.33 (1.03)	1.26 (0.97)	1.04 (0.80)
UV	0.63 (0.53)	0.81 (0.65)	1.00 (0.69)	1.15 (0.86)	1.34 (1.03)	1.26 (0.97)	1.03 (0.79)
Mean	0.62 (0.50)	0.81 (0.62)	0.980.69)	1.15 (0.85)	1.33 (1.00)	1.25 (0.95)	
CD (p=0.05)	Treatments (T) = 0.03(0.02)*; Storage (S) = 0.02(0.03)*; TxS = 0.04(0.05)*						

HWD= Hot water dip; - = Observations were not recorded due to spoilage of samples
*Figures in parenthesis are of reducing sugars

Table 5. Effect of different treatments on phytic acid (mg/100 g) content of moth bean sprouts during storage

Treatments	Storage period (h)						
	0	24	48	72	96	120	Mean
Room temperature							
Control	664	442	308	-	-	-	471
HWD	632	409	260	-	-	-	434
Ethanol	649	439	298	-	-	-	462
UV	589	420	241	-	-	-	417
Mean	634	428	277	-	-	-	
CD (p=0.05)	Treatments (T) = 7.8 ; Storage (S) = 6.7; TxS = 13.5						
Low temperature							
Control	650	579	486	376	270	189	425
HWD	624	549	452	345	239	161	395
Ethanol	635	565	470	364	252	172	410
UV	570	499	399	324	205	119	353
Mean	620	548	452	352	241	160	
CD (p=0.05)	Treatments (T) = 4.7 ; Storage (S) = 5.4; TxS =11.7						

HWD= Hot water dip; - = Observations were not recorded due to spoilage of samples

maximum in UV-treatment followed by hot water dip and ethanol vapour treatments Kala and Mohan (2011) also reported decreased levels in tannins and phytic acid in overnight soaked seeds of *Mucuna pruriens* var. *utilis* when treated with UV irradiation.

Organoleptic score: There was a decrease in overall acceptability score of moth bean sprouts with increasing storage period and became unacceptable at 48 h of storage at room temperature and 96 h of storage at low temperature (Table 7). There was no significant effect of various treatments on the sprout. However, under both the storage temperatures, overall acceptability of moth bean sprouts significantly increased by HWD and ethanol treatment, while it was decreased significantly by UV irradiation treatment. Goyal and Siddiqui (2014) also reported that mung bean sprouts remained acceptable upto 48 h and 120 h at room

Table 6. Effect of different treatments on polyphenols (mg tannic acid/100 g) content of moth bean sprouts during storage

Treatments	Storage period (h)						
	0	24	48	72	96	120	Mean
Room temperature							
Control	707	517	481	-	-	-	568
HWD	672	482	449	-	-	-	535
Ethanol	692	504	472	-	-	-	556
UV	656	467	435	-	-	-	519
Mean	682	493	460	-	-	-	
CD (p=0.05)			Treatments (T) = 5.4;		Storage (S) = 4.7 ;	TxS = 9.2	
Low temperature							
Control	710	603	524	436	321	286	480
HWD	675	572	501	405	290	197	440
Ethanol	695	689	516	425	304	208	473
UV	656	562	489	399	277	180	427
Mean	684	607	508	416	298	218	
CD (p=0.05)			Treatments (T) = 3.5;		Storage (S) = 4.3 ;	TxS =8.5	

HWD= Hot water dip; - = Observations were not recorded due to spoilage of samples

Table 7. Effect of different treatments on overall acceptability (9 point hedonic) of moth bean sprouts during storage

Treatments	Storage period (h)						
	0	24	48	72	96	120	Mean
Room temperature							
Control	9.0	7.0	4.0	-	-	-	6.7
HWD	9.0	8.1	5.0	-	-	-	7.4
Ethanol	9.0	7.1	4.0	-	-	-	6.7
UV	9.0	7.3	4.1	-	-	-	6.8
Mean	9.0	7.4	4.3	-	-	-	
CD (p=0.05)			Treatments (T) = 0.50;		Storage (S) = 0.45;	TxS = 0.95	
Low temperature							
Control	9.0	8.3	8.1	7.4	6.3	4.2	7.2
HWD	9.0	8.8	8.6	8.0	7.6	5.5	7.9
Ethanol	9.0	8.4	8.1	7.3	6.7	4.1	7.3
UV	9.0	8.6	8.1	7.3	6.7	4.2	7.3
Mean	9.0	8.5	8.2	7.5	6.8	4.5	
CD (p=0.05)			Treatments (T) = 0.42 ;		Storage (S) = 0.38 ;	TxS = NS	

HWD= Hot water dip; - = Observations were not recorded due to spoilage of samples

and low temperature storage conditions. The ethanol vapour and HWD treatments significantly improved the shelf life of mung bean sprouts both at room and low temperature storage.

CONCLUSIONS

The sprouting improved the nutritional value of the moth bean sprouts in terms of proximate and physicochemical composition. Different treatments given to the sprouts resulted in significant improvement of nutritional quality of moth bean sprouts during storage. Ethanol vapours significantly improved the ascorbic acid content and antioxidant activity of moth bean sprouts and UV radiation resulted in significance reduction of antinutritional compound. Keeping quality of moth bean sprouts can be maintained well upto 48 h at room temperature and 120 h at low temperature as against 24 and 96 h under control conditions by subjecting the sprouts to hot water dip treatment of 50^0C for 2 minutes.

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Technological Adoption for Livelihood Security of Small Holder Farmers' in Uttarakhand, India: Issues and Opportunities

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Abstract: Recent trends and transfer issues such as slower, more problematic development, adoption than expected and increasingly global competition to establish 'future agro-based industries' are viewed to identify a set of imperatives. With the aim to explain the notion of technological transfer, and their expected convergences by taking into consideration both their potential and issues faced in the rural context the present study was carried out in Ukhimath block of district Rudraprayag, Uttarakhand. Multistage random sampling method was used to select the sampling units. The most important factors influencing the adoption of technologies were education level of household head (HHedu), household income (IncomeL), and extension contact (ExCont). The results of the study also highlights emerging opportunities and challenges, focusing on how to examine alternative futures and perspectives which may help in enabling effective responses to technological transfer. Study suggests that agriculture technologies such as protected cultivation, organic composting, genetically modified crops and precision farming are helpful in explaining the rural development context.

Keywords: Adoption, Diversification, Farm-technology, Organic farming

In Himalayan region of the country a large section of the population depends on agricultural and allied activities for their livelihood mainly consisting of crop production, animal husbandry and forest resource based production systems (Maikhuri et al 2001). The productivity of the different traditional crops has continuously decreased in the area due to climatic variability (Singh et al 2011) and other regional factors of which the most important positive change is the diversification of agriculture towards high-value cash crops, including fruits, vegetables, medicinal and aromatic plants, especially in the areas falling in the temperate agro-climatic zones (Sati 2012). As a consequence, rural areas including remote regions are experiencing fluctuations in the climate due to erratic rainfall and unpredictable weather conditions (Singh et al 2011), increasing tourism activities in the region, and improved means of communication including road connectivity, among other developments. The empirical studies have shown that technological adoption and agriculture diversification has made a significant impact on the income and employment of the farming households in remote areas. The agricultural diversification towards high-value cash crops not only provides economic benefits but ameliorates stress also on natural resource base (Sharma 2005, Chauhan and Sharma 2010, Sharma 2011). Keeping in view the importance of practicing traditional agriculture system and adoption of new agriculture techniques, the present study was conducted to explore the changes in traditional agriculture system, process of technology adoption, and sources of awareness about new technology and the opportunities for the future of ongoing crop diversification in the remote mountainous regions of Garhwal Himalayas.

MATERIAL AND METHODS

The study has been conducted in the Ukhimath block of Rudraprayag district, Uttarakhand. Multistage random sampling technique was followed to select the sampling units where a household was the sampling unit. First stage was selection of Ukhimath block from Rudraprayag district, followed by selection of six villages namely, Triyuginarayan, Sersi, Barasu, Narayankoti, Kothera and Devsal at the second stage to represent agriculture diversification and technology adoption. In third stage households from each village were selected. A total of 122 households were selected randomly from these villages with sampling intensity $\geq$10% from each village. The data on different aspects of agricultural development were collected through semi-structured questionnaire and personal interview method during 2014. The data were analysed using simple statistical tools like averages, percentages etc. using MS Excel (Chauhan and Sharma 2010). Binary logistic regression method was used to find out the important factors influencing

technological adoption by using SPSS 16. The derivatives of the likelihood estimates of the coefficients of infiuencing factors yield the probability of being in one of the two groups (adopters or non- adopters). Each coefficient is a measure of the strength of response of the dependent variable for the independent variables. For the present study, a number of contextual variables were regressed with the dependent variable Y to derive estimates of the parameters (βi values). The binary logistic model is specified as:

$$E(Y)= \beta_0 + \beta_1 * X_1 + \beta_2 * X_2 + \beta_3 * X_3 + \beta_4 * X_4 + \ldots\ldots\ldots\ldots + \varepsilon$$

where the βis are population parameters of the model to be estimated, X_i are the explanatory variables, and ε is an error term.

Table 1. Demography of the studied villages

Village	Geographical location		Elevation (m asl)	No. of house hold	Sampled house hold
	Latitude	Longitude			
Triyuginarayan	30°38' N	78°58' E	2269	235	49
Sersi	30°36' N	79°01' E	1694	43	8
Barasu	30°33' N	79°08' E	1614	171	32
Narayankoti	30°05' N	79°07' E	1523	30	7
Kothera	30°33' N	79°04' E	1557	32	9
Devsal	30°32' N	79°04' E	1496	53	17
Total				564	122

Source: Census 2011

RESULTS AND DISCUSSION

Changes in traditional agricultural system: The kidney bean, potato, amaranthus, finger millet, barnyard millet and wheat were the important crops grown in the study area from decades. The villagers reported that the production of traditional crops is decreasing gradually due to uncertain weather conditions, invading of wild animals and lack of marketing facilities for traditional crops. Due to this people have start growing vegetables and fruits because of high demands in the area for tourism and local needs which had eventually decreased the practice of growing traditional crops. The vegetable cultivation was practiced in all the sampled villages and covered 27 per cent of the gross cropped area and apple, citrus species, peach, plum was introduced in 10 per cent of the villages and covered only 2 per cent of the cropped area. The area under vegetables has increased continuously in the sampled villages. Due to climate change, the apple cultivation is continuously decreasing in the surveyed villages. Similar results have also been reported by Basannagari and Kala (2013) due to changing climate the apple cultivation as well as production has decreased in Himalayan region. Kidney bean and potato is another important cash crop and were grown on more than 50 per cent of the gross cropped area in earlier and the remaining area was devoted to traditional crops like wheat, barley. According to respondent major reason of changing cropping pattern is high economic value of new crops and decreasing yield of traditional crops. All the village have same cropping pattern due to their almost same location and climatic conditions.

The time lag in the adoption of new crop technology by farmers of different villages is very large. During the first year of availability of new crop technology, about 1 or 2 per cent of the sample farmers h adopted it. Across villages, the extent of adoption was highest by farmers in Trijuginarayan (8%). Proper training, demonstration and institutional support for construction of polyhouse and compost pit might have encouraged the farmers for adoption of these technologies. The large farmers were the first to adopt the new farm technology, followed by village well-off household. The households whose family members were employed in government or in non-farm jobs were also among the initial

Table 2. Table show the changes and adoption percentage of new crop

Village	Traditional crops grown earlier	New crops grown at present with traditional crops	New crop adoption (%)
Triyuginarayan	Wheat, Mustard, Barley, Potato, Barnyard millet, Finger millet, Kidney bean	Cabbage, French bean, green leafy vegetables, cucumber, radish, carrot, apple, plum, peach	18.4
Sersi	Wheat, Mustard, Barley, Potato, Barnyard millet, Finger millet, Kidney bean	Cabbage, French bean, capsicum, tomato, green leafy vegetables, cucumber, radish, carrot	100
Barasu	Wheat, Mustard, Barley, Potato, Barnyard millet, Finger millet, Kidney bean	Cabbage, French bean, capsicum, tomato, green leafy vegetables, cucumber, radish, carrot	12
Narayankoti	Wheat, Mustard, Barley, Potato, Barnyard millet, Finger millet, Kidney bean	Cabbage, French bean, capsicum, tomato, green leafy vegetables, cucumber, radish, carrot	100
Kothera	Wheat, Mustard, Barley, Potato, Barnyard millet, Finger millet, Kidney bean	Cabbage, French bean, capsicum, tomato, green leafy vegetables, cucumber, radish, carrot, plum, peach	31
Devsal	Wheat, Mustard, Barley, Potato, Barnyard millet, Finger millet, Kidney bean	Cabbage, French bean, capsicum, tomato, green leafy vegetables, cucumber, radish, carrot	5.7

adopters of the new technology. The farmers lacked training/ demonstration about the technology and new crops and secondly, the crop failure in the wake of adoption of new technology. Thirdly, there was lack of timely availability of improved seed and other necessary inputs. The lack of funds and awareness about the new technology was also reported to be an important factor for the non-adoption of new technologies. The most adopted technologies were the use of inorganic fertilizer (67.2%) followed by improved seed (34.4), vermicomposting (17.2), biocompost (13.9) and polyhouse (6.6). The low technology usage as in the case of polyhouse is circumscribed by non availability of suitable land, lack of funds and high cost of technology installation. The result suggests that the ample opportunities exist for the farmers to increase their use of new technologies and thus improve on the productivity and income.

Table 3. Reasons for change in the cropping pattern

Reason	Frequency*	Response (%)
Availability of new crop varieties	25	20.49
Emergence of new markets	46	37.70
Better transportation facilities	07	05.73
Increasing demand of new crops	56	45.90
High economic value of new crop	89	72.95
Decreasing the yield of traditional crops	69	56.55
Demonstration effect	23	18.85

Source: Field survey, 2014 *Multiple response recorded

Table 4. Proportion of farmers for the source of information about new farm technology

Source of information about new farm technology	Frequency*	Response (%)
Officials of the department of agriculture	57	46,7
Officials of the department of horticulture	71	58.2
NGOs/Other institutions	29	23.8
Relatives and friends	21	17.2
Nearby village farmers	10	8.2
Others	3	2.5

*Multiple response recorded

The officials of the department of horticulture and agriculture were the most important sources for providing information about new farm technology to the farmers which followed by NGOs and other institutions (Table 4). The government agencies also played an important role in hastening the diffusion of new agricultural technology by ensuring a regular supply of necessary inputs like seeds, fertilizers and plant protection chemicals and improving the market infrastructure like road network, transportation . The field level demonstrations and field visits of progressive farmers to other parts of the state also helped in the dissemination and adoption of new technology.

Increasing demand of produce encourages farmers to grow more and transportation of agri-produce from the fields to market heads. The next important factor was decline in demand of traditional crops like *Eleusine coracana* (Finger Millets), *Echinochloa frumentacea* (Barnyard Millet) due to changing food habits of people. The availability of favourable micro climatic niches for growing high-value crops was another factor of change in cropping pattern. The availability of new crop inputs like hybrid seeds, chemicals and fertilizers also hastened the change in cropping pattern.

The results of the logistic regression show that the most important factors influencing the adoption of technologies were education of household head (HHedu), household income (IncomeL), and extension contact (ExCont). The household income was significantly related to innovation adoption. This implies that innovation adoption increases with increase in income. According to Iheke (2010),

Table 5. Estimated coefficients and other statistics of the logistic regression equation

Variable	B	SE	Wald	Sig.	Exp(B)	95 per cent CI for Exp (B)	
						Lower	Upper
HHGend	.224	1.087	.042	.837	1.251	.149	10.530
HHage	.014	.028	.262	.609	1.014	.961	1.071
HHedu	.656	.298	4.835	.028	1.926	1.074	3.455
Hsize	.000	.169	.000	.999	1.000	.718	1.394
IncomeL	.943	.305	9.527	.002	2.567	1.411	4.672
TLand	.003	.018	.031	.861	1.003	.968	1.040
Hasset	-.109	.073	2.259	.133	.896	.777	1.034
ExCont	2.218	.711	9.730	.002	9.190	2.281	37.036
Constant	-7.759	2.662	8.497	.004	.000		

Percent concordant = 78.7, -2 Log likelihood = 67.489, Cox & Snell R^2 = .383; Hosmer and Lemeshow Goodness-of-Fit Test = .55 (.79), Nagelkerke R^2 = 0.59
HHGend-Household head gender; HHage-Household head age; HHedu-Household head education; Hsize-Household size; IncomeL-Income level; TLand-Total land; Hasset-Household asset; ExCont-Extention contact

education increases the ability of the farmers to adopt agricultural innovation and hence improve their productivity and efficiency. This explains the direct relationship between education and adoption level. While extension services provide informal training that helps to unlock the natural talents and inherent enterprising qualities of the farmer and increase their ability to understand and work. These explain their significant and positive relationship with adoption of improved technologies. The increasing susceptibility of different crops to insect-pests and diseases, in particular of beans and potato, was reported to be a formidable threat to the ecological sustainability and economic viability of these crops (Sharma and Chauhan 2013) due to major crop damage/loss. The falling yield of existing varieties was another threat as 65% respondents reported. Erratic weather conditions like bouts of dry spell and hailing posed major challenge by 72% of the farm households. Some other challenges reported by the respondents included harmful effects on soil due to the adoption of same cropping sequences year after year and inadequate irrigation facilities. The problem has been compounded due to non-availability of inputs like good quality of farm yard manure and other micronutrients (zinc, lime, etc.). The climatic changes like the decrease in the snowfall over the years and consequent decrease in the amount of available water were reported to be yet another important threat to the existing high-value cash crops.

CONCLUSION

This study examined the impact of various technological, organizational, environmental, and inter-organizational factors on the adoption of farm technologies. The results of the analysis shows that education of household head, income level and extension contact has significant effect on the adoption of new farm technology. The adoption of new farm technology can improve the economic status of household. Thus, there is necessity of further research for more data-base assessment to attain enhanced understanding regarding the threats and opportunities associated with technology dissemination and adoption and factors which influence the adoption of new technology.

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Floristic Composition and Structure of Urban Landscapes of Agartala, Tripura

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Abstract: Urban parks, gardens and natural landscapes are better known for their non-market or intangible benefits than market or tangible benefits. An urban forest assessment is essential for developing a baseline from which to measure changes and trends. Urban open green spaces play an important role in offering town-dwellers a more stress free environment, irrespective of sex, age or socio-economic background. This paper assesses the perennial land use type, their floristic composition and structure of the urban forests of Agartala, Tripura. Multi-Stage Sampling was used to access the species composition, number, crown characteristics and tree characters. The results showed that the maximum land use type in the urban ecosystem belongs to the open spaces followed by housing area. A total, 111 species belonging to 92 genera and 48 families were reported. Three endangered and two vulnerable species were also reported. The maximum volume, frequency, abundance and density were observed for *Careya arborea* (2.25), *Artocarpus heterophyllus* (39.29), *Hevea brassiliensis* (12.50) and *Caryota mitis* (2.46), respectively. It was visualized that species occurring on landscapes used by various households had most of the species which contributed directly to their multifarious uses and similar was true with other land use practices.

Keywords: Urban forestry, Land use type, Floristic composition, Urban Tree diversity, Urban ecosystem

Urban population in India is more than 377 million (31.16%) of the total population in comparison to 25.70% and 27.82% in 1991 and 2001, respectively (Census India, 2001; 2011) and in Tripura 26.17 per cent people are staying in urban area, which is much higher from 17.50 per cent of 2001 census figure. Due to rapid urbanization, changes in landscape and urban environment have been witnessed in many cities and levels of urbanization have increased from 27.82 per cent in 2001 census to 31.16 per cent in 2011 census (Soffianian et al 2010). As urbanization is an unavoidable process, efforts could be taken for proper land use planning and natural resource management. Urban vegetation are the most significant and prominent component of the urban landscapes. Urban trees are called "the lungs of urban communities" (Kuchelmeister 2000, Yang et al 2005) due to purification of urban air by way of removal of pollutants. It is said that a tree planted in the city can be fifteen times more effective at combating the buildup atmospheric carbon dioxide than one planted in rural forest. This is because urban trees not only sequester atmospheric carbon, also reduce energy use and carbon emission by cooling cities in summer.

Urban vegetation, particularly trees, provides numerous benefits that can improve environmental quality and human health in and around urban areas. It is very clear now that average rise of global temperature is due to increase of CO_2 in our atmosphere. Greenhouse gases released from fossil fuels is one of the major contributors to surface temperature increase across the globe. Trees are the only cheapest and easiest source to clean and purify the air and reduce the atmospheric temperature by way of absorbing CO_2 from atmosphere in the process of photosynthesis (Moulton and Richard 1990, Nowak 1994a, IPCC 2007). Whenever consequence of trees is considered to mitigate the effect of global warming, only natural forest or forest in rural or jungle area gets imperative value. The role of forest or trees in urban area was always ignored earlier. Now a days forest or trees in urban area are getting importance in developing countries as well in India due to its non-market benefits (NMBs) or intangible benefits including public amenity, landscape and others multiple services related to improvement of air, water quality, building energy conservation, carbon sequestration, cooler air temperatures, reduction in ultraviolet radiation and noise reduction (Nowak 1994b, Coder and Kim 1996, Brack 2002) including social benefits like decrease in psychological stresses (Nowak et al 2006); quick recovery of patients (Ebenreck 1989) and a sense of wellbeing. In economic terms, urban trees offer benefits in the areas of energy conservation; microclimate improvement and increase in property values (Miller 1997, Akbari 2002). They also have aesthetic, socio religious and recreational value in urban contexts.

The importance of urban forests and trees have been studied by many researchers across the world like McPherson et al (1994); Chen and Jim (2008) on C sequestration in USA; Yang et al (2005) on the values of urban environments in USA and China, respectively. Structural or floristic diversity and phytosociological study of urban forest or Trees Outside Forest (TOF) is limited and at a beginning stage in our country. In India, limited work on urban tree species, its richness and biodiversity are available. Most of the researchers' preferred to study dense forest area only rather than urban area. In spite of much eco-sociological importance, urban trees in India have not yet received much attention due to limited studies. The present study has been undertaken to assess the tree biodiversity and vegetation analysis of urban forest of Agartala Municipal Corporation area of Tripura, India to document the urban trees and species diversity, population density which will in future emphasize on its importance in peri-urban and urban environments.

MATERIAL AND METHODS

Tripura is a third smallest state of India having an area of 10,491.60 km^2 bordered by Bangladesh to the north, south and west and two Indian states, namely Assam and Mizoram to the east. Agartala is the capital, hub of administrative and all economic activities of Tripura. Agartala Municipal Corporation(AMC). The study area is 76.504 sq km, which is 0.72 per cent of the state's geographical area and lies in between Latitudes 23°45' and 23°55' N and 91°15' and 91°20' E Longitudes and situated 12.8m above the mean sea level. As per 2011 census, Tripura state population was 36,73,917 (350 density km^{-2}), which is 0.30 per cent of the country's population. The population of Agartala city was 4,00,004 (Census 2011), which is 10.88 per cent of total state population and 41.60 per cent of total urban population of the state. Out of 20 urban local bodies in Tripura, AMC is the only largest and biggest urban local body. The administrative area of Agartala city has increased about 30.01 per cent from 58 .84 km^2 in 2001 to 76.504 km^2 in 2014 (Govt. of Tripura 2013).

Though Tripura is a hilly state but AMC area has a plain landscape and enjoy tropical monsoon climate. Climatically one calendar year could be divided into three distinct season namely winter from November to February, summer from March to May and rainy season from June to September. In Tripura rainfall is mostly received in June to September from south-west monsoon. Average rainfall of Agartala city is 220 cm, average temperature varies from 4° to 37.6°C and average humidity varies from 78 to 90 per cent. Howrah is longest perennial river of Tripura and passes through Agartala city. The soil is mostly red loamy and sandy soil. The AMC area is vulnerable to flood during rainy season. It is also vulnerable to earthquake as it is located in seismic zone five (V).

The area of AMC (76.504 km^2) was divided into 500 m^2 grid by superimposing map of AMC on Google map with the help of Tripura Space Application Research Centre (TSARC). A total of 365 full grids and 26 part grids fall within AMC area. A total of 10% grids (37) were randomly selected using excel generation random number. Partial grids were avoided. Within one grid 12 plot of 20 m x 20 m (0.04 ha) were identified from south corner of sample plot to north at 50 m interval of each plot for detailed survey. A guide map of AMC (1: 20,000 scale) was used to identify the sample plot location in the field. Cadastral map of AMC was also used to facilitate in field survey. For study, individual trees $\geq$10 cm in girth at breast height (1.37m) were enumerated. Shrubs and herbs were not recorded. Height and girth of trees were recorded using altimeter and tree caliper, respectively while crown, crown light exposure and species level identification trees were done in the field on visual observation. Longitude and Latitude of each grid and plot were also recorded using Global Positioning System (GPS) in pre designed field survey format Enumerations of all trees with in identified 444 sample plots were done from May, 2015 to December, 2016 at various intervals. Local names of trees were collected in consultation with local people, help from forest department officials and using Flora of Tripura (Deb 1981, 1983). Doubtful sample were collected and stored in herbarium for identification by taxonomists.

Girth at Breast Height (GBH) of sampled trees was converted into Diameter (D) by dividing the value of pi (π). Average Diameter at Breast Height (DBH) of all trees were calculated and arranged in 10 cm diameter classes. Similarly, heights of all measured tree species were arranged in 3 m height classes. Height and width of crown (N- S & E- W) of each tree were also measured in field to measure tree canopy cover. Crown light exposure of all trees was also measured by visual observation. Land use and land cover of all surveyed plots were also recorded directly from field into predefined 11 land use classes viz. Water Body, Park, Housing Area, Govt. Office, Road, Educational Institution, Play Ground, Religious Places, Cemented area, Open Spaces and Others. To analyse the level of diversity in tree vegetation, phytosociological parameters like frequency, relative frequency, density and relative density, relative dominance were calculated for all tree species using excel sheet following standard methods (Curtis and McIntosh 1950). The importance value index (IVI) for the tree species were also determined to assess the dominant species as the

sum of the relative density, relative frequency and relative dominance (Shannon 1963, Sahu et al 2008, Burak et al 2011). The number of trees were used as an indication of density. Shannon–Weiner diversity and Simpson dominance index (Simpson 1949, Shannon 1963) were calculated using Past-3 software.

RESULTS AND DISCUSSION

Floristic diversity: A total of 3470 trees (stem density 195.38 ha^{-1}) comprising 92 genera and 111 species belonging to 45 families were sampled in 444 sample plots (17.76 ha) of study area (Table 1). The distribution of tree species is largely dominated by families namely Fabaceae with 11 species (9.91% of total species) followed by Moraceae with 7 species (6.31%), Apocynaceae, Rutaceae and Myrtaceae with 6 species each (5.41%), Arecaceae, Euphorbiaceae, Malvaceae, with 5 species each (4.50%), Mimosaceae and Rubiaceae with 4 species each (3.60%) and Anacardiaceae, Lauraceae, Lythraceae, Combretaceae and Meliaceae with 3 species each (2.70%) and 7 least dominated families with 2 species each and another 23 families with one species each. Top 5 families contributing 57.76 per cent of total trees was Anacardiaceae which contributed 442 (12.74%) followed by Verbenaceae 434 (12.51%), Moraceae 424 (12.22%), Arecaceae 421(12.13%) and Meliaceae 277 (7.98%). Araucariaceae, Asteraceae, Bignoniaceae, Calophyllaceae, Nyctaginaceae, and Solanaceae are least contributing families in terms of number of trees in survey area (Fig. 1 & 2). The large number of species in study area indicates rich biodiversity in urban forest (Jim, 1986). In this study, highest percentage of tree species composition was found for members of Fabaceae. It has been posited that Fabaceae family is highly adoptable to AMC environmental conditions (Kuhns 2009 and Martin et al 2004).

Tree composition in surveyed area is markedly dominated by native species (86.48% and 96 species), over introduced (13.52% and 15 species) as these trees may have been existing prior to the development of city. Exotic or alien species may be introduced by residents or other means in the study area. Due to overwhelming dominance of native species in AMC area it maintains homogeneity of flora and in every 5 trees, 4 trees are of native species. In terms of abundance, out of 3470 trees, 3083 trees (86.48%) were native, 387 trees (13.52%) were introduced. Increased tree diversity minimizes overall effect of species specific insect or diseases. Presence of indigenous/native trees species favours biodiversity of the area and a spot to feel connection to nature by birds and animals. In other side many native species are not able to thrive in the artificial environments of our urban areas and the effect of climate change will exacerbate the situation (Kowarik 2013). Kuhns (2009) reported that native/ indigenous trees, are most apposite for local environments in contrast to exotics. In some cities like Phoenix, there appears to be a movement towards planting of native vegetation (Santamour and Frank 1990).

The result of the survey also indicated that it is not within the range of 30: 20 : 10 rule i.e., not more than 30 per cent of any one family, 20% of anyone genera or 10 per cent of species should be in an urban tree populations (Santamour 1990). In study area *Mangifera indica* constitute 12.73 per cent of total tree population which is not within recommendation of Santomour (1990). If we accept 30:20:10 rule strictly the study area will lose more urban canopy. It is vulnerable for pest and diseases attack if total populations represent more than 10 per cent from one species. It is also important that the majority of threats facing our urban trees are not from pest or diseases alone (Galvin 1999). They are also due to environmental stresses, too little water, too much heat, soil too hard and less in organic matter content. As urban soil is poor in humus or organic matter content, no tangible natural regeneration was observed in study area.

Of the 111 surveyed tree species, 85 (76.58%) species were evergreen and 26 (23.42%) species were deciduous. From the surveyed data it transpires that out of 3470 trees encountered in AMC area, 2759 (79.52%) were evergreen and rest 711(20.48%) trees were deciduous. *Mangifera indica* being highest (442 and 12.73 % of total trees) in total number of trees was the dominating evergreen species followed by *Artocarpus heterophylus* (434 and 12.50%) found in the survey area. Presence of 76.58 per cent of evergreen species also indicates that due to more rainfall in study area trees grow well and assimilate/storage more carbon by their huge numbers of leaves through photosynthesis. Among deciduous species *Gmelina arborea* (237 and 6.82%) was dominated the study area. The distribution pattern of individual species was uneven. Only 8 species showed equal to or more than 25% of frequency, 49 species showed equal to or more than 10 per cent of frequency and 54 species showed less than 10 per cent frequency.

All trees were grouped into 6 classes of average DBH ranging from 1-10 cm, 11-20 cm, 21-30 cm, 31-40cm, 41-50 cm and above 50 cm. The number of trees recorded in 11-20 cm DBH class was 1326 (38.21%) followed by 858 (24.72%) trees within 21-30 cm DBH. Above 51cm only 170 trees were found (Table 2). South zone of AMC represented highest numbers of trees followed by east. *Ficus bengalensis* (198.73 cm DBH) is the highest diameter tree in study area

Table 1. List of tree species recorded from Agartala Municipal Corporation (AMC) area

Local name	Species	Family	Phenology	Origin
Akashmani	*Acacia auriculiformis* Benth.	Fabaceae	Evergreen	Native
Acacia	*Acacia* indica (Poir.) Desv.	Mimosaceae	Deciduous	Native
Bel	*Aegle marmelos* (L.) Corrêa	Rutaceae	Evergreen	Native
Koroi	*Albizia procera* (Roxb.) Benth.	Fabaceae	Deciduous	Native
Albiziaspp	*Albizia lebbeck* (L.) Benth.	Fabaceae	Evergreen	Native
Samaneasaman	*Albizia saman* (Jacq.) Merr.	Mimosaceae	Evergreen	Native
Chatim	*Alstonia scholaris* (L.) R. Br.	Apocynaceae	Evergreen	Native
Kaju	*Anacardium occidentale* L.	Anacardiaceae	Deciduous	Native
Ata	*Annona reticulata* L.	Annonaceae	Evergreen	Native
Agar	*Aquilaria malaccensis* Lam.	Thymelaeaceae	Evergreen	Native
Arocaria	*Araucaria araucana* (Molina) K.Koch	Araucariaceae	Evergreen	Native
Supari	*Areca catechu* L.	Arecaceae	Evergreen	Native
Chamal	*Artocarpus chama* Buch.-Ham.	Moraceae	Evergreen	Native
Kathal	*Artocarpus heterophyllus* Lam.	Moraceae	Evergreen	Native
Deoa	*Artocarpus lacucha Buch.-Ham.*	Moraceae	Evergreen	Native
Kamranga	*Averrhoa carambola L.*	Oxalidaceae	Evergreen	Introduced
Neem	*Azadirachta indica Juss.*	Meliaceae	Evergreen	Native
Tula	*Bombax ceiba L.*	Malvaceae	Deciduous	Native
Tal	*Borassus flabellifer L.*	Arecaceae	Evergreen	Alien
Bougainvillea	*Bougainvillea glabra Choisy*	Nyctaginaceae	Deciduous	Introduced
Karach	*Pongamia pinnata (L),PIERRE*	Fabaceae	Evergreen	Native
Palash	*Butea monosperma (Lam.) Taub.*	Bignoniaceae	Evergreen	Native
Bottle brush	*Callistemon lanceolatus (Sm.) Sweet*	Myrtaceae	Evergreen	Introduced
Mandar	*Calotropis gigantea L.) Dryand.*	Apocynaceae	Evergreen	Alien
Kumira	*Careya arborea Roxb.*	Lecythidaceae	Deciduous	Native
Papaya	*Carica papaya L.*	Caricaceae	Deciduous	Introduced
Ornamental palm	*Caryota mitis Lour.*	Arecaceae	Evergreen	Native
Cassia fistula	*Cassia fistula L.*	Caesalpiniaceae	Deciduous	Native
Debdaru	*Polyalthia longifolia*	Annonaceae	Evergreen	Native
Parijat	*Cestrum nocturnum L.*	Solanaceae	Evergreen	Native
Tejpata	*Cinnamomum tamala (Buch.-Ham.) T. Nees & Eberm.*	Lauraceae	Evergreen	Native
Daruchini	*Cinnamomum verum J.Presl*	Lauraceae	Evergreen	Native
Lemon	*Citrus aurantiifolia (Christm.) Swingle*	Rutaceae	Evergreen	Native
Jambura	*Citrus maxima (Burm.) Merr.*	Ruraceae	Evergreen	Native
Orange	Citrus sinensis (L.) sbeck (pro. sp.)	Rutaceae	Evergreen	Alien
Coconut	*Cocos nucifera L.*	Arecaceae	Evergreen	Introduced
Barun	*Crateva nurvala Buch.-Ham.*	Capparaceae	Deciduous	Native
Krishna chura	*Delonix regia (Hook.) Raf.*	Fabaceae	Deciduous	Introduced
Chalta	*Dillenia indica L.*	Dilleniaceae	Evergreen	Native
Gab	*Diospyros malabarica (Desr.) Kostel.*	Febenaceae	Deciduous	Native
Haboni	*Diospyros ebenum J.Koenig ex Retz.*	Febenaceae	Deciduous	Native
Garjan	*Dipterocarpus turbinatus C. F.Gaertn*	Dipterocarpaceae	Deciduous	Native
Jalpai	*Elaeocarpus floribundus Blume*	Eleocarpaceae	Evergreen	Native
Rudraksha	*Elaeocarpus serratus L.*	Eleocarpaceae	Evergreen	Native

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Gum tree	*Eucalyptus tereticornis*	Myrtaceae	Evergreen	Native
Bat	*Ficus benghalensis L.*	Moraceae	Evergreen	Native
Dumur	*Ficus carica L.*	Moraceae	Evergreen	Native
Ficus	*Ficus religiosa L.*	Moraceae	Evergreen	Native
Garcinia	*Garcinia indica (Thouars) Choisy*	Clusiaceae	Evergreen	Native
Gandharaj	*Gardenia jasminoides J. Ellis*	Rubiaceae	Evergreen	Native
Gamai	*Gmelina arboreaRoxb.*	Verbenaceae	Deciduous	Native
Greeniamicrocos	*Grewia nervosa (Lour.) Panigrahi*	Malvaceae	Evergreen	Native
Rubber	*Hevea brasiliensis (Willd. ex A.Juss.) Müll.Arg.*	Euphorbiaceae	Evergreen	Native
Stalpadma	*Hibiscus mutabilis L.*	Malvaceae	Evergreen	Native
Jaba	*Hibiscus rosa-sinensis L.*	Malvaceae	Evergreen	Native
Kurcha	*Holarrhaena pubescens Wall. ex G.Don*	Apocynaceae	Deciduous	Native
Rangan	*Ixora coccinea L.*	Rubiaceae	Evergreen	Native
Jetropha	*Jatropha curcas L.*	Euphorbiaceae	Evergreen	Native
Jarul	*Lagerstroemia speciosa (L.) Pers.*	Lythraceae	Evergreen	Native
Mehendi	*Lawsonia inermis L.*	Lythraceae	Evergreen	Native
Shubhafal	*Leucaena leucocephala (Lam.) de Wit*	Mimosaceae	Evergreen	Alien
Litchi	*Litchi chinensis Sonn.*	Sapindaceae	Deciduous	Native
Medda	*Litsea glutinosa (Lour.) C.B.Rob.*	Lauraceae	Evergreen	Native
Chapa	*Magnolia champaca (L.) Baill. ex Pierre*	Magnoliaceae	Evergreen	Native
Melotus	*Mallotus philippensis (Lam.) Müll.Arg.*	Euphorbiaceae	Evergreen	Native
Mango	*Mangifera indica L.*	Anacardiaceae	Evergreen	Native
Sabeda	*Manilkara zapota (L.) P.Royen*	Sapotaceae	Evergreen	Native
Nageswar	*Mesua ferrea L.*	Calophyllaceae	Evergreen	Native
Pichli	*Microcos paniculata L.*	Tiliaceae	Evergreen	Native
Bakul	*Mimusops elengi L.*	Sapotaceae	Evergreen	Native
Sajna	*Moringa oleifera Lam.*	Moringaceae	Deciduous	Native
Tut	*Morus alba L.*	Moraceae	Evergreen	Native
Karipatta	*Murraya koenigii (L.) Spreng.*	Rutaceae	Evergreen	Native
Kamini	*Murraya paniculata (L.) Jack*	Rutaceae	Evergreen	Native
Banana	*Musa paradisiaca L.*	Musaceae	Evergreen	Native
Musanda	*Mussaenda roxburghii Hook. f.*	Rubiaceae	Evergreen	Native
Kanak	*Schima wallichii Choisy*	Theaceae	Evergreen	Native
Kadam	*Neolamarckia cadamba (Roxb.) Bosser*	Rubiaceae	Evergreen	Native
Karabi	*Nerium oleander L.*	Apocynaceae	Evergreen	Introduced
Shiuli	*Nyctanthes arbor-tristis L.*	Oleaceae	Evergreen	Native
Saranga	*Gliricidia sepium (Jacq) Walp*	Fabaceae	Deciduous	Native
Radhacharan	*Peltophorum Pterocarpum*	Fabaceae	Evergreen	Native
Khejur	*Phoenix sylvestris (L.) Roxb.*	Arecaceae	Evergreen	Native
Arboroi	*Phyllanthus distichus Hook. &Arn.*	Euphorbiaceae	Evergreen	Native
Amalaki	*Phyllanthus emblica L.*	Euphorbiaceae	Evergreen	Native
Kathgulap	*Plumeria alba L.*	Apocynaceae	Evergreen	Introduced
Jarul	*Lagestroemia parviflora Roxb.*	Lythraceae	Evergreen	Native
Guava	*Psidium guajava L.*	Myrtaceae	Evergreen	Introduced
Lalchandan	*Adenanthera pavonina L.*	Fabaceae	Deciduous	Native
Dalim	*Punica granatum L.*	Punicaceae	Evergreen	Alien
Asoca	*Saraca asoca Roxb.) Willd*	Fabaceae	Evergreen	Native

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Cassia	*Senna siamea (Lam.) H. S. Irwin & Barneby*	Caesalpiniaceae	Deciduous	Native
Bakful	*Sesbania grandiflora (L.) Pers.*	Fabaceae	Evergreen	Native
Sal	*Shorea robusta Gaertn.*	Dipterocarpaceae	Deciduous	Native
Amra	*Spondia spinnata (L. f.) Kurz*	Anacardiaceae	Evergreen	Native
Mahogany	*Swietenia mahagoni (L.) Jacq.*	Meliaceae	Evergreen	Native
Jam	*Syzygium cumini (L.) Skeels*	Myrtaceae	Deciduous	Native
Bhootijam	*Syzygium nervosum A.Cunn. ex DC.*	Myrtaceae	Evergreen	Native
Guluk jam	*Syzygium samarangense (Blume) Merr. & L.M. Perry*	Myrtaceae	Deciduous	Native
Tara	*Tabernaemontana divaricata (L.) R.Br. ex Roem. & Schult.*	Apocynaceae	Evergreen	Native
Tetul	*Tamarindus indica L.*	Fabaceae	Deciduous	Introduced
Segun	*Tectona grandis L.f.*	Verbenaceae	Evergreen	Native
Arjun	*Terminalia arjuna (Roxb. ex DC.) Wight &Arn.*	Combretaceae	Evergreen	Native
Bahera	*Terminalia bellirica (Gaertn.) Roxb.*	Combretaceae	Evergreen	Native
Haritaki	*Terminalia chebula*	Combretaceae	Evergreen	Native
Jiol	*Thespesia populnea (L.) Sol. ex Corrêa*	Malvaceae	Evergreen	Native
Rangil	*Toona ciliata M.Roem.*	Meliaceae	Evergreen	Native
Naichya	*Trema orientalis (L.) Bl.*	Cannabaceae	Evergreen	Native
Lohakath	*Xylia xylocarpa (Roxb.) Taub.*	Mimosaceae	Evergreen	Native
Bajna	*Zanthoxylum limonella (Dennst.) Alston*	Rutaceae	Evergreen	Native
Boroi	*Ziziphus jujuba Mill.*	Rhamnaceae	Deciduous	Native

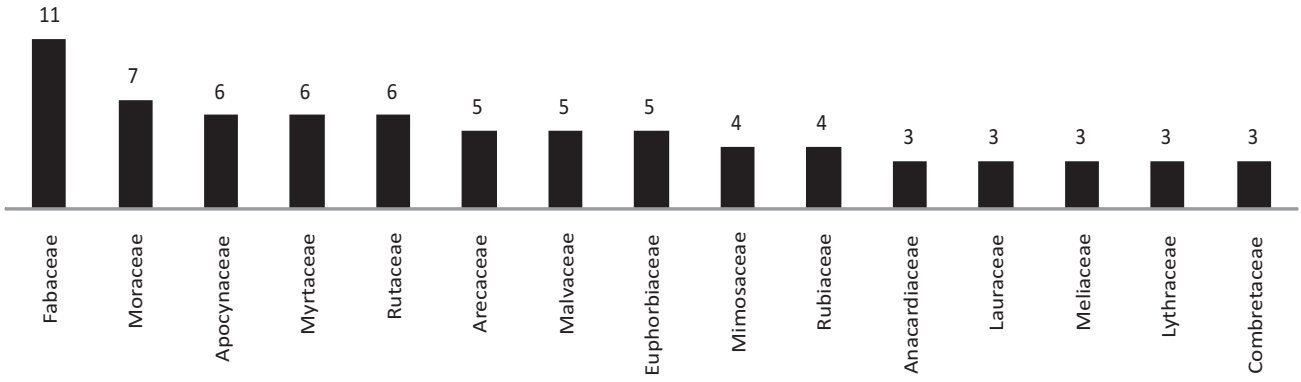

Fig. 1. Top 15 families with number of species

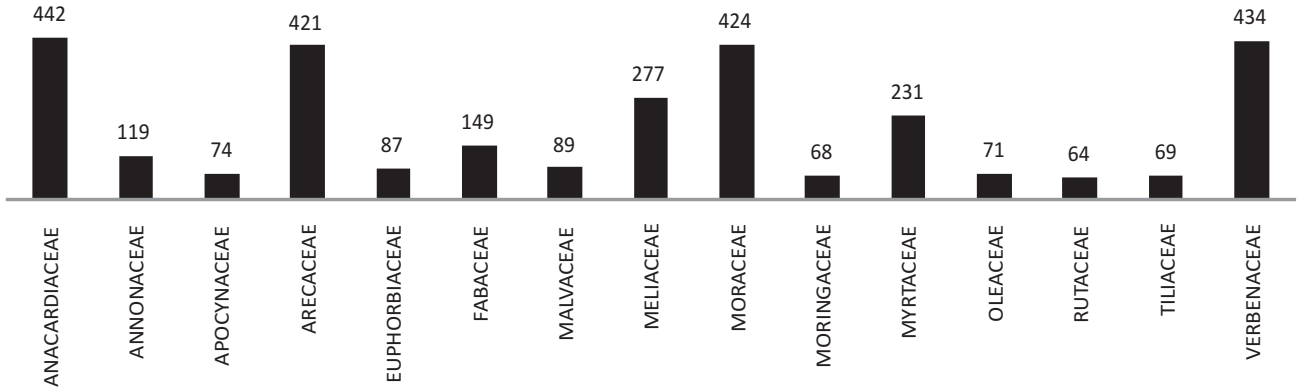

Fig. 2. Top 15 families with number of trees

and was found in the vicinity of temple/ place of worship.

Average height of all trees were grouped into 6 classes at 3 m interval ranging from < 3m, 4-6 m, 7-9m, 10-12m, 13-15m and above 16m. The number of trees recorded in 7-9m range was1138 trees (32.79%) followed by 1045 trees (30.11%) within 10–12 m range. Above 16 m height only 193 (5.56%) trees were found. *Eucalyptus tereticornis* (21.8 m) was the tallest amongst all trees (Table 3). Out of four zones of the study area, it was observed that south zone has highest number of trees as well as tree species followed by north and central zone. South zone with its highest number of trees and species is the greenest and best for residential area then central zone.

The majority of trees (38.21%) are in the lower size category 10-20 cm DBH. Urban forests are unique and there is no 'one size fits all' target distribution. The percentage of trees, tree species richness as well as diversity decreased with increasing diameter classes and as a result the percentage of medium and large trees is lower than the ideal scenario. Highest numbers of trees in respect of size (10-20 cm diameter classes) and height (7-9 m) was found in south zone followed by east. The presence of low number of higher DBH class tree species indicate that the vegetation or trees are young and have potential to withstand unfavorable climatic condition and have the capacity to sequester more carbon. The high proportion of average small size of trees in study area may be due to considering species, which are equal to or more than 10 cm girth at breast height (1.37m) resulting in a lower average tree diameter for entire population and inclusion of small stature species (e.g. fruit and flowering trees) that will never achieve large diameters. Moreover, during the process of rapid urbanization land use classification changes (from Agricultural land to residential area/concrete building) also lead to removal or destruction of old and big size trees. Besides, utility services like electricity, telephone and displaying of posters are most common hindrances of trees growth and development.

Studies on urban forest in Indian cities are juvenile but a few like Bangalore city (Sudha and Ravindranath 2000); Vishakapatnam City (Mitra 1993, Madan 1993) Chandigarh city (Chaudhry 2006, Chaudhry and Tewari 2010a,b) and Delhi (FSI 2009) and some studies such as biodiversity and carbon storage are also available for Bhopal (Dwivedi et al 2009); Jaipur (Verma 1985); Mumbai (Zérah 2007) and Pune (Patwardhan et al 2001). A few studies are also available for specific locations within the urban ecosystems, such as NEERI Campus, Nagpur (Gupta et al 2008) and Indian Institute of Science Campus, Bangalore (Mhatre 2008, Sankara Rao 2009). Urban forest in 43 ha of NEERI campus at Nagpur, Maharashtra has only 46 tree species (Gupta et al 2008). A comprehensive study on urban forests of 360 km^2 of Bangalore found 374 species in the different land-use categories (Mhatre 2008; Nagendra and Gopal 2010). The IISc campus, in Bangalore has rich collection of plants: 112 species of trees belonging to 32 families (Mhatre 2008). The campus is one of the rich species centers of Bangalore; others are Cubbon park (approximately 300 sp). The 114 Sq km area of Chandigarh which is considered to be the greenest city of India has about 200 species which includes about 66 multipurpose trees (Kohli et al 1994). The urban tree diversity of Karwar town of Karnataka comprises 3667 trees of 106 species, 86 genera and 40 families (Shivanand et al 2010). More over in Karwar town 70 per cent tree species are indigenous and 30% are introduced or exotic. Similarly several large sized sacred and religious trees such as *Ficus benghlensis* was found at the vicinity of temples and worship places. Top 10 species together account for about 65% of the total trees of Karwar town. Our study result in respect of species dominance, origin of species, a few species representing more than 50 per cent of total tree population, large size tree from *Ficus benghlensis,* which is scared tree found in vicinity of temple or worship place support the result of Karwar town of Karnataka urban tree diversity.

It is also revealed from a report on the findings from the UK i-Tree Eco pilot project that in Torbay city density of trees was 128 ha^{-1}, ten most common species accounts 67% of total trees and 51.4 per cent are native species which is also similar to the result of AMC area. These results of survey are closely related to size of survey area and methods of sampling. The phenological study indicates that evergreen trees constitute 77.48 per cent and deciduous trees 22.52 per cent of the total trees. The increased number of evergreen trees in study area could be due to favourable environmental factor. In this study also it was observed that residential areas are rich in number of species and trees. Residential/housing area normally are higher in species richness than the surrounding because of intentional introduction of trees by residents as a result of which 69.72 per cent trees are found in private ownership and rest 30.28 per cent in public domain (Walker et al 2009, Karp et al 2012, Adekunie et al 2013). These trees have many beneficial functions such as fruit, shade, fuel wood, timber and raw material for cottage industry and have been actively grown on roadsides and courtyards of their houses (Hope et al 2003). On the other hand, more plots were sampled from agricultural lands but plant species richness was lowest in agricultural land use areas. This finding was consistent with the general observation that intensive agriculture lowers species diversity.

As per International Union for Conservation of Nature (IUCN) Red Data Book, 2016, out of 111 species, 3 species

Table 2. Zone wise average DBH ranges of trees

Zone	Diameter Class						Total
	1-10cm	11-20cm	21-30cm	31-40cm	41-50cm	> 51 cm	
North	135	293	187	112	43	75	845
Central	75	267	185	86	27	14	654
East	181	358	229	81	27	21	897
South	159	408	257	132	58	60	1074
Total	550	1326	858	411	155	170	3470

Table 3. Zone wise height of trees

Zone	Height of tree (m)						Total
	< 3 m	4-6 m	7-9 m	10-12 m	13-15m	>16m	
North	13	118	249	225	167	73	845
Central	3	183	208	201	46	13	654
East	5	203	305	276	57	51	897
South	4	149	376	343	146	56	1074
Total	25	653	1138	1045	416	193	3470

(2.70%), 2 species (1.80%), 14 species (12.61%) and 92 species (82.88%) were recorded as endangered, vulnerable, least concerned and not assessed category, respectively. *Araucaria araucana*, *Calotropis gigantea and Citrus aurantifolia* are the species found in IUCN list under endangered and *Grewia nervosa* and *Sarca asoca* are the species recorded as vulnerable species (Fig. 3).

Moreover, it is also observed that in study area 2706 (78%) trees were standalone according to their visual crown light exposure and rest 764 trees (22%) were very close to each other in the stand. They are not getting light from all five directions (from north, south, east, west and top) and they face common competition for light for growth and survival. Of the 3470 trees, 2419 (69.72%) were found in private ownership area and 1051 (30.28%) in public domain. The maximum numbers of average GBH trees were found in private land and they are the product of regular thinning and pruning. It is also found that 2914 (84%) trees were planted and rest 556 (16%) was unknown (either planted or self-seeded) but in natural forest area natural regeneration is the only dominant method of regeneration.

Land use classification: Among 11 land use categories, open space category occupied highest area (42.22%) followed by others categories (19.14%). Land use classifications that represented lower percentages particularly less than 1 per cent of cover were educational institution (0.33%), religious places (0.86%) and park (0.31%) (Fig. 4).

This study found that plant species richness was highest under residential housing with 14 species in a single survey plot followed by 11 species in educational institution. Least 3 tree species was found in religious places.

Phytosociological description: Study indicated that Caryota mitis has the highest density (2.46) and IVI (12.5) among 111 species followed by density (2.08) and IVI (10) for *Hevea brasiliensis*. Some other tree species like *Mangifera indica* (7.85), *Tectona grandis* (6.98) and *Artocarpus heterophyllus* (6.93) also had good IVI though their density was comparatively less and frequency was highest in case of *Mangifera indica* followed by *Artocarpus heterophyllus.*

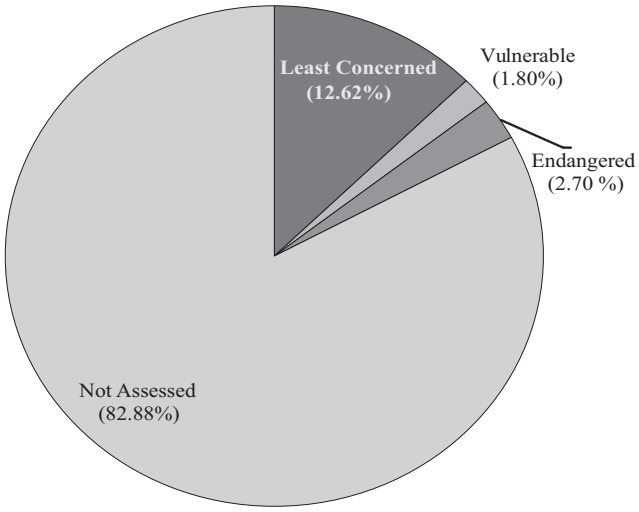

Fig. 3. No. of species according to IUCN status

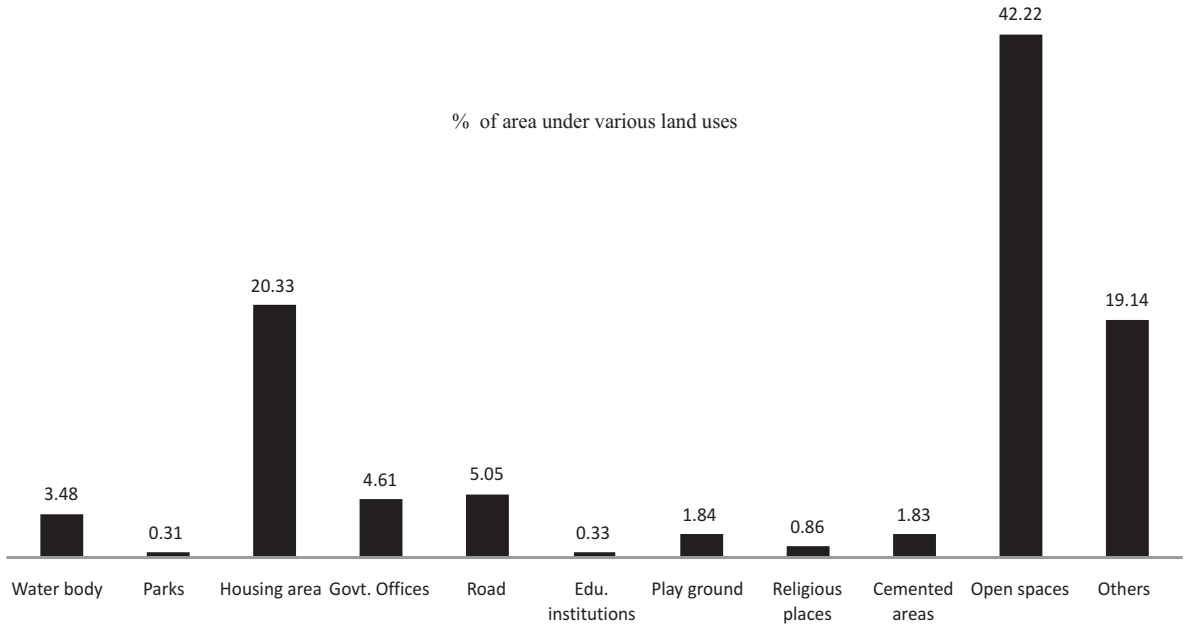

Fig. 4. Land use and land classification (% of area)

Citrus sinensis (0.94) and *Jatropha curcas* (1.03) are the 2 species having nominal IVI and minimum relative dominance of 0.02 and 0.11, respectively. The relative dominance of *Careya arborea* (4.95) was the highest followed by *Grewia nervosa* (3.66) and *Aquilaria malaccensis* (2.70). Although *Careya arborea* and *Grewia nervosa* have low IVI but they have highest basal area amongst all the species. 111 species as sampled in AMC area equated to 6.25 species/ha. Shannon - Wiener diversity index for study area was observed to be 0.1599 with Simpson (Dominance) - 0.84*0,* Shannon H -2.4413 and Evenness-0.6781. It was found that most abundant plant species is *Hevea brasiliensis* and it lack proper growth (basal area) whereas *Careya arborea* have highest basal growth but less abundant in study area. In addition, another two species *Caryota mitis* and *Tectona grandis* are also abundant with less basal area. Thus more than one species are dominant in the study area irrespective of their basal area. These finding supports the theories of co-dominant succession.

The distribution of 6 species namely *Mangifera indica, Artocarpus heterophyllus, Areca catechu, Tectona grandis, Azadirachta indica and Gmelina arborea* jointly made about 57.58 per cent of total population. This result corroborates with Jim (1986); Glibertson and Bradshaw (1985); Kunick (1987) and Sreetheran et al (2011), who observed that few tree species dominate in urban area. *Mangifera indica* and *Artocarpus heterophyllus* were found in maximum numbers and such state could be ascribed to their structure and above all fast rate of development, having ornamental, fruit value, shade and wood value.

Shannon and Weiner index represents entropy. It is a diversity index that considers the number of individual species as well as the number of taxa in study area. It ranges from zero to higher value. The community with only single taxa has the value of zero. Increase of the value of diversity index reveal higher number of taxa in the community. Simpson's dominance Index indicates the dominance of species in the stand. Simpson's dominance index (D) (Simpson 1949) was found 0.1599, which is much less than 1 and showed that the study site is not dominated by single species. If all species share same number of individuals D will be low. In a pure forest of 2 species, Simpson's dominance index will be 0.5. More species in a study area indicates less D value. Its range is 0.1 to 0.9. On the other hand though many species (111) are found during survey but a few species dominate the study area. Shannon–Weiner Index also known as species diversity (Shannon and Wiener 1963) for tree species (Shannon H) in the study area was found 2.4413, whereas, dominance index was observed as 0.339. The higher value of the diversity indices revealed a forest with high tree species diversity and abundance.

CONCLUSION

Biodiversity study of an area is necessary to assess ecosystem health because it affects key ecological process. Tree species are key components of the forest ecosystem and are responsible for forest architecture and influence the overall composition of forest community. Documenting the

pattern of tree diversity and their distribution provides a good database for management of present and future use. Tree species density, distribution and population structure analyzed in this study will be useful to the forest department, researchers, town and country planners and AMC itself as an urban trees inventory for their future plan. The preservation of these urban forest is essential and crucial not only for conservation of rich biodiversity but also for meeting the basic needs of the urban populace keeping in mind the pace of urbanization. The study recommends further research to be carried out to study succession pattern including tree species losses, regeneration ability, carbon sequestration and landscape planning. Within AMC area further planting of trees like mango and jackfruit should be restricted as population of said trees reached maximum in numbers to avoid monoculture. People prefer to plant fruit and flower trees in their small size of land holding than large trees which produce timber.

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Performance of Aonla with *in-situ* Moisture Conservation Techniques

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Abstract: The investigation was carried out to assess the response of various *in-situ* moisture conservations on growth and yield of anola under agroforestry system on sloping lands. The experiment was laid out with four treatments *viz*., farmer's practice of aonla planting with 0.027 m^3 pit (control), Pit filled up to 0.75 m with 1 m^3 pit, crescent shaped and V-shaped micro-catchment with 1 m^3 pit with four replications in runoff plots of 21 m × 14 m at 2% slope. Data revealed that soil moisture techniques significantly influenced the plant growth and yield of anola. Plant treated with V-shaped micro-catchment recorded highest plant height, collar diameter, canopy spread and number of branches (4.57 m, 12.45 cm, 4.62 m and 11, respectively) followed by pit filled up to 0.75 m, crescent shaped while minimum in farmer's practices. The percentage increase in fruit yield of aonla over farmer's practice was observed by 8, 13 and 40% with75% pits, crescent shaped and V-shaped micro-catchment, respectively. Based on present findings, V-shaped micro-catchment could be a suitable in-situ moisture conservation practice for enhancing growth and yield of aonla under agroforestry system.

Keywords: Soil moisture conservation, Aonla , *Emblica officinalis*, Litterfall, Agroforestry, Bundelkhand region

Conservation and sustainable utilization of natural resources are key issues of concern within the international community. Land degradation is a genuine ecological issue and requires urgent attention for sustainability of agriculture and economic development. Resource degradation leading to an unsustainable production system has lead to our focus on sustainable practices to assure continued production by adopting different soil and moisture conservation practices in the water scarce areas of Bundelkhand region. In this context, aonla (*Emblica officinalis* Gaertn.) based agroforestry system had the immense potential for conservation and sustainable utilization of resources for betterment of poor farmers. Bundelkhand region (7.04 M ha) of central India has undulating terrain, scarce vegetation cover, harsh climate and unfavourable edaphic conditions. Nearly 70 per cent of total area of the region has been affected by varying degree of erosion hazards (Tiwari and Narayan 2010). The productivity of red soils (alfisols), which comprises more than 50 per cent area in the region, is very low due to low water holding capacity, low fertility and limiting soil depth and even crop failure due to frequent drought and long dry spells during rainy season. Though the rainfall received is scanty and erratic but high intensity showers received during the monsoon season results in sizable runoff (runoff ranged between 50 to 60 per cent of rainfall and soil loss between 8 to 9 t ha^{-1} at 2 per cent slope on cultivated fallow land in red soils) and soil loss (Lakaria et al 2010). The water availability for crop production can be improved through various soil and water management practices. Rainwater *in-situ* conservation would give the possibilities of setting up of new ecological system and whereby ameliorate local environments in the semi-arid regions (Li et al 2002). The soil and moisture conservation techniques not only conserve the soil moisture but also check the soil erosion, which is useful for profitable cultivation of fruit crop under dry land condition. Anola is the most suitable semi-arid rainfed fruit crop for the red soils of Bundelkhand. The comparative economics worked out indicated that aonla with maize based agroforestry in semi-arid rainfed area is more remunerative than sole cropping system (Hiwale and Sharma 2011, Thakur et al 2017).

The systematic works on the growth and yield of aonla in combination with agriculture crops along with different soil-moisture conservation techniques has been lacking. Owing to better prospects, local farmers have adopted aonla for cultivation in their wastelands. It has been felt necessary to evaluate aonla performance and its intercrop yield under agroforestry system in Bundelkhand with special emphasis on rain water harvesting and resource conservation in the region as low rainfall, limiting soil depth and degraded land is

constraints for agricultural production. Taking into consideration above points, the present study has been undertaken in order to identify suitable soil-moisture conservation techniques on growth and yield performance of aonla under agroforestry system in the rainfed areas of Bundelkhand region.

MATERIAL AND METHODS

A field experiment was initiated in 2011 on 2 per cent slope at ICAR-IISWC Research Centre, Datia, Madhya Pradesh (78° 26' 16.56" E and 25° 42' 1.62" N). Soil of experimental site comes under red soil (alfisol), which has developed over granite and gneiss type parent material. Red soils in the region are shallow, holds less water content and often fail to support crop on residual soil moisture. These are course gravelly textured, shallow, neutral in nature, having low organic carbon and available nutrients. The experimental soil was sandy loam in texture with pH-7.3, organic carbon-0.31 per cent, EC-0.12 dS m^{-1}, available N, P and K-396.7, 20.5 & 230.7 kg ha^{-1}, respectively. Climate of the region is hot semi-arid. Average annual rainfall is 800 mm with high degree of spatial and temporal variations. The region has short rainy season concentrated mainly July-August, erratic rainfall, winter temperature plunges down to minus 1°C and summer boils up to 47°C. The detail weather parameter was depicted in (Fig. 1). Water stress conditions are common even in rainy season with high annual evaporation losses ranges between 1400 and 1700mm.

The present investigation was carried out at established anola plantation on ICAR-IISWC, Research centre, Datia (M.P.) during year 2015-16 and 2016-17 at the 4th and 5th year of anola plantation, respectively. The experiment was laid out in randomized block design (RBD) with four treatments *viz.*, (i) farmer's practice of aonla planting with 0.027m^3 pit (control), (ii) pit filled up to 0.75 m with 1m^3 pit, (iii) Crescent shaped micro-catchment with 1m^3 pit and (iv) V-shaped micro-catchment with 1m^3 pit with four replications on 2 per cent sloppy plots (14 m x 21 m) in an aonla based agroforestry system under red soils of Bundelkhand. The runoff plots (16 nos., plot size: 21 m x 14 m; 6 aonla plants per plot) with runoff gauging devices i.e., multi-slot devisors (11 slots) were installed in each plot. Aonla (Kanchan) plantation was done during *kharif* 2011 at the spacing of 7 x 7m by procuring uniform aonla budded from ICAR-CAFRI, Jhansi (UP). In each treatment, 6 plants were considered as a unit to present one treatment plan. The uniform horticulture and cultural practices were applied, which were grown purely under rainfed condition. In inter-spaces, alley cropping system such as black gram - Indian mustard crop sequence was practiced. Tree biometric parameters such as plant height, collar diameter, No. of branches and canopy spread were recorded. Plant height was measured with the help of

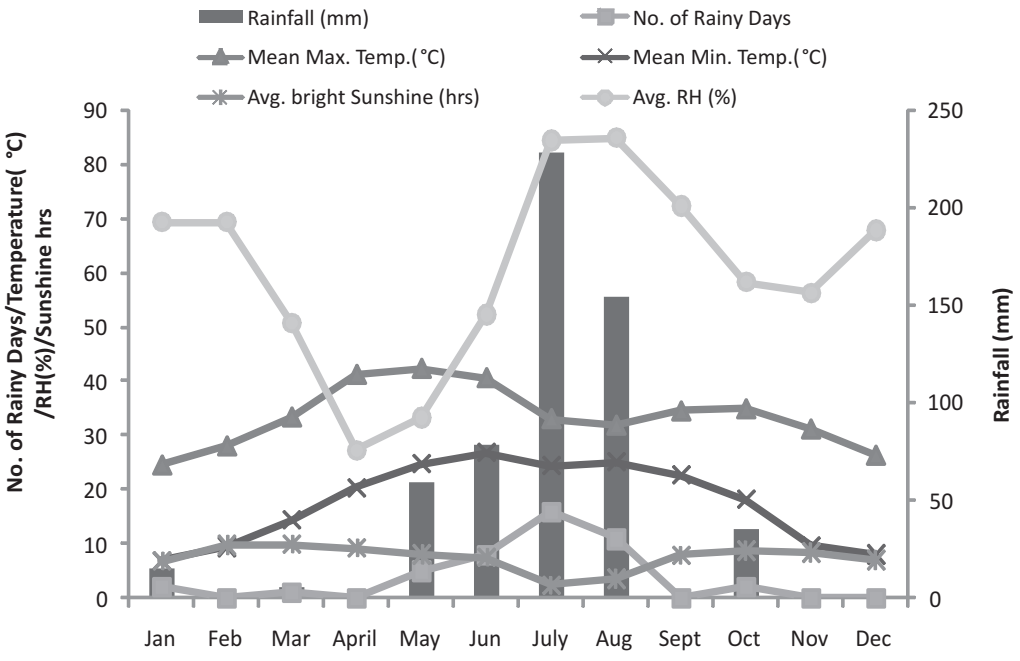


Fig. 1. Weather parameters recorded during the study period (Jan. to Dec. 2016) at Datia (M.P.)

measuring poles marked in metre and collar diameter was recorded with the help of digital caliper at a height of 10-15 cm above the ground level. Canopy spread was measured with the help of measuring tape in East-West and its perpendicular direction. Fruit yield and yield contributing characters like fruit dimension and weight; stone dimension and weight; fruit productivity during fruiting period i.e., 2015-16 and 2016-17. Ten fruits of uniform physiological age from each treatment plots were randomly selected on the date of observation from harvested fruits of the tree. The fruits were thoroughly washed and weighed. The fruit and stone dimension was measured. The pulp of fruit was separated and relative weight of seed was determined.

Litter fall estimation: Total 64 litter traps of standard dimension were installed in 16 plots at four directions i.e. East, West, North and South direction of tree under the canopy cover. Leaf litter fall were collected at one month periodic interval whole the year through litter traps but leaf falls were not collected during June to September (no leaf fall during the period). Litter biomass including rachis was calculated based on oven dried weight for all the samples and expressed in qha^{-1}.

Statistical analysis: The data were analyzed statistically as per the standard procedure by using online design resource server, IASRI (www.iasri.res.in/design), New Delhi and the means compared by the Duncan's multiple range tests (DMRT) at the $\leq$0.05% level of probability for interpretation of results and drawing conclusions.

RESULTS AND DISCUSSION

The growth parameters *viz*. plant height, collar dia., canopy dia. and no. of branches of aonla trees influenced significantly by adopting different *in-situ* rain water harvesting practice over farmer's practice of aonla planting (Table 1). The V-shaped micro-catchment was more effective than farmer's practices. Plant treated with V-shaped micro-catchment recorded highest growth parameters, plant height, collar diameter, canopy spread and number of branches (456.75 cm, 12.45 cm, 462.50 cm and 10.96 respectively) followed by pit filled up to 0.75 m and crescent shaped micro-catchment, while minimum in farmer's practices. The percent growth of anola was increased by 3, 5, 8 in plant height; 11, 9, 17 in collar diameter; 8, 12, 14 in canopy spread and 8, 11, 16 in number of branches under pit filled up to 0.75 m, crescent and V-shaped micro-catchment, respectively over farmer's practice. The plant height recorded with pit filled up to 0.75 m and crescent shaped micro-catchment was intermediate and at par with both treatment i.e. V-shaped micro-catchment as well as farmer's practice of aonla planting. Collar diameter also followed the similar trends. However, canopy spread (CS) and number of branches followed the similar trend in which only crescent shaped micro-catchment was at par with farmer's practice of aonla planting. Various *in-situ* soil moisture conservation practices helped in conserving higher rainwater, reduced soil and nutrients loss that in turn resulted in higher growth of aonla plants in comparison to farmer's practice. The findings of present study are in accordance with earlier findings of Kumar et al (2014) and Narayan et al (2017). The higher growth of aonla plants in V-shaped micro-catchment might be attributed to sufficient moisture regime in the root zone of tree during establishment phase, which improved the nutrient uptake by the plant. These results confirm the findings of several workers, who also reported enhanced growth of fruit plants due to better conservation of soil moisture (Badhe and Magar 2004, Oweis and Hachum 2006, Lal et al 2011). Similarly, *In-situ* moisture conservation was found to be effective in improving the tree survival and growth, canopy spread in bael by Shukla et al (2014).

Yield and yield attributes: First time fruiting in aonla were observed during 2015-16 at the age of 5th year from planting since 2011 in monsoon season. During 1st year of flowering and fruiting of aonla, only actual fruit yield and predicted yield were found significant by adopting soil moisture conservation practices and other yield attributes *viz*. fruit weight, Number of fruits $tree^{-1}$, stone and pulp percentage differences in aonla were found to be non-significant due to different soil moisture conservation practices. The maximum (13.91 kg) and significantly higher fruit yield was recorded under V-shaped micro-catchment than other treatment but, there was no significant differences among pit filled up to 0.75 m, crescent shaped micro-catchment and farmer's practice of aonla

Table 1. Plant growth parameters as influenced by different soil-moisture conservation treatments

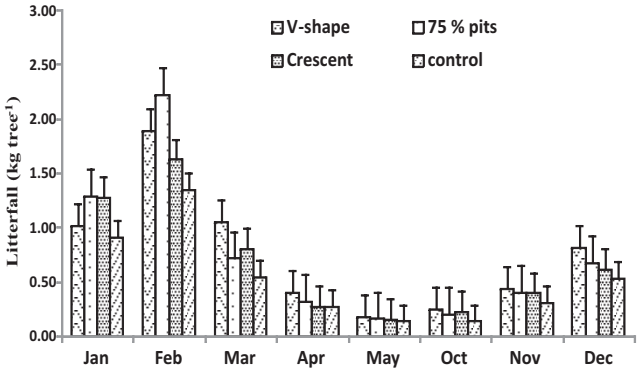
Treatment	Plant height (m)	Collar dia. (cm)	No. of branches	Canopy spread (cm)		
				East-West	North-South	Mean
V-shape	4.57^{a}	12.45^{a}	11^{a}	455.71	469.29	462.50^{a}
Pit filled up to 0.75 m	4.46^{ab}	11.51^{ab}	10^{a}	457.00	454.79	455.90a
Crescent	4.36^{ab}	11.74^{ab}	10^{ab}	434.38	444.79	439.58^{ab}
Control	4.25^{b}	10.60^{b}	9^{b}	405.21	406.04	405.62^{b}

Letter (^{a,b}) indicates significant differences at 5% level of significance ($p < 0.05$)

planting. However, during year 2015-16, the percentage increase in fruit yield of aonla over farmer's practice was observed by 13, 18 and 53 per cent under pit filled up to 0.75m, crescent shaped and V-shaped micro-catchment, respectively.

The fruit yield of aonla was influenced significantly by adopting soil moisture conservation practices. The total fruit yield of aonla (278.20 kg) was significantly higher with V-shaped micro-catchment than farmer's practice of aonla planting but at par with pit filled up to 0.75 m and crescent shaped micro-catchment (Table 2). The percentage increase in fruit yield of aonla over farmer's practice was observed by 8, 13 and 40 per cent under pit filled up to 0.75m, crescent shaped and V-shaped micro-catchment, respectively. The significantly higher fruit weight of aonla was with crescent shaped micro-catchment than farmer's practice of aonla planting but was at par with V-shape micro-catchment and 75% pits aonla planting. The significantly lower fruit weight was under farmer's practice of aonla planting than other treatment but at par with 75% pits planting. Number of fruits per tree and predicted fruit yield ha^{-1} (1557.40 and 103.06 qha^{-1}, respectively) were maximum and significantly higher under V-shaped micro-catchment than other treatments but, there were no significant differences among 75 per cent pits, crescent shaped micro-catchment and farmer's practice of aonla planting. More number of fruits might have increased the fruit yield per tree and productivity in aonla with V-shape micro-catchment treatment for higher moisture conservation potential. Kumar and Shukla (2010) also reported significantly higher yield and improvement in quality of Indian jujube through *in-situ* moisture conservation (bunding). The growth of aonla was better with *in situ* moisture conservation techniques as compared to control and started fruiting after four year of plantation and increased the yield was up to extent at 228.7 kg plant^{-1} (Solanki et al 2001).

Litterfall pattern: Usually, leaf falls in aonla were initiated in the month of October and almost ceases in May. Litterfall followed a pattern with a major peak during February (Fig. 2). The total litter fall of aonla during January 2016 to December 2016 was highest (6.04 kg tree^{-1}) with monthly variations



Note: Negligible litterfall was observed during June-September

Fig. 2. Effect of soil-moisture conservation techniques on monthly variation of litterfall production in Aonla

Table 3. Leaf litter fall as influenced by different *in-situ* moisture conservation treatment

Treatment	Litter fall (Kg/tree/year)	Litter fall (q/ha/year)
V-shape	6.04^{a}	12.33
Pit filled up to 0.75 m	5.99^{a}	12.23
Crescent	5.38^{ab}	10.98
Control	4.21^{b}	8.59

Letter (a,b) indicates significant differences at 5% level of significance ($p < 0.05$)

under V-shape micro-catchment and it was significantly higher than farmer's practice of aonla planting but at par with other treatment (Table 3). The maximum (12.33 q ha^{-1} year^{-1}) litterfall was recorded under V-shape micro-catchment, which may be attributed to higher vegetative growth of aonla due to enhanced availability and utilization of key growth resources (moisture and nutrients). Litter production indicated profound monthly variation and recording the highest litter fall per tree in February. More than 79-82 per cent of the litter fall in aonla occurred during December to March (Fig. 2). Litterfall followed a pattern with a major peak during February, which might be associated with natural senescence of leaves induced by temperature and/or moisture stress in the region In our study, litter quantity (12.33 q ha^{-1} year^{-1}) is slightly more than estimated 9.37 qha^{-1} reported by Hiwale and Sharma (2011) at 7 year age in semi-

Table 2. Aonla yield and yield attributes as influenced by *in-situ* moisture conservation treatments

Treatment	Actual fruit yield (Kg)		Avg. fruit wt. (g)		No. of fruit tree^{-1}		Predicted fruit yield (q ha^{-1})	
	2015-16	2016-17	2015-16	2016-17	2015-16	2016-17	2015-16	2016-17
V-shape	13.91^{a}	278.20^{a}	38.52	32.49^{a}	61.66	1557.40^{a}	4.73^{a}	103.06^{a}
Pit filled up to 0.75 m	10.74^{b}	224.56^{ab}	39.88	31.12^{ab}	43.03	1198.55^{b}	3.65^{ab}	75.62^{b}
Crescent	10.24^{b}	214.47^{ab}	35.95	34.22^{a}	53.95	1045.47^{b}	3.48^{b}	73.48^{b}
Control	9.08^{b}	198.84^{b}	40.45	28.76^{b}	37.62	1097.51^{b}	3.09^{b}	64.61^{b}

Letter (^{a,b}) indicates significant differences at 5% level of significance ($p < 0.05$)

arid rainfed condition without any soil moisture conservation treatment, which clearly indicated that soil moisture conservation technique has beneficial effect on plant growth and yield attributes. Leaf litter fall of 17.50 and 14.14 q ha^{-1} was recorded in NA-7 and NA-10 cultivar of aonla, respectively (Rathore et al 2011), which is slightly above to our study and litter fall is directly related with soil fertility, vegetative growth and tree age. Addition of leaf litter fall will improve the nutrients status, soil physical properties and soil fertility, which improved vegetative growth of aonla (Rathore et al 2011).

CONCLUSION

Aonla could be successfully grown by adopting the *in-situ* rain water harvesting practices in red soils of Bundelkhand. V-shaped micro-catchment could be a suitable for *in-situ* moisture conservation practice for enhancing growth and yield of aonla under agroforestry system on sloping lands in red soils.

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Physico-chemical and Nutritional Changes during Fruit Development in Mango (*Mangifera indica*) cv. Dusehri

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Abstract: Physico-chemical and nutritional changes during fruit development in mango fruit cv. Dusehri were observed at Punjab Agricultural University, Ludhiana. Fruit samples were analysed from 35 to 95 days after fruit set at 10 days interval. The fruit weight, fruit size and stone size increased linearly with advancement of fruit development. The titratable acidity declined with advancement of fruit maturity while total soluble contents increased towards the maturity of the fruit. Specific gravity of fruits increased with fruit growth but it showed a slight decline towards fruit maturity. With advancement of season the N, P, K concentrations of fruit pulp decreased while Ca, Mg contents increased. For micronutrients, no definitive pattern was recorded in Fe and Mn concentrations while Cu and Zn contents decreased with advancement of fruit maturity.

Keywords: Mango, Fruit development, Fruit quality, Nutrient content

Mango (*Mangifera indica* L.), is regarded as 'King of fruits', owing to its capitatitve flavor, excellent taste, attractive fragrance and sweetness (Valavi et al 2012) and are generally harvested at physiologically mature stage to get proper fruit quality. Immature fruits exhibits erratic ripening behaviour, may not develop full flavor and aroma, which ultimately leads to their rejection (Jha et al 2006). Information on the bio-chemical changes and correlation among different fruit characteristics at various stages of mango fruit development is important in determining the optimum harvest period to meet the market demand for specific purpose. Depending on the stage of maturity mango fruit is used for preparation of different dishes. The fruits at green stage is used to prepare pickle, chutney, raw mango squash, amb paapar and ripe mango are used to prepare RTS, squashes, jam, jelly, etc. Of the three parts of the mango, pulp is the most utilized part for human consumption (Shafique et al 2006). The time required for complete development and maturation of the fruits differs considerably from variety to variety, region where it is cultivated and the methods employed for determining the development rate. A series of bio-chemical changes such as degradation of chlorophyll, biosynthesis of carotenoids, anthocyanin, flavour components and cell wall degradation occurs due to ripening process.

Generally mango fruits are harvested before the onset of the climacteric to get best fruit quality (Jha et al 2006). Dusehri is most important variety of mango cultivated in northwestern region of India owing to its high yield potential and is mostly utilized for fresh fruit consumption. Knowledge about optimum maturity of this variety is of paramount importance to determine ideal time of fruit harvest. The objective of present study is to evaluate physico-chemical and nutritional changes in mango fruits at different stages of development.

MATERIAL AND METHODS

Fresh fruits of mango cv. Dusehri were collected from commercial bearing plants managed under uniform cultural practices in the orchard of Department of Fruit Science, Punjab Agricultural University, Ludhiana during the year 2016. The experimental site was situated at 30° 12 'N' and 74° 21 E with an altitude of 190 meters above the mean sea level. Fruits were picked manually at 10 days intervals starting from at 35, 45, 55, 65, 75, 85 and 95 DAFS for determination of various physico-chemical parameters viz., fruit weight, fruit size, specific gravity, fruit firmness, TSS, titratable acidity (TA) and nutrient concentrations. The stone size was observed from 65 to 95 DAFS. Fruit weight and stone weight was recorded with the help of electronic pan balance and expressed as mean weight in gram. The fruit size and stone size was measured and expressed in cm. The specific gravity was measured by water displacement method. The total soluble solids were recorded by digital hand refractometer (Atago Japan) and expressed in per cent. The TA content of fruits was determined by titrating juice against 0.1 N sodium hydroxide, using phenolphthalein as an indicator. For estimation of mineral elements, fruits from the fruiting

terminals of the plants were collected from all the directions. Fruits were rinsed with distilled water to remove surface residue and pulp was extracted from fruits and then were kept at 65°C in oven until it reached constant weight. Subsequently, pulp was grounded for further nutrient analysis. Nitrogen was analyzed by Kjeldahl's method using Kelplus semi-auto analyzer nitrogen estimation system (Pelican Equipment, India). For other elements, 0.50 g of samples was wet digested using concentrated nitric acid and perchloric acid (4:1 v/v). Phosphorus content of samples were determined by vandate-molybdate colorimetric method. Potassium was estimated by flame photometer. Pulp Ca, Mg, Fe, Zn, Cu and Mn concentrations were determined using atomic absorption spectrophotometer (Analyst 200, Perkin Elmer, Shelton, CT, USA). The nutrient contents were expressed on dry matter basis. Data were analyzed statistically to an analysis of variance (ANOVA) and difference among the means were determined by LSD test using the statistical analysis software version 9.3 (SAS institute Inc., Cary, NC, USA) at 5 per cent level of probability.

RESULTS AND DISCUSSION

Fruit weight: Fruit weight of mango cv. Dusehri increased significantly during fruit development (Table 1) and continued until end of fruit maturity. The mean maximum fruit weight (168 g) was at 95 DAFS i.e., on the last harvesting date. The increase in weight was slow at initial stages and then become rapid at middle stage of fruit development from 45 to 55 DAFS. Afterwards, the increment in fruit weight slowed down and a non-significant improvement in fruit weight was registered after 75 DAFS. The increase in weight might be due to both active increase in cell size and accumulation and storage of food materials in cells of the fruit flesh (Zhang et al 2006). Similarly, Weerakkody et al (2010) observed increase in weight of fruit with growth pattern throughout fruit development in 'Wonderful' cultivar of pomegranate.

Fruit size: The fruit size in term of length and breadth of mango fruits increased significantly during fruit growth (Table 1), the gain in size was continued till the end of fruit sampling. The mean maximum fruit length (9.92 cm) and fruit breadth (5.57cm) was on 95 DAFS. The increase in fruit length was greater than breadth and this increase become rapid in the middle stage of fruit development i.e., from 45 to 75 DAFS. After this stage the rate of increase in fruit size become steady and showed non-significant improvement. Wongmetha et al (2015) also recorded an increase in fruit size of mango during growth and length of mango is 58 per cent of its width at the end of maturity.

Stone size: The size of mango stone increased continuously during the period of fruit development from 65 to 95 DAFS (Table 1). The breadth of mango stone is approximately 30 per cent of its length at the end of sampling. Minimum stone length (7.5 cm) and stone breadth (1.64 cm) was at 65 DAFS, while the maximum at 95 DAFS. Greatest increase in stone breadth was observed from 65 to 75 DAFS and subsequently the increase in stone breadth was non-significant.

Specific gravity: Specific gravity of fruits harvested at initial sampling and fruits harvested at the end of sampling showed fluctuating pattern with regard to harvest time. Specific gravity of the fruit increased from 35 to 75 DAFS and then declined slightly towards end of sampling. However, highest specific gravity (1.061) was at 75 DAFS. Increase in specific gravity might be due to higher rate of accumulation or synthesis of food material. Similarly Narayana et al (1999) reported that specific gravity in 'Surkha' and 'Bombay Green' cultivars of mangoes was more than 1.0. Decline in specific gravity towards fruit maturity was also observed by Dubey et al (2003).

TSS content: TSS content of mango fruits was significantly affected during fruit development (Table 1). The TSS content during the initial period of fruit sampling was minimum (6.33%) and continuously increased till 95 DAFS (8.39 %). However, maximum increase in total soluble solids was from 35 to 55 DAFS. The increase in TSS content might be the

Table 1. Changes in physico-chemical characteristics during fruit development of mango cv. Dusehri

Time of sampling	Fruit weight (g)	Fruit length (cm)	Fruit breadth (cm)	Stone length (cm)	Stone breadth (cm)	Specific gravity	TSS (%)	Acidity (%)
35 DAFS	32.5	4.24	3.07	-	-	0.97	6.33	2.89
45 DAFS	63.2	5.56	4.39	-	-	0.99	6.74	2.94
55 DAFS	114.3	6.51	4.91	-	-	1.002	7.36	2.73
65 DAFS	130.0	8.53	5.04	7.53	1.64	1.009	7.41	2.55
75 DAFS	157.6	9.73	5.29	8.05	2.92	1.061	8.00	2.42
85 DAFS	164.4	9.89	5.54	8.73	3.16	1.055	8.14	2.18
95 DAFS	168.00	9.92	5.57	9.23	3.18	1.032	8.39	1.96
CD (p=0.05)	15.70	1.106	0.620	0.86	0.61	0.033	0.839	0.608

result of degradation of starch during the later stage of harvest maturity. Similar results were reported in persimmon fruits where TSS increased with advancement of fruit maturity (Candir et al 2009).

Titratable acidity: The titratable acidy content in the fruits decreased with the advancement of fruit maturity (Table 1). The maximum TA content (2.89%) was at 35 DAFS while the minimum acid content (1.96%) at 95 DAFS. This decline in acid content of fruits was slow up to 65 DAFS and afterwards rate of decrease in TA was higher. The decrease in acidity may be due to starch breakdown and sugar synthesis enzymes during ripening (Udea et al 2000). Similar, results were reported by Soares et al (2007) in guava fruit at different maturity stages.

Pulp macro-nutrient: Various macro-nutrients like N, P, K, Ca and Mg content of mango fruit pulp were significantly affected during fruit development period (Table 2). The concentration of N, P and K in pulp declined during the fruit development. However, the Ca and Mg followed an increasing trend with advancement in fruit development period. The highest nitrogen content in the pulp of the fruit was recorded at 35 DAFS. The fruit nitrogen content significantly decreased from 35 DAFS (1.35%) to 65 DAFS (0.67%) and afterwards significantly increased from 65 to 75 DAFS. The nitrogen content of fruit pulp was maximum at 35 DAFS (1.35%) and minimum was at 65 DAFS (0.67%). This difference may be due to nitrogen consumption by fruits for development process. The phosphorus content was higher in younger fruits at 35 DAFS (0.29%) then followed the steady decline upto 85 DAFS and a slight increase in P content was observed at 95 DAFS (Table 2). The lowest concentration of fruit pulp phosphorus was recorded on 75 and 85 DAFS i.e., 0.19 per cent. However, period of maximum decline of phosphorus was from 35 to 45 DAFS. The potassium content in fruit pulp increased from 35 to 45 DAFS and then declined till the end of sampling . Significant highest concentration of K was observed at 45 DAFS (1.43%) and lowest concentration at 95 DAFS (0.99%). The concentration of potassium showed steady trend from 75 to 95 DAFS. Ca content increased with age of fruits . Calcium content was highest in fruits harvested at 95 DAFS (1.91%), while the lowest concentration of calcium was at 35 DAFS (1.30 %). The period of maximum accumulation of calcium was 55 to 95 DAFS. Likewise, the concentration of Mg in the fruit pulp increased with advancement of fruit maturity. The Mg content was highest in fruits harvested at 75 DAFS (0.88%) and remain stable until 95 DAFS. The period of maximum accumulation of Mg was from 35 to 55 DAFS. Mirdehghan and Rahemi (2007) observed that most of the macro-nutrient in pomegranate fruit follow declining trend with advancement of season. The decline in nutrient concentration in early growth is largely the result of rate of nutrient accumulation less than of the growth of fruit.

Pulp micro-nutrients: The Fe concentration in the fruit pulp did not follow the definite pattern during growth (Table 2). It was significantly higher in the middle stage of fruit growth i.e., 65 DAFS (164.3 ppm) as compared to initial or final growth stages. Minimum concentration of Fe was observed at 35 DAFS (123.5 ppm). Similarly, greater fluctuations were observed in Mn content of pulp during fruit growth . The increment in Mn content of pulp was highly significant from 35 to 55 DAFS. Mn concentration was highest at 55 DAFS (33.96 ppm) and subsequently no change in Mn content was observed. The concentration of Zn decreased with the advancement of fruit maturity). Significantly higher Zn content (25.14 ppm) was at 35 DAFS and minimum at 95 DAFS (9.73 ppm). The decline in Zn content was quite apparent from 45 to 55 DAFS. Cu content decreased with **the** development of fruits . The content of Cu was highest in fruits harvested at 35 DAFS (25.52 ppm), while the lowest concentration was observed at 95 DAFS (14.39 ppm). Significant decrease in Cu content was recorded from 35 to 65 DAFS. Mirsoleimani et al (2014) examined seasonal variations of micro-nutrient contents, which was not uniform.

Table 2. Changes in macro and micro nutrient content in fruit pulp during fruit development of mango cv. Dusehri

Time of sampling	N (%)	P (%)	K (%)	Ca (%)	Mg (%)	Fe (ppm)	Mn (ppm)	Zn (ppm)	Cu (ppm)
35 DAFS	1.35	0.29	1.40	1.30	0.67	123.5	15.14	25.14	25.52
45 DAFS	1.19	0.24	1.43	1.49	0.77	131.3	21.93	22.12	24.35
55 DAFS	1.09	0.22	1.30	1.67	0.81	124.8	33.96	13.16	21.26
65 DAFS	0.67	0.20	1.13	1.76	0.85	164.3	23.74	10.13	18.47
75 DAFS	0.94	0.19	1.20	1.83	0.88	150.5	25.63	11.78	17.31
85 DAFS	0.92	0.19	1.00	1.86	0.88	143.9	23.30	10.04	16.32
95 DAFS	0.93	0.21	0.99	1.91	0.88	149.1	23.24	9.73	14.39
CD (p=0.05)	0.26	0.04	0.13	0.23	0.11	12.2	3.87	2.58	3.22

The decreasing trend of Cu and Zn was also observed by Nachtigall and Dechen (2006) in apple fruit.

CONCLUSION

Various physico-chemical characteristics and nutrient composition of mango fruits cv. Dusehri varied significantly with advancement of fruit development period. A linear increase in fruit and stone size was observed till maturity. Fruit growth was slow during initial period and becomes rapid at middle stage of fruit development. A continuous increase in specific gravity was observed during maturation but it declined during latter half of fruit growth. With fruit maturity the TSS increased while the acid content declined. The concentration of nutrients like N, P, K, Zn and Cu in pulp declined during the fruit development. However, the Ca, Mg and Fe followed an increasing trend with advancement in fruit development period.

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Effect of Surface Coatings on Physico-Chemical Characteristics of Stored Baramasi Lemon Fruits

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Abstract: The aim of this study was to access the efficiency of edible surface coatings on the extension of shelf life and fruit quality of Baramasi lemon *cv.* PAU Baramasi lemon-1. Mature light green, uniform and healthy fruits of Baramasi lemon *cv.* PAU Baramasi lemon-1 were harvested and subjected to surface coating with different concentrations (0.25, 0.50 and 0.75%) of chitosan, carboxymethyl cellulose and *Aloe vera* gel. The coated fruits were stored at 11±1°C & 90-95% RH and analyzed after 15, 30, 45 and 60 days for various physico-chemical parameters. Results revealed that mean maximum peel percentage (45.89%) sensory quality rating (7.21) and mean minimum total soluble solids (7.18%), reducing sugars (1.28%) and non-reducing sugars (0.72%) were observed in the fruits coated with chitosan @ 0.75 per cent. Moreover, no spoilage was observed in fruits coated with chitosan @ 0.75 per cent during the entire storage period. Therefore, Chitosan @ 0.75 per cent was found the most effective surface coating to enhance the storage life of Baramasi lemon fruits at low temperature storage conditions.

Keywords: Baramasi lemon, Edible coatings, Shelf life, Fruit quality

Citrus fruits are one of the world's most important fruit crops, known for their taste, nutritive value and widespread availability. Among the citrus, lemon is the third most important fruit after orange and mandarin. In India, fresh lemons are primarily consumed for a cooling effect in summers. Baramasi lemon (*Citrus limon* L. Burm) is an evergreen citrus fruit plant. In Punjab, winter crop of baramasi lemon matures in December and January and due to low demand of fresh lemons in these month a glut like situation occurs in the market, which leads to low returns to the farmers. So to regulate the market, there is a need to store the surplus lemon fruits during the winter months, but baramasi lemon are extremely sensitive to low temperature, so it is difficult to store in the commercial cold stores, which are generally operated at low temperature (Kaur et al 2014). The post harvest losses can be minimized by extension of shelf life through checking the rate of transpiration and respiration, microbial infection and protecting membranes from disorganization (Hayat et al 2017).

Recently, due to people's increasing concern about human health and environmental protection issues, the development of biodegradable edible natural coatings to maintain the postharvest quality of fruits and vegetables is considered as new option (Arnon et al 2014). Edible natural coatings comprised polysaccharides, proteins and lipids. These coatings provide a semipermeable barrier against oxygen, carbon dioxide (CO_2), moisture and solute movement; thereby reducing respiration, water loss and oxidation reaction rates (Ghost et al 2015). The present research was conducted to study the effect of surface coatings on storage life and quality of Baramasi lemon fruits under low temperature storage conditions.

MATERIAL AND METHODS

Fresh, fully mature, light green, uniform and healthy fruits of Baramasi lemon *cv.* PAU Baramasi lemon-1 were harvested in January and storage studies were conducted at Punjab Agricultural University, Ludhiana during 2017. Harvested fruits were selected and washed with chlorinated water (100ppm). Washed and shade dried fruits were coated with different coating materials *viz*; T_1, T_2 and T_3 - chitosan @ 0.25, 0.50 and 0.75%, respectively, T_4, T_5 and T_6 - carboxymethyl cellulose (CMC) @ 0.25, - 0.50 and 0.75% respectively, T7 ,T8 and T9-*Aloe Vera* gel @ 0.25 0.50 and 0.75% respectively, T_{10}-Control (uncoated). Coated fruits were air dried under shade and fruits from each replication of each treatment were packed in ventilated (5% perforation) corrugated fiber board (CFB) boxes with paper lining before storage at 11 ± 1°C and 90-95% relative humidity for 60 days. Fruit samples were analyzed for various physico-chemical properties after 15, 30, 45 and 60 days of storage.

Physical parameters: The percentage of peel was calculated on fresh fruit weight basis by dividing peel weight with weight of the fruit and then converted into percentage value. Fruit spoilage percentage was calculated by counting the total number of fruits that had rotten at each storage

interval. Sensory quality rating of fruits was done by a panel of six judges on the basis of Hedonic scale described by Amerine et al (1965). This scale consists of 1-9 points; viz: 9 (extremely desirable), 8 (very much desirable), 7 (moderately desirable), 6 (slightly desirable), 5 (neither desirable or undesirable), 4 (slightly undesirable), 3 (moderately undesirable), 2 (very much undesirable) and 1 (extremely undesirable) that describes the sensory quality of fruits. Total soluble solids were determined from the juice at room temperature with the help of hand refractometer (Model Erma, Japan) and expressed in percentage. The readings were corrected with the help of temperature correction chart at 20°C temperature (AOAC 1990). The reducing sugars were analyzed by the method suggested by AOAC (2000). The non-reducing sugars were calculated by subtracting reducing sugars from total sugars and multiplied by 0.93.

RESULT AND DISCUSSIONS

Peel content: The peel percentage of fruits decreased with the advancement of storage after 30, 45 and 60 days of storage (Table 1). The interaction between treatments and storage was significant. During entire storage period, highest peel percentage was observed in fruits coated with chitosan @ 0.75% and lowest in control fruits. Nanda et al (2001) reported higher peel percentage in shrink film wrapped fruits of 'Ganesh' variety of pomegranate during storage at 8, 15, 25^{o}C as compared to unwrapped fruits.

Fruit spoilage: The mean minimum (1.46%) fruit spoilage was recorded after 15 days and mean maximum (7.07%) was recorded after 60 days of storage (Table 1). After 15 and 30 days of storage, spoilage was recorded only in CMC @ 0.25 and 0.50% coated fruits, whereas, all other treatments showed no spoilage. After 45 days of storage, maximum (14.36%) spoilage was observed in the fruits coated with CMC @ 0.25% and minimum (1.12%) in the fruits coated with chitosan @ 0.50%. At the end of storage, no spoilage was observed in fruits coated with chitosan @ 0.75% and *Aloe vera* gel @ 0.75%. But, the maximum (16.73%) spoilage was observed in the fruits coated with CMC @ 0.25%. This might be due to the high antimicrobial properties of edible coatings, which reduces post-harvest decay. The results corroborate the findings of Bisen et al (2012) where fruits of 'Kagzi' lime when treated with chemicals and coatings showed less spoilage as compared to control fruits. Sogvar et al (2016)

Table 2. Effect of surface coatings on sensory quality of Baramasi lemon fruits during storage

S No.	Sensory quality rating (1-9)				
	Days after storage (DAS)				
	15	30	45	60	Mean
T1	7.05	6.95	6.32	5.50	6.46
T2	7.10	7.05	6.88	5.95	6.75
T3	7.20	7.60	7.25	6.80	7.21
T4	5.50	4.95	4.85	4.75	5.01
T5	5.97	5.02	4.92	4.82	5.18
T6	7.06	6.95	5.25	4.80	6.02
T7	7.02	6.85	6.25	5.45	6.39
T8	7.10	7.04	6.84	5.88	6.72
T9	7.20	7.45	7.05	6.66	7.09
T10	7.02	6.63	5.95	4.91	6.13
Mean	6.82	6.65	6.16	5.55	
CD (p=0.05)- Treatment: 0.04, Storage:0.02, Storage x Treatment: 0.09					

Table 1. Effect of surface coatings on peel content and spoilage of Baramasi lemon fruits during storage

S No.	Days after storage (DAS)									
	Peel (%)					Spoilage (%)				
	15	30	45	60	Mean	15	30	45	60	Mean
T1	46.03	44.55	42.49	38.82	42.97	0	0	0	3.74	0.94
T2	46.49	45.29	43.13	40.71	43.91	0	0	1.12	1.89	0.75
T3	47.95	47.01	45.26	43.32	45.89	0	0	0	0	0.00
T4	43.19	41.97	38.81	35.23	39.80	7.88	10.54	14.36	16.73	12.38
T5	43.34	40.36	38.42	35.01	39.28	6.74	9.55	11.88	13.65	10.46
T6	45.59	44.21	41.44	38.58	42.46	0	0	8.5	15.37	5.97
T7	44.85	42.86	40.32	36.05	41.02	0	0	3.07	6.63	2.43
T8	45.59	44.08	41.72	39.04	42.61	0	0	0	1.9	0.48
T9	47.47	46.15	44.35	41.24	44.80	0	0	0	0	0.00
T10	42.43	38.83	36.23	30.53	37.01	0	0	4.25	10.75	3.75
Mean	45.29	43.53	41.22	37.85		1.46	2.01	4.32	7.07	
CD (p=0.05) - Treatment: 0.04, Storage:0.02 Storage x Treatment: 0.08						CD (p=0.05) - Treatment: 0.03, Storage:0.02, Storage x Treatment : 0.08				

revealed that *Aloe vera* gel and ascorbic acid when used in combination on strawberry fruits reduced spoilage.

Sensory quality: Sensory quality rating of fruits in all the treatments decreased with storage period, except in chitosan @ 0.75% and *Aloe vera* gel @ 0.75% coated fruits where an increase in sensory quality rating was recorded up-to 30 days of storage and thereafter a decline was recorded up-to 60 days of storage (Table 2). The results are in confirmity with previous findings of Gol et al (2013) who reported that strawberry fruits coated with chitosan, carboxy methyl cellulose and hydroxypropyl methyl cellulose with different combinations such as CMC (1%), CH (1%) + HPMC (1%), CH (1%) + CMC (1%), HPMC (1%) showed higher palatability rating as compared to control fruits. Shahkoomahally and Ramezanian (2014) also observed that *Aloe vera* coatings when used with combination of citric acid and calcium chloride have beneficial effect on sensory characters of grapes.

Total soluble solids: The TSS content varied significantly on different storage intervals. An increase in TSS content was recorded with extension of storage period. After 30 days of storage the lowest (7.15%) TSS content was observed in the fruits coated with chitosan @ 0.75%, followed by the *Aloe vera* gel @ 0.75% (7.18%). However, TSS content was recorded highest (7.34%) in control fruits (Table 3). Similar trend was observed after 45 and 60 days of storage. This increase in total soluble solids with advancement of storage interval might be due to the moisture loss from fruits. The results are in agreement with findings of Hong et al (2012) who reported that guava fruits coated with different concentration of chitosan showed a slow increase in TSS content during storage. Shah et al (2015) observed that uncoated 'Kinnow' fruit (*Citrus reticulata*) showed significant increase in TSS content as compared to fruits coated with CMC and Guar Gum based Silver Nanoparticle coatings during storage.

Table 3. Effect of surface coatings on total soluble solids of Baramasi lemon fruits during storage

S No.	Total soluble solids (%)				
	Days after storage (DAS)				
	15	30	45	60	Mean
T1	7.19	7.26	7.28	7.30	7.26
T2	7.18	7.21	7.23	7.27	7.22
T3	7.14	7.15	7.19	7.23	7.18
T4	7.27	7.32	7.34	7.35	7.32
T5	7.25	7.31	7.33	7.34	7.31
T6	7.20	7.28	7.30	7.32	7.28
T7	7.25	7.30	7.31	7.33	7.30
T8	7.20	7.24	7.27	7.30	7.25
T9	7.13	7.18	7.21	7.24	7.19
T10	7.32	7.34	7.36	7.38	7.35
Mean	7.21	7.26	7.28	7.31	
CD (p=0.05) -	Treatment: 0.04, Storage : 0.02, Storage x Treatment: NS				

Reducing and non-reducing sugars: There was an increase in the content of reducing and non-reducing sugars in all treatments during storage. Among the treatments, mean minimum sugars (reducing and non-reducing sugars) were

Table 4. Effect of surface coatings on reducing and non-reducing sugars of Baramasi lemon fruits during storage

S No.	Days after storage (DAS)									
	Reducing sugars (%)					Non- Reducing sugars (%)				
	15	30	45	60	Mean	15	30	45	60	Mean
T1	1.33	1.34	1.35	1.37	1.35	0.77	0.78	0.79	0.81	0.79
T2	1.32	1.33	1.35	1.36	1.34	0.76	0.77	0.79	0.80	0.78
T3	1.26	1.27	1.29	1.30	1.28	0.71	0.72	0.73	0.74	0.72
T4	1.35	1.36	1.38	1.40	1.37	0.79	0.80	0.82	0.83	0.81
T5	1.34	1.34	1.38	1.39	1.36	0.78	0.78	0.81	0.83	0.80
T6	1.33	1.33	1.35	1.38	1.35	0.77	0.77	0.79	0.81	0.79
T7	1.33	1.35	1.37	1.38	1.35	0.77	0.79	0.80	0.82	0.79
T8	1.31	1.33	1.35	1.36	1.34	0.75	0.77	0.79	0.80	0.78
T9	1.27	1.28	1.30	1.31	1.29	0.71	0.73	0.74	0.75	0.73
T10	1.35	1.37	1.39	1.41	1.38	0.79	0.80	0.83	0.84	0.82
Mean	1.32	1.33	1.35	1.36		0.76	0.77	0.79	0.80	
CD (p=0.05)	Treatment: 0.03,Storage : 0.02, Storage x Treatment: NS					CD (p=0.05): Treatment: 0.03, Storage: 0.02, Storage x Treatment: NS				

recorded in the fruits coated with chitosan @ 0.75%, followed by the fruits coated with *Aloe vera* gel @ 0.75% but the maximum were recorded in untreated fruits (Table 4). An increase in reducing sugars during storage might be due to the breakdown of complex polysaccharides into simple ones. Shahid and Abbasi (2011) observed that bee wax coated 'Blood red' sweet oranges showed lowest reducing sugars as compared to control fruits when stored at 17-19°C.

CONCLUSION

Chitosan @ 0.75% maintained the high peel percentage and sensory quality during storage without any spoilage. This treatment also maintained the minimum total soluble solids, reducing sugars and non-reducing sugars during storage.

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