

INDIAN  
JOURNAL OF  
*ECOLOGY*

ISSN 0304-5250

Volume 45

Issue-1

March 2018



THE INDIAN ECOLOGICAL SOCIETY

# INDIAN ECOLOGICAL SOCIETY

([www.indianecologicalsociety.com](http://www.indianecologicalsociety.com))

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## Studies on Air Pollution Tolerance Index of Native Plant Species to Enhance Greenery in Industrial Area

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**Abstract:** Air pollution tolerance index of the native plants were assessed to evaluate their response to tolerance level of pollution by analyzing four biochemical and physiological parameters namely relative water content, pH, total chlorophyll and ascorbic acid content of twenty two plant species during the summer and monsoon seasons during 2016. On the basis of high air pollution tolerance indices the plant species *Mangifera indica*, *Albizia lebbek*, *Magnolia champaca*, *Psidium guajava*, *Bougainvillea spectabilis*, *Thespesia populnea* and *Terminalia catappa* are grouped as tolerant. The species *Bauhinia variegata*, *Tecoma stans*, *Tabernaemontana divaricate* and *Muntingia calabura* with low air pollution tolerance indices are grouped as more sensitive to air pollution. The species with high air pollution tolerance index are given importance and suggested for plantation to enhance greenery and to minimize air pollution. This may be technically helpful for air pollution management in the industrial area.

**Keywords:** Air pollution tolerance index, Native plants, Chlorophyll content, Plantation, Pollution management

Air is never found to be clean due to natural and man-made pollution discharge. Air pollutants and contaminants are present in the air in concentration that disturbs the equilibrium in the environment and tend to affect the living environment of human beings. It is clearly understood that evaluation of pollutants at their source does not provide correct information as minor pollutants are regarded dangerous than the major existing pollutants. Air pollution is a serious problem tackled by people worldwide. Rapid industrialization and road traffic in the urban areas fades the air quality emitting  $\text{SO}_x$ ,  $\text{NO}_x$ , CO, soot particles, heavy metals, organic molecules and radioactive isotopes (Bhattacharya et al 2013). The impact of gaseous emission into the troposphere and their movement in the biosphere by transformation reaction is mainly responsible for chronic and acute diseases (Rawat and Banerjee 1996). Various methods have been used in controlling air pollution, but growth of plants provide one of the best, low cost and simpler strategy of cleaning the atmosphere. Air pollution affect plants via leaves and indirectly via soil acidification (Kumar and Nandhini 2013). However, all the plants are not very sensitive to air pollutants. Some plants species can combat high levels of pollution and can be employed as indicators of air pollution. Several researchers during their research have understood that any air pollutant could affect plants growth (Roa 2006). It is clearly understood that plants show physiological changes in response to pollution, with season. This changes the pollution level and response of plants. Air

pollution tolerance index is an inherent quality of plants to meet air pollution stress which is presently of prime concern predominantly in urban and industrial areas of the world. Hence plants are employed to monitor air pollution by studying their tolerance level towards air pollution and can be employed as biological indicators of pollution.

A study of single parameter may not give a clear overview of pollution induced changes. In the present study air pollution tolerance index centered on four important parameters have been utilized for the identification of tolerance level of all selected plant species. The determination of air pollution tolerance index of native species of plants have always become an essential requirement. Air pollution tolerance level play a crucial role for the selected native plants for assessing tolerance level of pollution. In the present study a proper planning was done to select twenty two native plants present in the industrial zone, Thanneer panthal, Coimbatore, Tamil Nadu, India during two different seasons namely summer and monsoon. This would provide a low cost green tool to improve air quality and help in preserving biodiversity. Thus by monitoring and identifying the tolerant species available in this location it can be more effectively used by planners and green belt developers for effectively enhancing greenery and mitigating air pollution.

### MATERIAL AND METHODS

**Area of study:** Coimbatore formally known as Kovai is considered the Manchester of South India. It is one of the

industrial city and a major commercial centre in India. Thanneer panthal Peelamedu, suburb city of Coimbatore is attributed to the manufacturing sectors, factories, textile units and foundries. Thanneer panthal is located at 11° 2' 13" N 77° 1' 13" E.

**Sampling:** The study was conducted continuously for two different seasons namely summer and monsoon. A total of twenty two numbers of dominant varieties of native plants available around the industrial area were selected. The fully grown leaves from the selected plants present in abundance around the industrial area were collected during the early morning hours and carried to the laboratory and carefully stored for further examination done within a short period of 5 to 6 hours.

**Analysis of parameters:** The biochemical and physiological parameters like leaf relative water content, leaf extract pH, total chlorophyll content and ascorbic acid content were analyzed. These parameters were used to compute the air pollution tolerance index of the native plant species.

**Relative water content:** Three replicates of the fully expanded leaves of the plants were taken for study. The fresh leaves were then immediately weighed (F.W.). The leaves were then floated in a deionized water in a closed petridish under dim light. After hydration the samples were taken out of water and well dried using filter paper and immediately weighed to obtain fully turgid weight (T.W.). Then the samples were dried in oven at 80°C until a constant dry weight (D.W.) was obtained. All measurements were made using an analytical scale with precision of .0001g. The F.W., T.W. and D.W. values were used to calculate relative water content using the equation (Singh et al 1977).

$$RWC = [(F.W - D.W)/(T.W - D.W)] \times 100 \quad (1)$$

F.W T.W and D.W – Fresh turgid and dry weight of leaf sample in g

**Leaf extract pH:** Well cleaned fresh leaves of the plant leaf samples were taken for the determination of leaf extract pH. Using 10ml of the deionized water 0.5 g of the leaf samples were crushed and homogenized and transferred in to a beaker (Singh and Roa1983). The true mixture was filtered well using filter paper and the filtrate was examined for measuring pH.

**Total chlorophyll content:** Cleaned fresh leaf samples obtained was weighed using single pan balance. 1 g of the leaf sample was taken and was crushed using mortar and pestle. The liquid extract was mixed with addition of 10 ml of 80 percent acetone. The liquid portion was decanted into another tube and centrifuged at 2500 rpm for 3 minutes. The supernatant was collected and the absorbance was taken at 645 and 663nm using spectrophotometer. The chlorophyll content obtained during the analysis was calculated using

the equation (Arnon 1949).

$$\text{Chlorophyll a} = [(12.7 \times OD_{663}) - (2.69 \times OD_{645})] \times \text{dilution factor} \quad (2)$$

$$\text{Chlorophyll b} = [(22.9 \times OD_{645}) - (4.68 \times OD_{663})] \times \text{dilution factor} \quad (3)$$

$$\text{Total Chlorophyll} = [(20.2 \times OD_{645}) - (8.02 \times OD_{663})] \times \text{dilution factor} \quad (4).$$

**Ascorbic acid:** 1 g of the well cleaned sample of leaf extract was homogenized with 4percent trichloroacetic acid and centrifuged up to 2000rpm. To the supernatant charcoal was added, and shaken well. This extract is then centrifuged to remove the residue of charcoal. The volumes of the clear supernatant were noted and stored. 0.5ml and 1ml of the aliquot of the supernatant were used for determination. The assay volume was made to 2 ml with 4percent trichloroacetic acid solution. 0.2 to 1.0ml of the working standard solution containing 20 – 100µg of ascorbic acid respectively were taken and pipetted out into clean dry test tubes, the volumes of which were also made up to 2.0ml with 4% trichloroacetic acid solution. 0.5 ml of dinitrophenylhydrazine reagent were added to all the test tubes, followed by addition of 2 drop of 10percent thiourea solution. It is then incubated at 370°C for a time period of 3 hours. The osazones formed were dissolved in 2.5ml of 85percent sulphuric acid, in cold in drops, without any temperature rise. To the blank alone dinitrophenylhydrazine reagent and thiourea were added after the addition of sulphuric acid. The tubes were incubated for a period of 30minutes at room temperature, and then the absorbance was clearly read using spectrophotometer at 540nm. Using the standard graph the ascorbic acid content in the sample was calculated (Roe and Kuether1943).

**Air pollution tolerance index (APTI):** A total of four parameters namely relative water content, pH, total chlorophyll content and ascorbic acid form the basis for calculation of tolerance index. It is computed using the method adopted by Singh and Rao 1983.

$$APTI = \{A(T+P) + R\} / 10$$

A-Ascorbic acid content in mg/g, T-Total Chlorophyll content in mg/g, P-pH of leaf extract, R-Relative water content in %  
The air pollution tolerance index ranges were identified and classified into four different grades referring to (Liu et al 2008) as tolerant, moderately tolerant, intermediate and sensitive.

i) Tolerant:  $APTI > \text{mean} > APTI + SD$

ii) Moderately tolerant:  $\text{mean} < APTI < \text{mean} + SD$

iii) Intermediate:  $\text{mean} - SD < APTI < \text{mean}$

iv) Sensitive:  $APTI < \text{mean} < APTI - SD$

Where SD indicates is the standard deviation

## RESULTS AND DISCUSSION

**Relative water content:** In the present study *Psidium*

*guajava* has the maximum relative water content during summer season. The *Bougainvillea spectabilis* indicated a maximum value of water content during the monsoon season. The relative water content of the plants in the study area ranges between 55 to 98 percent. Large quantities of water are essential for the plant in maintaining physiological balance under stress. Higher relative water content have been reported as an indicator of drought resistance (Verma 2003).

**Leaf Extract pH:** The pH ranged from 4.5 to 7.5. The pH was higher in *Nerium oleander* in summer and *Bougainvillea spectabilis* exhibited a maximum value during monsoon (Kulkarni 2014). Plants having lower pH are more sensitive while higher pH around 7 are observed to be more tolerant (Singh and Verma 2007). High pH is associated with efficiency of conversion of hexose sugar to ascorbic acid. However reducing activity of ascorbic acid is pH dependent being more at higher pH. Plants with high pH value are found to show greater tolerance to stress (Miria and Anisa 2013).

**Total chlorophyll content:** The chlorophyll content of *Psidium guajava* was a maximum during hot summer. Chloroplast is the main attacking site for all air pollutants. It plays an essential role during photosynthesis by carbon dioxide fixation. The reducing power of chlorophyll is

dependent on its concentration. Higher level of total chlorophyll signifies its tolerance nature (Jyothi and Jaya 2010). Any reduction in the pigment chlorophyll signifies presence of air pollution (Chauhan 2010, Ninave 2001). The chlorophyll content of *Ficus religiosa* was maximum during monsoon. All other plants indicate lower value of chlorophyll content. Decrease in chlorophyll level in the industrial area is an indicator of higher level of pollution.

**Ascorbic acid:** Among the plants studied the maximum amount of ascorbic acid was in *Albizia lebbbeck* during summer season. The other plants indicated a lower value of ascorbic acid. The presence of low level ascorbic acid indicates its sensitivity towards pollutants. The reducing power of ascorbic acid is directly proportional to its concentration (Kumar 2013, Seyednjad 2011). The species like *Albizia lebbbeck* show maximum higher level of ascorbic acid during monsoon. Plants having high ascorbic acid content under conditions of pollution stress are found to be tolerant to pollutants (Varshney 1984).

**Air pollution tolerance index:** Air pollution tolerance index is the capacity of the plant species to defend air pollution. On this basis the plants were categorized in to tolerant, moderately tolerant, intermediately tolerant and sensitive.

**Table 1.** Bio-chemical changes of plants in industrial area –Thanneer panthal during summer

Plant species	RWC (%)	Leaf extract pH	Ascorbic acid (mg g <sup>-1</sup> )	Total chlorophyll (mg g <sup>-1</sup> )	APTI
<i>Nerium oleander</i>	93.21	7.39	0.52	0.28	9.72
<i>Tecoma stans</i>	79.70	6.67	0.68	0.21	8.44
<i>Pongamia pinnata</i>	87.71	5.58	0.24	0.35	8.91
<i>Mangifera indica</i>	95.15	6.71	1.33	0.46	10.47
<i>Azadirachta indica</i>	91.01	6.68	0.45	0.21	9.41
<i>Albizia lebbbeck</i>	89.09	5.66	2.64	0.15	10.44
<i>Thespesia populnea</i>	93.76	6.32	0.92	0.37	9.99
<i>Muntingia calabura</i>	69.80	6.76	0.91	0.43	7.64
<i>Annona squamosa</i>	82.65	6.84	0.39	0.13	8.54
<i>Phyllanthus emblica</i>	92.53	6.60	0.82	0.30	9.82
<i>Psidium guajava</i>	98.56	6.95	0.55	0.48	10.26
<i>Terminalia catappa</i>	96.80	6.57	0.42	0.25	9.96
<i>Jasminium sambac</i>	93.98	6.40	0.73	0.20	9.88
<i>Syzygium cumini</i>	61.49	7.10	1.15	0.15	6.98
<i>Allamanda cathartica</i>	72.66	5.83	0.39	0.34	7.51
<i>Bougainvillea spectabilis</i>	82.71	7.18	0.47	0.23	8.62
<i>Tabernaemontana divaricate</i>	76.92	7.11	1.02	0.28	8.45
<i>Hibiscus rosasinensis</i>	88.27	6.17	0.51	0.24	9.15
<i>Bauhinia variegata</i>	56.60	6.64	0.50	0.36	6.01
<i>Magnolia champaca</i>	85.09	7.02	2.60	0.30	10.41
<i>Ficus religiosa</i>	92.86	6.52	0.54	0.19	9.65
<i>Santalum album</i>	91.32	6.65	0.86	0.25	9.49

**Table 2.** Bio-chemical changes of plants in industrial area –Thanneer panthal during monsoon

Plant species	RWC (%)	Leaf extract pH	Ascorbic acid (mg g <sup>-1</sup> )	Total chlorophyll (mg g <sup>-1</sup> )	APTI
<i>Nerium oleander</i>	95.40	7.25	0.35	0.15	9.80
<i>Tecoma stans</i>	55.41	5.54	0.63	0.11	5.89
<i>Pongamia pinnata</i>	83.85	7.11	0.20	0.16	8.53
<i>Mangifera indica</i>	94.41	5.27	1.26	0.60	10.18
<i>Azadirachta indica</i>	77.65	5.50	0.15	0.18	7.85
<i>Albizia lebbbeck</i>	72.62	5.06	1.80	0.16	8.20
<i>Thespesia populnea</i>	87.25	5.58	0.93	0.24	9.27
<i>Muntingia calabura</i>	79.08	6.20	0.83	0.39	8.45
<i>Annona squamosa</i>	88.44	5.57	0.39	0.63	9.08
<i>Phyllanthus emblica</i>	78.46	6.54	1.42	0.33	8.82
<i>Psidium guajava</i>	86.27	6.28	0.42	0.22	8.90
<i>Terminalia catappa</i>	96.80	5.30	0.41	0.55	9.92
<i>Jasminium sambac</i>	90.88	4.69	0.54	0.12	9.34
<i>Syzygium cumini</i>	90.90	5.85	1.11	0.57	9.80
<i>Allamanda cathartica</i>	88.71	5.80	0.23	0.64	9.02
<i>Bougainvillea spectabilis</i>	98.39	7.32	0.27	0.22	10.04
<i>Tabernaemontana divaricate</i>	76.77	7.10	0.85	0.28	8.31
<i>Hibiscus rosasinensis</i>	88.43	7.21	0.26	0.59	9.05
<i>Bauhinia variegata</i>	62.47	6.64	0.38	0.48	6.51
<i>Magnolia champaca</i>	94.22	6.00	1.59	0.14	10.40
<i>Ficus religiosa</i>	74.84	5.89	0.40	0.79	7.75
<i>Santalum album</i>	78.65	5.09	0.64	0.77	8.24

Plants like *Nerium oleander*, *Mangifera indica*, *Bougainvillea spectabilis*, *Magnolia champaca* showing higher value in air pollution tolerance index were tolerant during monsoon seasons, whereas *Mangifera indica*, *Albizia lebbbeck*, *Magnolia champaca* with high value in air pollution tolerance index were also tolerant during summer and can be considered as much as a sink to reduce pollution stress. Plants like *Tecomastans*, *Bauhinia variegata* show lower value of tolerance index during monsoon and *Muntingia calabura*, *Syzygium cumini*, *Allamanda cathartica* and *Bauhinia variegata* during summer shows lower value in tolerance index. They are considered sensitive and hence are used as bio-indicators for monitoring pollution stress. On the basis of seasonal variation, the plants possessing highest air pollution tolerance index are considered and given priority for plantation at polluted industrial area in Thanneer panthal, Peelamedu, Coimbatore.

#### CONCLUSION

The importance of all trees, shrubs and herbs in controlling pollution was well clearly identified from the study. On the basis of classification of native plant species the tolerant

species and highly sensitive species are easily identified. The plants species like *Magnolia champaca* and *Mangifera indica* have higher air pollution tolerance index value and are found to be capable to combat against pollution and can be used as a very good sink to mitigate the problem of pollution while species like *Tecoma stans* and *Bauhinia variegata* having lower air pollution tolerance index are found to show less tolerance and can be used well as indicators of pollution. The tolerant native plant species have better chances of survival and growth in the industrial area. These tolerant varieties of plants can be hence recommended for pollution mitigation by planners and developers and also for greenery enhancement in an urban Industrial area in Thanneer panthal, Peelamedu with fast growing population in Coimbatore.

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**Table 3.** Air pollution tolerance index of plants

Plant species	APTI
<i>Mangifera indica</i>	10.47
<i>Albizia lebbek</i>	10.44
<i>Magnolia champaca</i>	10.41
<i>Psidium guajava</i>	10.26
<i>Bougainvillea spectabilis</i>	10.04
<i>Thespesia populnea</i>	9.99
<i>Terminalia catappa</i>	9.96
<i>Jasminum sambac</i>	9.88
<i>Phyllanthus emblica</i>	9.82
<i>Syzygium cumini</i>	9.80
<i>Nerium oleander</i>	9.80
<i>Ficus religiosa</i>	9.65
<i>Santalum album</i>	9.49
<i>Azadirachta indica</i>	9.41
<i>Hibiscus rosasinensis</i>	9.15
<i>Annona squamosa</i>	9.08
<i>Allamanda cathartica</i>	9.02
<i>Pongamia pinnata</i>	8.91
<i>Muntingia calabura</i>	8.45
<i>Tabernaemontana divaricata</i>	8.45
<i>Tecoma stans</i>	8.44
<i>Bauhinia variegata</i>	6.51

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## Agriculture Drought Analysis using Remote Sensing based on NDVI-LST Feature Space

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**Abstract:** Agriculture drought occurs due to rainfall deficiency and decreased level of residual soil moisture in cropping area and varies spatially with cropping pattern, available soil moisture and growing environment. In this study soil moisture index (SMI) value and crop growth is used to assess agricultural drought. The remote sensing (MODIS) data is used to estimate NDVI to analyse crop growth between 2010 and 2016. NDVI deviation values helps to identify crop growth at different stages and to define crop condition. SMI is calculated from the Landsat images using the NDVI-LST feature space. According to the SMI value below 0.2 indicates low or moderate moisture and above 0.2 refers to normal moisture condition. SMI for 2010 observed to be with 66% normal soil moisture, for 2016 it is only with 33% normal soil moisture. Integration of the crop condition classified image with SMI values helps to assess drought with four different classes like extreme drought, moderate drought, normal and no drought (better). For 2016, extreme drought, moderate and normal and no drought area was 14, 26 and 59%.

**Keywords:** Crop Condition, Normalized difference Vegetation index, Seasonal Max NDVI, Soil moisture index, Drought

Agricultural drought results in decline in productivity of crops, which is due to irregular rainfall and decrease in the residual moisture which is stored in the soil (Thenkabali et al 2004). Rainfall deficiency for long time results in decreased vegetation thus reducing photosynthetic activity, which causes low crop productivity. Remote sensing technology has been effectively using to study vegetation stress and to monitor drought conditions in large areas (Senay et al 2015). Vegetation indices are extremely used for drought studies. Normalized Difference Vegetation Index (NDVI) is effectively used for monitoring natural disaster (Rajkumar et al 2018), land use land cover classification (Franco and Mandla 2012) and most commonly used in drought studies (Vani and Mandla 2017). Vegetation Condition Index (Kogan 2001), Soil Adjusted Vegetation Index, Enhance Vegetation Index are some of the indices used for drought studies. Wang et al (2004) concluded that drought assessment serves as indicator to calculate soil water status. Land Surface Temperature is sensitive to water stress and relation of NDVI-LST is a indicator for monitoring vegetation health and drought in the middle of growing season (Karnieli et al 2010). The Vegetation Temperature Condition Index used for agriculture drought severity in rangelands (Damavandi et al 2016), Water Deficit Index (WDI) has inverse relation with NDVI-LST.

Soil moisture index (SMI) developed by using NDVI-LST relation. Surface soil moisture also used as an indicator for drought monitoring (Zhan et al 2004). NDVI-LST feature space method is shown as triangular feature space with surface features inside the triangle (Carlson et al 1984). Lambin and Ehrlich (1996) described the feature space of NDVI and LST in trapezoidal shape, which is an empirical parameter to estimate SMI. Parida et al (2008) assessed the agricultural drought in rice cropping area using SMI and rainfall data. In present study image based vegetation indices such as NDVI and SMI used to assess vegetation health and drought situation monitoring. The Moderate Imaging Spectrophotometer (MODIS) is used in the present study to assess crop growth and Landsat data used for developing SMI images.

### MATERIAL AND METHODS

**Study area:** The Anantapur is located in between tropical region of 13°30' and 15°-15' latitudes, 76°-50' and 78°-30' longitudes. The district is divided into 63 mandals and belong to the arid-ecological zone with hot bioclimatic condition with dry summer and mid winter. The annual rainfall of the district is 554cm. Deep loamy and clayey mixed red and black soils are observed in this area.

**Data:** MODIS13Q1 data was downloaded from LPDAAC (<https://lpdaac.usgs.gov>) and processed using ERDAS to generate NDVI time series images from 2010 to 2016 for only *kharif* season. Landsat 5 and 8 data was downloaded from the USGS website from 2010 to 2016. LULC maps were derived from Bhuvan portal and modified with current year using high resolution images. The LULC maps helps to identify cropping area. The rainfall data was collected from IMD from 2010 to 2016 to study rainfall deficit for 2016. The statistical data was collected from the Andhra Pradesh State Development Planning Society (APDPS) and Directorate of Economics and Statistics (DES). The crop calendar was collected from the Central Research Institute for Dryland Agriculture (CRIDA) website.

**Pre-processing:** The MODIS13Q1 data is available in HDF format and top of the atmosphere for red and near infra red bands was calculated. Landsat 8 images contains nine OLI bands and two thermal bands (TIR). The SMI images were generated for 2010 and 2016 using the Landsat images.

**Crop condition monitoring method:** The NDVI time series images were generated from MODIS data for the 2010 and 2016 years with cloud masking. The *kharif* season data was used for this study. Non agricultural area was masked using the LULC image for the Study area. For 2016 LULC map was not available, so to mask non agriculture area NDVI threshold delineating method was adopted and to delineate crop area with other land classes like permanently fallow areas. The NDVI images for each month was combined with maximum value composite (MVC) method and generated MVC images from June to November for every year and layer stacking was carried out for both years individually. The 2010 was normal year (without drought) and with sufficient rainfall, where as 2016 received shortage of rainfall. The 2016 NDVI profiles were compared with the 2010 year to calculate the deviation of NDVI. In case the difference between the NDVI for the current year with previous (normal) year is less than  $-0.075$ , then it will identified as worse condition. If NDVI difference is larger than  $0.075$  then it represents better crop condition, otherwise the crop condition in between these values considered as normal level (Wu 2010). The seasonal maximum NDVI values for the each pixel calculated gives seasonal maximum NDVI (SMN).

**Normalized difference vegetation index (NDVI):** NDVI is used to study the vegetation vigour (Rouse, 1994). Dense vegetation phenology reflects low in visible light and more near infra red (NIR) region. Sparse vegetation or the non vegetated area gives more reflectance in the visible and less in NIR. The NDVI is derived from the reflectance values of Red and NIR regions as ratio. NDVI is derived as:

$$NDVI = \frac{NIR - RED}{NIR + RED} \quad (\text{eq.1})$$

Where, NIR –Near Infra-Red band, R –Red band

The NDVI values are between  $-1$  and  $+1$ . Positive values increases with green vegetation and negative values indicate the non-vegetated surface features like water, ice, snow or clouds.

**Land surface temperature (LST):** Thermal bands were used for the determination of the land surface temperature (LST). The sixth band is the thermal band for Landsat -5 and band 10 in the Landsat -8 TIR sensor to measure top of atmosphere (TOA) radiance first and deriving brightness temperature next. The brightness temperature is in Kelvin this can be converted to Celsius.

Step 1: The conversion of digital number (DN) into spectral radiance (L) using eq.2.

$$L = LMIN + (LMAX - LMIN) \times \frac{DN}{255} \quad (\text{eq. 2})$$

Where L = Spectral radiance, LMIN = 1.238 (DN value 1), LMax = 15.600 (DN value 255), DN = Digital Number

Step 2: Conversion of Spectral radiance to brightness temperature in Kelvin

$$T_b = \frac{K_2}{\ln(K_1 + 1)} \quad (\text{eq. 3})$$

Where:  $K_1$  607.76 (Landsat -5) and 774.89 (Landsat -8 band 10),  $K_2$  1260.56 (Landsat -5) and 1321.08 (Landsat -8 band 10),  $T_b$  = Surface Temperature

Step: 3 Conversion of brightness temperature from Kelvin to Celsius

$$T_b (\text{Celsius}) = T_b - 273 \quad (\text{eq.4})$$

**Soil moisture index:** soil moisture index is computed based on the NDVI/LST feature space. NDVI and LST used as input parameters for model and the empirical coefficients are used to estimate warm edge and cold edge from linear regression equation of LST-NDVI resulting in trapezoidal shape (Fig. 1). The A-C in the figure shows the upper side of the trapezoid, which indicates high LST values for unique NDVI values, this is considered as warm edge. The B-D indicates low LST values for unique NDVI and treated as wet edge, which indicates well water conditions.

SMI defined as:

$$SMI = \frac{LST_{max} - LST_{min}}{LST_{max} + LST_{min}} \quad (\text{eq. 5})$$

Where, LSTmax, LSTmin and LST –maximum, minimum and land surface temperature for NDVI

The empirical parameters are calculated from eq.6 and eq.7

$$LST_{max} = a_1 \cdot NDVI + b_1 \quad (\text{eq.6})$$

$$LST_{min} = a_2 \cdot NDVI + b_2 \quad (\text{eq.7})$$

Where,  $a_1, a_2, b_1, b_2$  are empirical parameters

The maximum NDVI value for given month (selected

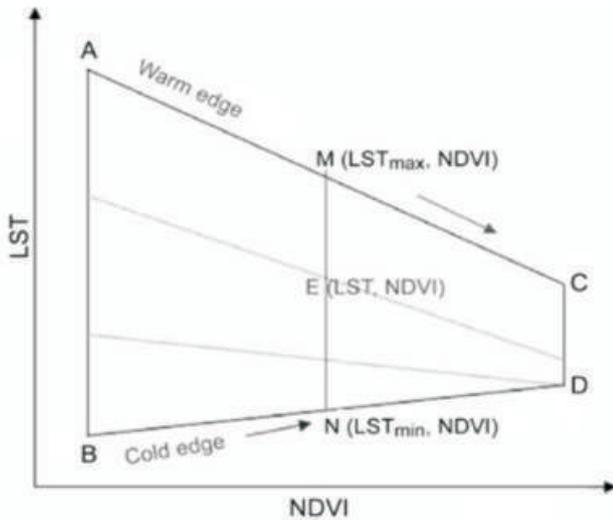


Fig. 1. Scatter plot of LST-NDVI feature space

using the profile NDVI images observing visually) for 2010 October and September 2016, landsat images were used to generate the NDVI/LST feature space. The feature space contains cluster of values with uniform values in trapezoid shape, where the extreme values are eliminated to build true relationship between NDVI-LST. Integrating the crop condition studies with the soil moisture index values and generated drought condition maps.

## RESULTS AND DISCUSSION

The study area comes under the hot arid area which having the low to medium available water content and the length of crop growing period is 90 days. The NDVI profiles were employed for these images based on the mean values for each biweekly products. It is noticed that NDVI values were continued to be approximately uniform till August 2016 like normal year but decreased due to low rainfall in 2016. The SMI mean values varied during crop peak stage between 2010 and 2016.

**Crop condition:** The NDVI profiles shown similarity in June and July months for 2010 and 2016. The deviated values are in between  $-0.003$  to  $0.01$ , which indicates the starting period of the season with normal crop condition. In August 2<sup>nd</sup> fortnight, September 1<sup>st</sup> fortnight, October 2<sup>nd</sup> fortnight and Nov 1<sup>st</sup> fortnight NDVI deviation is more than  $-0.075$ , which indicates the worse crop condition. In August the deviation values were increased negatively upto  $-0.078$  due to less rainfall. It was also observed that the crop growth also decreased. November images are indicating that the harvest of the crop done earlier. The seasonal maximum NDVI image were classified into classess depending on crop condions as low(worse), moderate, normal and better crop condition.

**Relationship between LST and NDVI:** The NDVI image for the 2010 and 2016 were showing variation in the values. LST values were most of the time varied between  $30-40$  degrees Celsius for 2016, in 2010  $20-30^{\circ}\text{C}$  and  $30-40^{\circ}\text{C}$  (Fig. 2). September and October month images were used in analysis, because of the reproductive period with more sensitive to thermal stress (due to soil moisture stress). The linear regression equation between NDVI and LST was given in Table 1. It is observed that dry edge slope is negatively correlated and wet edge is positively correlated.

The SMI was calculated using empirical parameters which are taken from linear regression equation. It was observed that the SMI value is in between  $0-1$ . SMI images were further classified into four categories low moisture ( $<0.1$ ), moderate ( $0.01-0.2$ ), normal ( $0.2-0.3$ ) and high soil moisture (above  $0.4$ ). The SMI images are shown in (Fig. 3). In 2010 SMI image showed that above 60% of area is under normal with high soil moisture. 2016 SMI image show 66% of area is under moderate and low moisture classes and only 33% area under normal to high moisture conditions. 12% area in 2010, and 6% area in 2016 were under high moisture class. In study area irrigation support was more the SMI image gave  $>0.3$  value (high moisture).

**Drought assessment:** The SMI mean values of 2010 and 2016 with each crop condition is extracted using the zonal statistics (Table 2). Results of SMI mean values for 2010 image were under threshold limit (above  $0.3$ ) with moderate and normal crop condition, for 2016 results show decrease of SMI mean values. SMI values combined with crop condition used to classify drought severity (Table 3).

According to the results derived from the integration of crop condition with SMI values study area is classified drought severity with four different classes like extreme drought, moderate drought, normal and no drought. The drought severity classified image was shown in (Fig. 4). The area percentage of the drought classes were calculated (Table 4).

From the results, it is demonstrated that the area under drought severity with moderate drought is less (8% area) and maximum (above 90%) cropped area is under no drought condition for 2010. Similarly during 2016, area under extreme, moderate and no drought is 14, 26 and 59 percent. It is observed that area under irrigation supply was well cropped and resulted as no drought condition in 2010 and 2016. The major portion of the study area falls under rainfed condition with ground nut cropping. Due to rainfall shortage, 30% of total area comes under the moderate drought condition in 2016. This study illustrates that integration of crop growth and residual soil moisture for the assessment of vegetation condition gives better results.

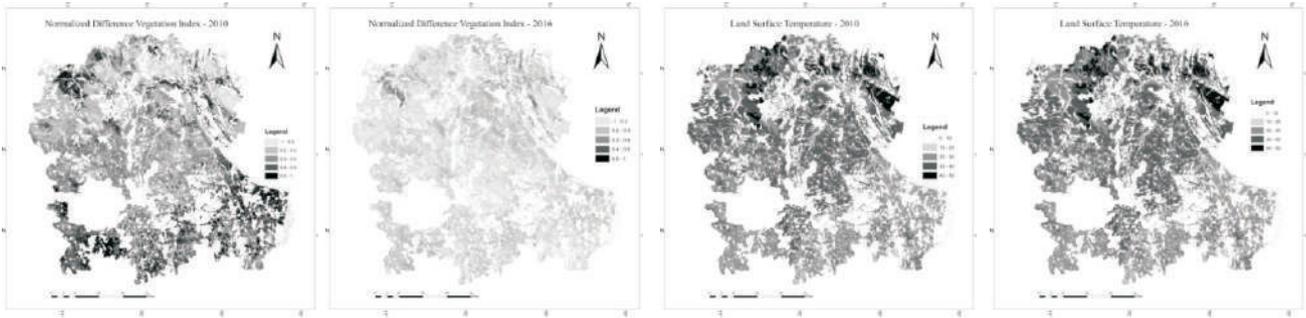


Fig. 2. NDVI and LST images for September 2010 and October 2016

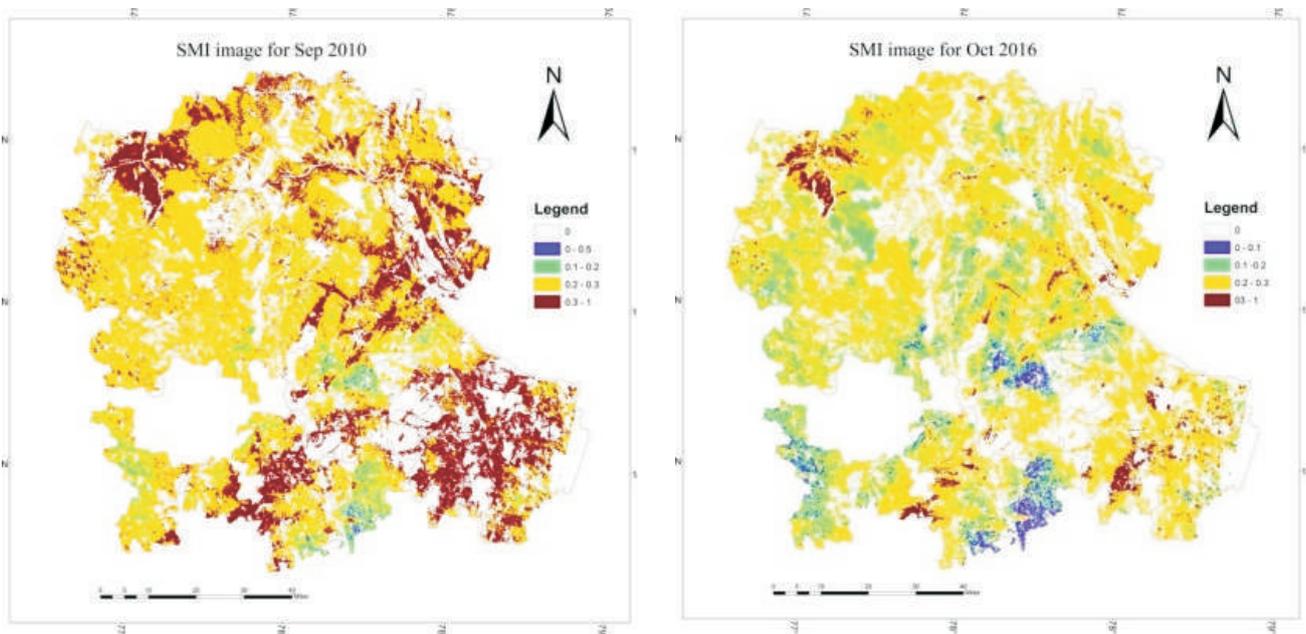


Fig. 3. Soil Moisture Index images for 2010 and 2016

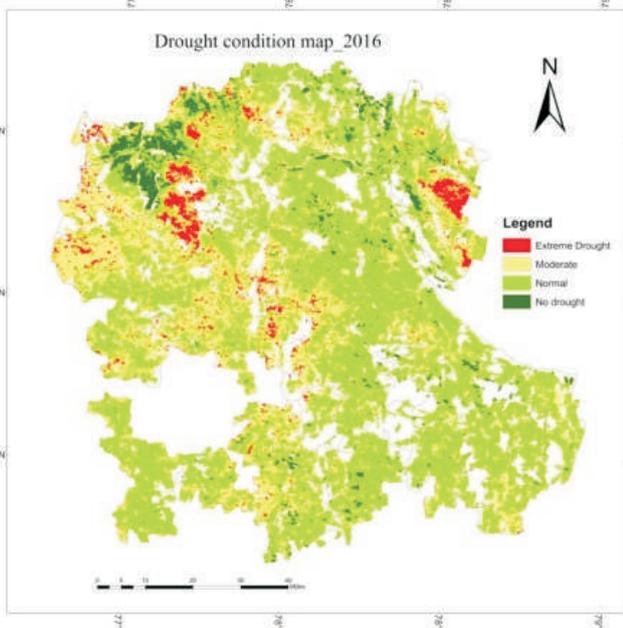


Fig. 4. Drought Map for 2016

Table 1. Dry and wet edges in NDVI/LST space estimated by linear regression

Date	DRY Edge	R <sup>2</sup>	WET Edge	R <sup>2</sup>
8 June 2010	$y = -10.18x + 26.51$	0.973	$y = 21.9x + 3.29$	0.941
28 Sep 2010	$y = -25.62x + 26.06$	0.982	$y = 9.11x + 23.03$	0.969
11 Aug 2016	$y = -18.04x + 35.42$	0.927	$y = -14.5x + 24.23$	0.978
14 Oct 2016	$y = -21.05x + 48.87$	0.94	$y = 37.28x + 10.56$	0.985
15 Nov 2016	$y = -19.18x + 38.87$	0.96	$y = 31.20x + 5.49$	0.949

Table 2. The SMI values for the crop condition maps

Crop condition/Years	2010			2016		
	Max	Mean	STD	Max	Mean	STD
Low	0.64	0.278	0.175	0.59	0.23	0.049
Moderate	0.81	0.317	0.101	0.59	0.251	0.050
Normal	0.99	0.366	0.125	0.70	0.281	0.057
Good	0.99	0.396	0.160	0.69	0.332	0.082

**Table 3.** SMI threshold values with crop condition

Crop condition	SMI values	Drought Class
Better and Normal	> 0.4	No drought
Better	>0.2 and <0.4	No drought
Normal	>0.2 and <0.4	Normal
Moderate	>0.3 and <0.4	Normal
Moderate	>0.2 and <0.3	Moderate drought
Normal and Moderate	>0.05 and <0.2	Moderate drought
Better, Normal and Moderate	Below 0.05	Extreme drought
Low	All values	Extreme drought

**Table 4.** Drought classes for 2010 and 2016

Drought condition	Cropped area in percentage	
	2010	2016
Extreme drought	0.08	14
Moderate	8	26
Normal	59	54
Better/Good	32	5

### CONCLUSIONS

This study provided accurate spatial and temporal information for drought assessment using remote sensing methods. Time series NDVI data gives crop profiles which are useful for crop condition assessment. Remote sensing approach like (SMI) technique has shown good agreement in identification of the occurrence, severity and distribution of drought in the study area by identifying water stress. LST in the study area is 30°-40° Celsius for 2016 and 20°-30° Celsius for 2010 were calculated. The SMI results revealed for 2016 that most of the study area (64%) is under moderate and low soil moisture. The drought classification for 2016, shows that area under extreme and moderate drought was 40 percent and under normal and no drought was 59 per cent.

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## Exploring Rainfall Scenario of Periyar Vaigai Command Area for Crop Planning

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**Abstract:** The present work was taken up, to understand the rainfall situation and its characteristics over the dry Periyar Vaigai Command (PVC) area located over the southern parts of Tamil Nadu. Data from 19 rain gauge stations over PVC area were utilized. Periyar Vaigai Command area has normal annual rainfall of 865 mm with considerable spatial variations (564 to 1052 mm). The normal annual rainy days of PVC area is 45. Rainy days clearly indicate a good distribution. Among the monsoons, NEM (20) had more number of rainy days than SWM (16), which clearly demarcates a good distribution during NEM that supports major cropping activities during the season. Crop sowing and establishment is decided by the month of peak rainfall; October was the wettest month while January was the driest month in terms of rainfall received. Second highest rainfall recorded was during November month followed by September invariably in all the locations. The minimum amount of rainfall required for cultivation of crops is 750 mm. Among the locations studied, Edayapatti, Viraganur, Gudalur and Pulipatti locations receives less than 750 mm. In these locations crops may suffer from water stress that may lead to decrements in crop yield and ultimately crop failure.

**Keywords:** Rainfall, Seasons, Variability and crop planning

Water is the most vital input for increasing agricultural productivity in tropical countries is beyond doubt, but its availability for irrigation is largely inadequate owing to uneven or uncertain rainfall patterns across regions as well as inadequate or poor management. Rainfall being a nature's blessing and drought a curse for the whole living world is decisive weather phenomenon for ensuring or threatening our food security. In semiarid tropics, climate-triggered risks are heavy for crop production. Characterization of these weather events would certainly be helpful in framing out the strategies to minimize the risk toward sustainable production (Pragyan Kumari et al 2014). To optimize agricultural productivity in the region, there is an urgent need to quantify rainfall variability at a local and seasonal level as a first step of combating extreme effects of persistent dry-spells/droughts and crop failure. Since rainfall that is heterogeneous, in particular, is the most critical factor determining rainfed agriculture, knowledge of its statistical properties derived from long-term observation could be utilized in developing optimal cropping strategies in the area. Apart from analyzing the variability, some authors have utilized probability analysis (Kumar et al 2014, Gill et al 2015) for crop planning. Studies by Seleshi and Zanke (2004) and Tilahun (2006) noted high variations in annual and seasonal rainfall totals and rainy

days and their importance in crop planning. On the other hand, the much-needed information on inter-/intra-seasonal variability of rainfall in the region is still inadequate despite its critical implication on soil-water distribution and final crop yield.

The agricultural activities in the PVC area are mainly rainfed dependent on monsoon rains. The yearly variation makes the planning of sowing and the selection of the crop type and variety rather difficult. In order to plan rainfed agriculture, rainfall amount, distribution and the length of the rainy period are important. In this study rainfall from 18 stations of PVC area are analyzed with the objective to determine the patterns of rainfall.

### MATERIAL AND METHODS

**Data:** Daily rainfall data of different 18 rainguage stations over Periyar Vaigai Command area was collected from Department of Economics and Statistics, Government of Tamil Nadu and Ground Water Division of Water Resource Department, Government of Tamil Nadu. Data was converted in to weekly, monthly and seasonal and variability over the different time series was worked out.

**Study area:** Periyar Vaigai Command area (Fig. 1) was taken for the study. Periyar Vaigai irrigation system is a trans-

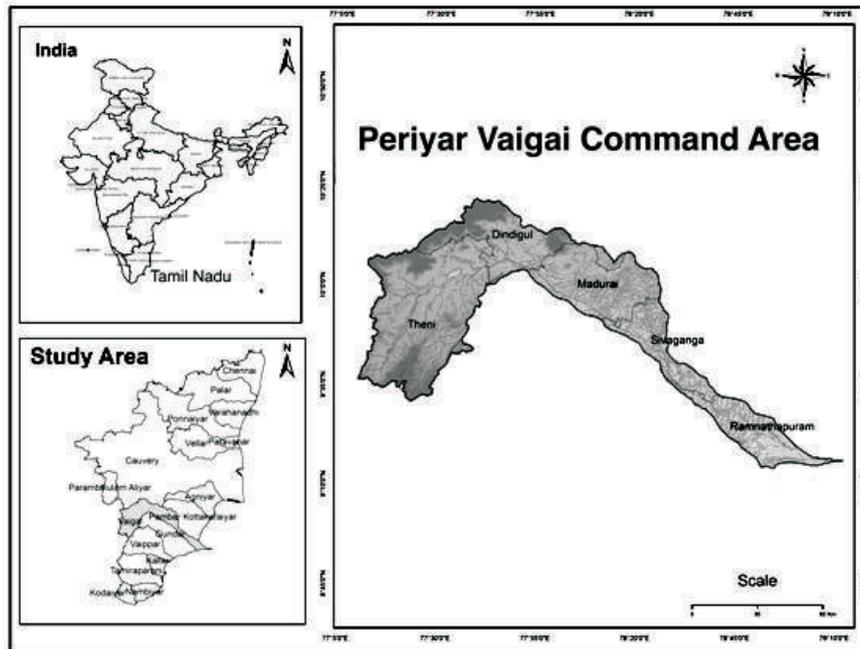


Fig. 1. Periyar Vaigai command (PVC) area map

basin scheme, which made it possible to divert waters from the Periyar basin in the state of Kerala to the Vaigai basin in Tamil Nadu. The Periyar reservoir system is evolved based on the concept of uniform release through Periyar tunnel meeting the irrigation requirement at Periyar – Vaigai command.

**Rain gauge locations and their geographic coordinates:**

Daily rainfall data for a period of 30 years from 1981 to 2011 was collected for the 18 locations are given below in Table 1.

**Rainfall Analysis**

**Daily data:** The data of Julian days are referred as daily data. The data may either be used as it is or be estimated according to the parameter and need. For example, in the case of rainfall, measured rainfall data from each rain gauge station (height of accumulated water in rain gauge) at 8.30 Indian Standard time (IST) and normally expressed in millimeter is used for the study.

**Weekly data:** The Julian day's data are converted in to meteorological standard week data as per the guidelines of the India Meteorological Department (IMD). There are 52 meteorological standard weeks in a year each consists of seven/eight days which starts from January 1<sup>st</sup> every year. The 52<sup>nd</sup> (Last) standard week will have always 8 days. The ninth standard week from February 26<sup>th</sup> to March 4<sup>th</sup> will have 8 days during a leap year. In the case of rainfall, cumulative (total) value for the seven days is taken for the standard week.

**Monthly data:** According to Gregorian calendar, the Julian

**Table 1.** Rainfall stations and their geographic coordinates

Locations	Latitude	Longitude
Andipatti	09° 59'53" N	77° 37'21" E
Edayapatti	10° 04'04" N	78° 04'16" E
Gudalur	09° 40'30" N	77° 15'00" E
Kallandiri	10° 02'12" N	78° 12'03" E
Madurai airport	09° 50'10" N	78° 05'22" E
Madurai south	09° 53'29" N	78° 07'23" E
Melur	10° 01'52" N	78° 20'20" E
Mettupatti	10° 06'42" N	78° 06'22" E
Peria aruvi	10° 05'50" N	78° 06'40" E
Periapatti	10° 01'50" N	78° 09'40" E
Pulipatti	10° 05'90" N	78° 17'21" E
Reddiyarchatram	10° 25'49" N	77° 52'10" E
Sathiyar dam	10° 04'16" N	78° 06'42" E
Sholavandan	10° 01'35" N	77° 57'44" E
Tallakulam	09° 56'04" N	78° 06'59" E
Thirumangalam	09° 48'36" N	77° 58'48" E
Usilampatti	09° 58'12" N	77° 48'00" E
Viraganur	09° 53'44" N	78° 12'40" E

day's data can be grouped in to monthly data based on the days of the particular month. For rainfall, the cumulative value is more useful and was taken for the study.

**Seasonal data:** Monthly data are grouped in to seasonal data based on the season specified by the India Meteorological Department, Government of India. The four

seasons and corresponding months of the seasons are

1. Winter (Cold weather period): January – February
2. Summer (Hot weather period): March – May
3. South West Monsoon: June – September
4. North East Monsoon: October–December

**Annual data:** The total or the annual mean of weather parameters for all the 365 / 366 days of a year is referred as annual data. In the case of rainfall, cumulative total from 1<sup>st</sup> January to 31<sup>st</sup> December normally constitute the annual data in millimeter.

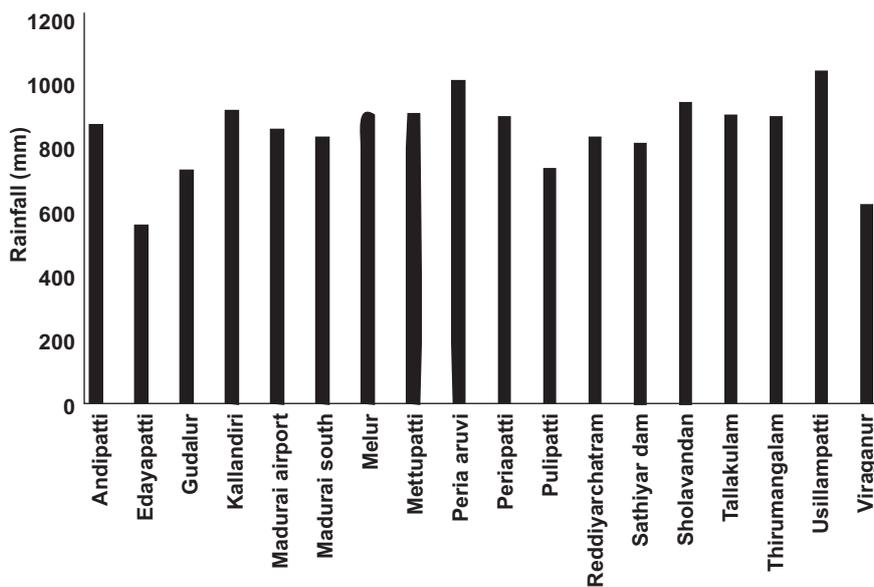
**Variability analysis:** The variability analysis of rainfall is important to understand the rainfall behavior of a particular location with respect to agriculture. The first step in working out the coefficient of variation is to find out the standard deviation of the particular time series using the following formula. From the standard deviation and mean rainfall of the particular time series, the coefficient of variation was calculated. Based on the magnitude of the coefficient of variation, the dependability of rainfall is normally ascertained (Table 2).

**Table 2.** Rainfall dependability classification

Period	Dependable CV (Per cent)	Non-Dependable CV (Per cent)
Daily rainfall	<250	>250
Weekly rainfall	<150	>150
Monthly rainfall	<100	>100
Seasonal rainfall	<50	>50
Annual rainfall	<25	>25

**RESULTS AND DISCUSSION**

**Spatio-temporal variability of annual rainfall:** Annual rainfall normal (Table 3 and Fig. 2) was worked out for all the locations with the data available for the study period 1981 to 2011. The variation in amount of rainfall among the locations well indicates the spatial variability while its coefficient of variation (CV) explains its temporal variability (Fig. 3). The normal annual rainfall of PVC area is 865 mm with a standard deviation of 237 mm. The coefficient of variation is 28 percent. In the PVC area, Usilampatti had the highest normal rainfall of 1052 mm and Edayapatti had the lowest of 564 mm. Among the locations, for the historical period, least of 132 mm annual rainfall was recorded at Viraganur while the highest amount of rainfall 2010 mm was recorded at Usilampatti. Among the locations Peria aruvi and Usilampatti alone had normal annual rainfall above 1000 mm and the least rainfall was recorded at Edayapatti (564 mm). Among the locations Thirumangalam (Table 3) had less standard deviation of 164 mm and Usilampatti had highest of standard deviation of 331 mm. Thirumangalam had the least coefficient of variation of about 18 per cent and Edayapatti had the maximum coefficient of variation of 40 per cent out of dependable rainfall category for annual rainfall. The other locations percent coefficient of variation, Madurai airport (19), Madurai south (22), Kallandiri Sholavandan Tallakulam (24 each), Mettupatti and Viraganur (25 each) are coming under dependable category. The locations like Melur, Andipatti, Reddiyarchatram) and Sathiyar dam (registered coefficient of variation between 25 to 30 per cent.



**Fig. 2.** Annual normal rainfall of Periyar Vaigai command area

**Table 3.** Annual normal rainfall of Periyar Vaigai Command (PVC) area

Locations	Normal rainfall (mm)	SD (mm)	CV (%)	Minimum rainfall (mm)	Maximum rainfall (mm)
Andipatti	882	236	27	356	1440
Edayapatti	564	230	40	232	1275
Gudalur	738	330	39	344	1949
Kallandiri	925	226	24	594	1594
Madurai airport	865	165	19	492	1153
Madurai south	841	181	22	547	1283
Melur	913	234	26	567	1506
Mettupatti	915	226	25	500	1474
Peria aruvi	1020	324	32	565	1790
Periapatti	904	258	29	264	1365
Pulipatti	742	266	36	377	1297
Reddiyarchatram	843	240	28	447	1515
Sathiyar dam	820	231	28	446	1251
Sholavandan	950	230	24	520	1442
Tallakulam	912	222	24	628	1419
Thirumangalam	908	164	18	599	1268
Usilampatti	1052	331	32	467	2010
Viraganur	631	166	25	132	956

Edayapatti, Gudalur, Pulipatti, Peria aruvi and Usilampatti registered values above of 30 percent deviating slightly from dependability levels.

The minimum amount of rainfall required for cultivation of crops is 750 mm. Among the locations studied, Edayapatti, Viraganur, Gudalur and Pulipatti locations receives less than 750 mm. In these locations, crops may suffer from water stress that leads to decrements in crop yield and crop failure may occur regularly. All other locations receives rainfall between 750 to 1150 mm and may suffer from soil water deficiency in greater part of the years. In these locations, supplemental irrigation is necessary for successful crop production (Majundar 2014). Based on the annual rainfall most of the locations are coming under semi-arid category.

**Spatio-temporal Variability of annual rainfall distribution:** Annual rainy days normal was worked out for all the locations with the data available for the study period 1981 to 2011 (Table 4). The normal annual rainy days of PVC area is 45 with a standard deviation of 10 days. The coefficient of variation is 22 per cent. Among the locations of PVC area, least of 35 rainy days were recorded at Edayapatti while the highest of 52 rainy days were recorded at Gudalur. Gudalur recorded the highest of 101 rainy days during 2004, it is the highest in the entire study area and the less distributed one was at Viraganur, 9 rainy days during 2008

and Co efficient of annual rainy days varied from 14 to 47 percent.

### Seasonal Rainfall

**Spatial variability:** To understand the seasonal variation of rainfall, the daily rainfall data of different places of PVC area (Table 5 and Fig. 4) were aggregated into four season's viz., cold weather period (CWP), hot weather period (HWP), southwest monsoon (SWM) and northeast monsoon (NEM). Among the monsoons, NEM contributes higher percent of rainfall to annual rainfall followed by SWM, HWP and CWP. Both the monsoons together contribute more than 75 per cent of the annual rainfall received over PVC area. NEM rainfall over the PVC area varied between 564 (Usilampatti) to 257 mm (Edayapatti) and the locations Peria aruvi and Sholavandan registered a rainfall of 487 and 474 mm respectively. During SWM highest amount of rainfall was recorded over Peria aruvi 365 mm and least amount of rainfall was recorded at Edayapatti 201 mm. During hot weather period (summer) Usilampatti has recorded highest rainfall amount of 195 mm and lowest rainfall of 91 mm was observed in Edayapatti.

Almost all the locations contribute more than 40 percent from NEM to annual rainfall declaring less spatial variability during NEM (Table 5). Maximum of 54 per cent was

**Table 4.** Annual normal rainy days of Periyar Vaigai command area

Locations	Average rainy days (days)	SD (days)	CV (%)	Maximum rainy days (days)	Minimum rainy days (days)
Andipatti	44	10	22	74	25
Edayapatti	35	8	23	55	21
Gudalur	52	24	47	101	24
Kallandiri	47	8	17	62	32
Madurai airport	46	6	14	60	29
Madurai south	45	8	18	58	26
Melur	48	9	19	54	31
Mettupatti	46	8	17	66	30
Peria aruvi	49	12	25	70	23
Periapatti	48	13	27	72	16
Pulipatti	42	10	23	63	25
Reddiyarchatram	45	10	21	64	28
Sathiyar dam	47	10	20	66	23
Sholavandan	47	8	17	65	31
Tallakulam	49	9	18	68	32
Thirumangalam	46	8	16	62	31
Usilampatti	44	8	19	59	32
Viraganur	38	9	25	59	9

witnessed in Usilampatti and minimum of 40 per cent was at Edayapatti. For SWM, per cent contribution varied between 25 and 39 per cent for Usilampatti and Reddiyarchatram, respectively. Among the locations Reddiyarchatram had minimum difference between the monsoons 39 and 42 per cent respectively for SWM and NEM while Usilampatti had the highest difference of 25 and 54 per cent respectively.

Contribution of non-monsoon rainfall to the annual rainfall is considerably less in all the locations. Among the

seasons, HWP recorded comparatively high rainfall than CWP. Rainfall during HWP period varied between 91 (Edayapatti) to 195 mm (Usilampatti). CWP had variation between 15 (Viraganur) and 32 mm (Peria aruvi). HWP had contribution varying between 13 (Peria aruvi) and 22 (Gudalur) per cent. To the annual while CWP had invariably 2 or 3 percent for all the stations studied.

**Seasonal rainfall variability-Temporal:** Among the seasons NEM (Fig. 5) has high CV than SWM (Fig. 4).

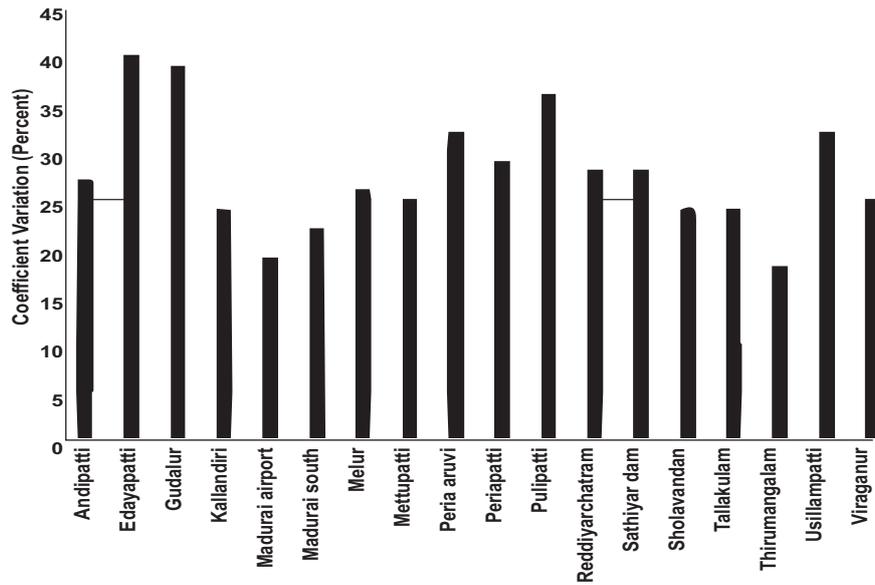


Fig. 3. Annual rainfall variability of PVC area

Table 5. Seasonal normal rainfall of Periyar Vaigai command area

Locations	Normal rainfall (mm)				Per cent contribution (%)			
	CWP	HWP	SWM	NEM	CWP	HWP	SWM	NEM
Andipatti	20	172	263	427	2	20	30	48
Edayapatti	16	91	201	257	3	16	36	46
Gudalur	15	163	267	293	2	22	36	40
Kallandiri	18	167	336	404	2	18	36	44
Madurai airport	28	156	305	376	3	18	35	44
Madurai south	20	142	281	397	2	17	33	47
Melur	25	139	343	407	3	15	38	45
Mettupatti	21	147	311	436	2	16	34	48
Peria aruvi	32	137	365	487	3	13	36	48
Periapatti	27	152	309	416	3	17	34	46
Pulipatti	18	110	273	341	3	15	37	46
Reddiyarchatram	19	141	329	354	2	17	39	42
Sathiyar dam	23	134	284	379	3	16	35	46
Sholavandan	23	185	268	474	2	20	28	50
Tallakulam	26	151	307	428	3	17	34	47
Thirumangalam	21	169	301	416	2	19	33	46
Usilampatti	28	195	266	564	3	19	25	54
Viraganur	15	112	211	293	2	18	34	47

Individually, Andipatti, Edayapatti, Kallandiri, Madurai south, Melur, Mettupatti, Peria aruvi, Pulipatti, Reddiyarchatram, Sathiyar dam, Sholavandan and Tallakulam locations have comparatively less CV for SWM than NEM. The remaining locations Gudalur, Madurai airport, Thirumangalam, Usilampatti and Viraganur have less CV for NEM. Exceptionally Periapatti has same CV for both the monsoons (42 percent). Though there are variations among the seasons, the magnitude is very less between them. Most importantly, most of the location in both the monsoons has dependable CV for seasons (< 50 per cent). Even though both monsoons have dependable CV, NEM receives good amount of rainfall making it possible to raise crops. The locations like Edayapatti, Viraganur and Usilampatti registered more than 50 percent CV during SWM Edayapatti and Peria aruvi registered more than 50 per cent during NEM. Among the locations studied, more than 70 per cent of CV was noticed in Gudalur during the both the monsoons. During SWM, Tallakulam registered lowest CV value of 29 per cent and next value of 30 in Reddyarchatram, 31 in Madurai South, 32 in Melur and Kallandiri, 33 in Andipatti, 34 in Mettupatti and Madurai airport.

The coefficient of variation during HWP generally high compared to monsoon seasons. Thirumangalam registered lowest CV value of 38 per cent and followed by 43 per cent in Sholavandan and Tallakulam, 44 in Andipatti and Usilampatti, 47 in Madurai airport. The highest CV value

recorded in Gudalur (83 %), Edayapatti (%) (Table 6). Though summer season recorded considerable amount of rainfall its variability is not dependable in most of the locations (more than 50 per cent). This indicates year to year variability is more therefore it may not be useful for growing crops during this season but definitely useful for summer ploughing in rainfed lands and beneficially help to increase the productivity of irrigated dry crops grown during summer season where normally water stress experienced due to less ground water availability. Where ever rainfall variability is less (Thirumangalam, Sholavandan, Tallakulam and Usilampatti) may be helpful in growing green manure crops to increase soil fertility.

**Seasonal rainfall distribution:** Comparatively NEM (20) had more number of rainy days than SWM (16), which clearly demarcates a good distribution during NEM that supports major cropping activities (Table 7). Number of rainy days during SWM varied from 11 to 23 and that of NEM is 16 to 22 with a standard deviation of 5 and 7 days respectively. The coefficient of variation varied between 23 to 53 per cent and 26 to 52 per cent during SWM and NEM periods, respectively.

**Monthly rainfall:** Monthly rainfall normals were derived to understand monthly distribution of rainfall (Table 8). Among the months, October was the wettest month while January was the driest month in terms of rainfall received. Second highest rainfall recorded was during November month followed by September and August invariably in all the

**Table 6.** Seasonal rainfall variability of PVC area

Locations	Southwest			Northeast			Summer		
	Rainfall (mm)	SD (mm)	CV (%)	Rainfall (mm)	SD (mm)	CV (%)	Rainfall (mm)	SD (mm)	CV (%)
Andipatti	263	84	33	427	206	49	172	76	44
Edayapatti	201	106	55	257	144	57	91	75	82
Gudalur	267	191	72	293	204	71	163	135	83
Kallandiri	336	106	32	404	176	43	167	85	51
Madurai airport	305	101	34	376	120	32	156	75	47
Madurai south	281	87	31	397	137	36	142	83	58
Melur	343	107	32	407	162	41	139	83	58
Mettupatti	311	104	34	436	200	46	147	77	51
Peria aruvi	365	143	42	487	275	58	137	71	53
Periapatti	309	130	42	416	173	42	152	74	47
Pulipatti	273	125	48	341	167	50	110	76	70
Reddiyarchatram	329	98	30	354	168	48	141	87	62
Sathiyar dam	284	108	39	379	189	50	134	66	48
Sholavandan	268	101	38	474	211	45	185	80	43
Tallakulam	307	86	29	428	167	41	151	64	43
Thirumangalam	301	104	36	416	141	34	169	66	38
Usilampatti	266	147	56	564	235	42	195	87	44
Viraganur	211	116	55	293	143	49	112	74	66

locations. Apart from monsoon months, April and May months have considerably more rainfall than most of the non-monsoon months. Highest rainfall in a single month was

**Table 7.** Seasonal normal rainy days of Periyar Vaigai command area

Locations	Southwest			Northeast		
	Rainy days (days)	SD (days)	CV (%)	Rainy days (days)	SD (days)	CV (%)
Andipatti	14	4	30	20	9	43
Edayapatti	12	5	47	16	7	43
Gudalur	23	12	53	18	9	52
Kallandiri	17	5	27	20	7	36
Madurai airport	16	4	26	20	6	30
Madurai south	16	6	35	20	6	30
Melur	18	5	27	22	7	34
Mettupatti	16	4	23	21	8	37
Peria aruvi	20	7	38	21	7	33
Periapatti	17	7	41	21	9	41
Pulipatti	14	5	33	20	7	34
Reddiyarchatram	17	5	30	20	7	36
Sathiyar dam	16	5	34	21	7	33
Sholavandan	15	6	38	22	7	31
Tallakulam	16	5	29	22	8	35
Thirumangalam	16	5	31	21	5	26
Usilampatti	12	4	31	22	7	30
Viraganur	11	6	48	17	8	45

recorded during October for the location Usilampatti (274 mm). Monthly rainfall variation indicates that from April to November there is considerable amount of rainfall in each location with a minimal variation in their amounts. Though there is rainfall during April and May it is not sufficient to support a whole crop, it may support an irrigated crop of previous season. In the monsoon months, June to November has reliable rainfall for raising crops. A crop with suitable duration has to be planned based on this rainfall and rainy day details. Pearl millet based intercropping in light textured soils or sorghum based intercropping in black soils/better soils can be taken up as suggested by Ashish and Yadav (2013). Further analysis also indicates that there is possibility of dry spell is common in between the crop-growing period therefore *in-situ* moisture conservation measures are necessary to get higher yield.

### CONCLUSION

The basic rainfall statistics and their analysis are imperative in agricultural planning. Periyar Vaigai command area has normal annual rainfall of 865 mm with considerable spatial variations (564 mm to 1052 mm). This spatial variation of rainfall mainly attributed by its exposure conditions to the wind during monsoon seasons. The distribution of rainfall decides the success of a crop. The normal annual rainy days of PVC area is 45. Rainy days clearly indicate a good distribution during NEM that supports major cropping activities. Based on the amount and distribution of seasonal and monthly rainfall, it is clear that water stress during cropping season is a regular

**Table 8.** Monthly normal rainfall (mm) of Periyar Vaigai command area

Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Andipatti	6	14	41	64	67	22	37	78	126	210	170	48
Edayapatti	6	10	17	28	46	25	35	62	79	122	99	36
Gudalur	8	8	22	62	79	68	71	49	80	163	103	27
Kallandiri	5	12	24	66	77	36	70	90	140	199	157	48
Madurai airport	16	12	18	59	79	36	58	93	118	183	143	49
Madurai south	6	14	21	51	70	35	47	76	124	189	159	49
Melur	8	17	25	42	72	51	65	95	132	192	152	62
Mettupatti	5	16	32	52	63	32	57	87	135	224	161	51
Peria aruvi	16	17	19	44	74	45	77	103	140	203	193	91
Periapatti	9	18	24	60	68	33	56	91	129	220	150	46
Pulipatti	9	9	13	39	57	37	60	67	109	165	127	49
Reddiyarchatram	8	11	25	40	76	59	71	91	107	166	133	55
Sathiyar dam	10	13	24	54	56	21	43	84	136	198	129	52
Sholavandan	9	14	40	76	70	24	33	78	133	234	187	53
Tallakulam	7	19	14	52	84	31	55	81	141	199	177	53
Thirumangalam	9	13	23	63	84	27	61	79	135	203	159	55
Usilampatti	14	14	56	73	66	26	29	61	150	274	227	63
Viraganur	5	9	17	45	49	24	36	53	99	147	107	40

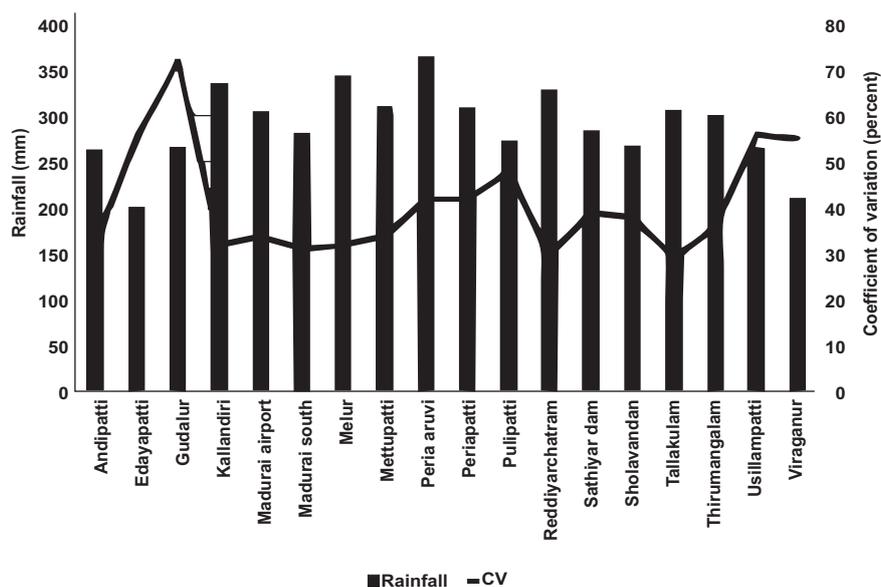


Fig. 4. South West Monsoon rainfall and variability of PVC area

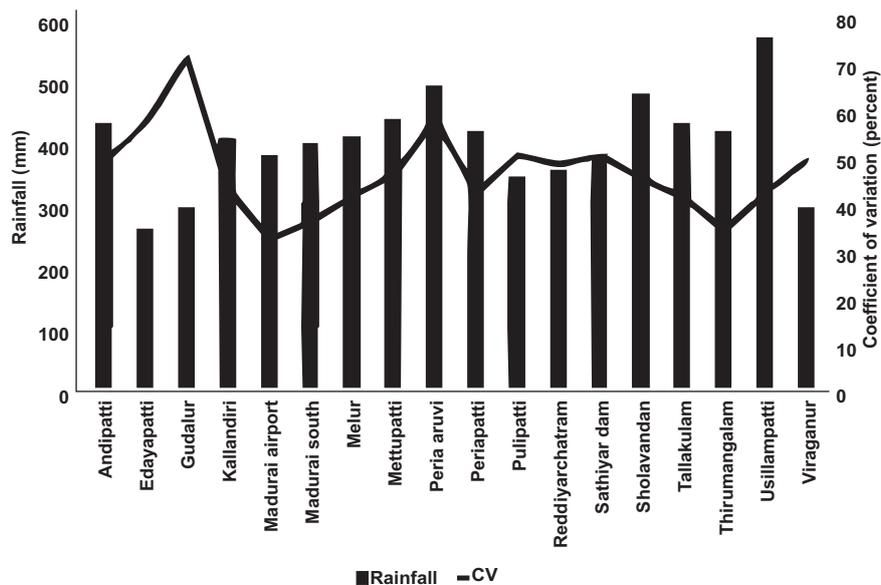


Fig. 5. North East Monsoon rainfall variability of PVC area

scenario in PVC area. Hence, suitable crop selection based on duration of rainfall period, water harvesting, water management and moisture conservation techniques have to be devised for the PVC area for successful crop production.

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# Modelling for Reference Evapotranspiration of Pantnagar using Various Training Functions in Artificial Neural Network

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**Abstract:** The main objective of this study was to estimate climate based reference evapotranspiration on daily basis and to develop the models using various training functions of Artificial Neural Network (ANNs). This study deals with the location and climate of study area, collection of meteorological data and methodology adopted for reference evapotranspiration estimation and modelling it using artificial neural networks for Pantnagar and criteria for evaluating performance of the models is also discussed. Gradient Descent with Momentum and One Step Secant training function are almost equally fitted. The reference evapotranspiration in 5 years (2011-15) varies from 0.65 to 6.01 within 5 years. The correlation coefficient for testing data for Levenberg Marquardt function is 0.832, for Gradient Descent with Momentum function is 0.976 and for One Step Secant function is 0.981. One Step Secant training function produce the high value of correlation coefficient rather than Levenberg Marquardt. So it is considered as best model for evapotranspiration modelling of Pantnagar.

**Keywords:** Artificial neural network (ANN), Cropwat 8.0, Meteorological parameters and Training functions

In Agriculture, evapotranspiration is defined as the combined loss of water from soil as evaporation and from plants as transpiration towards the atmosphere and exact evapotranspiration rate can be helpful in crop consumptive water use. For effective scheduling of irrigation. Regions near to the equator, evapotranspiration is relatively more than northern or southern regions at same level of elevations. Evaporation from the rivers, dams and lakes are among the most important losses in many hydrological project design and water resources planning studies. The amount of evaporation per unit area is calculated by Dalton's law as a rational approach Yavuz et al (2016) and also by multilayer perceptron based artificial neural network and multiple linear regression techniques (Bhagwat et al 2017)

Penman Monteith method is a standard method for estimating evapotranspiration as per FAO-56. It is impractical to use this method on field level due to its complex behaviour (Singh and Xu 1997). So for researchers it is difficult to measure evapotranspiration with high accuracy. However many indirect methods are used for estimation of evapotranspiration. In the direct techniques of estimation, the observation from United States Weather Bureau (USWB) Class A Pan evaporimeter and eddy correlation methods were used the evaporation pans and associated automated measurement devices are relatively expensive, whereas indirect techniques use meteorological data like rainfall, temperature, relative humidity, sunlight, wind velocity etc. to

simulate evapotranspiration by empirical based methods or statistical and probabilistic approaches. In the field of ANN evaporation modelling (Kisi 2009) used two different ANN techniques namely multi-layer perceptron and radial basis neural networks (RBNN), in the simulation of monthly pan evaporation and found both the methods were better than regression method. Sudheer et al (2002) applied a multi-layer perceptron with back-propagation training algorithm to simulate daily pan evaporation and concluded that ANN performed better than the Stephens and Stewart model. Bruton et al (2000) compared ANN outputs with the multiple linear regression models and Priestley-Taylor model, and concluded that ANN model performed better. The specific objectives of the study are estimation of reference evapotranspiration on daily basis for the study area using CROPWAT 8.0, modelling of reference evapotranspiration using Artificial Neural Network and comparison of various developed models for finding best model to estimate reference evapotranspiration for the Pantnagar.

## MATERIAL AND METHODS

**Location of the study area:** Pantnagar is located in Tarai region in Udham Singh Nagar district of Uttarakhand, India. Geographically it is located at 29.01°N latitude and 79.38°E longitude, at 243.84 m elevation above mean sea level. Geographical area of Pantnagar is 4053.45 ha. It is located in semi-humid and subtropical climatic zone in Tarai belt of

Shivalik range of foot hills of Himalayas. Generally, monsoon starts in the last week of June and continues up to September. The mean annual rainfall of Pantnagar is 1350 mm of which 80-90 % occurs during June to September. South-west monsoon causes max rainfall during four months of rainy season from June to September. May and June are the hottest months of the year; December and January are coldest months of the year. The temperature variation is very large. In summer temperature reaches approximately 42 to 45 °C while in winter it falls up to 2 to 4 °C. The mean relative humidity remains almost 80-90 per cent from mid-June to February end. The average pH value of the soil is 7.2 to 7.4; the soil of this region is good for agriculture and holds enough moisture to produce good crops. The daily weather data of maximum and minimum temperature, wind velocity, relative humidity and sunshine hours of 5 years (1825 days) for the year 2011 to 2015 were collected from Meteorological Observatory at Crop Research Centre of G.B. Pant University of Agriculture and Technology Pantnagar.

**Development of models for study area:** The dataset formulation was taken as standard meteorological weather data of maximum and minimum temperature, mean of relative humidity, sunshine hours and wind velocity as input and using these inputs evapotranspiration is estimated by CROPWAT 8.0. These inputs and output are then modelled using various training functions, such as Levenberg Marquardt, Gradient Descent with Momentum and One Step Secant training functions in ANN in Matlab-2011. Total number of data for each year's period comes out to be 365. Then the whole numbers of data of 5 year are 1825. Out of which, 70% data are used for training purpose and 30% are used for testing purpose.

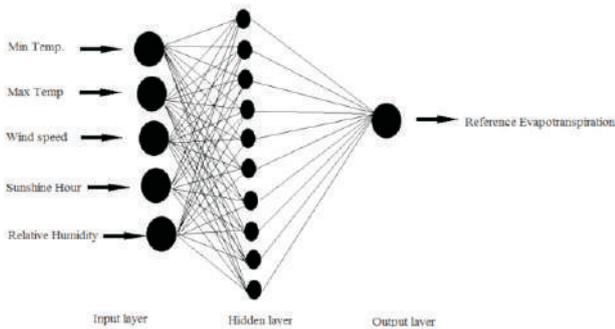


Fig. 1. Input, hidden and output layer

Fig. 1 shows the input layer, hidden layer and output layer. It can be noted that input layer consist of 5 neurons, hidden layer consist of 10 neurons and output layer consist of 1 neuron. Each input is connected to each neuron and each neuron is connected to output neuron. In Fig 1 the network of all the input neurons i.e. min temperature, max temperature,

wind speed, sunshine hour and relative humidity is shown. Similarly each input neuron makes a network, which is very complicate network.

**FAO-56 Penman-Monteith method:** The ICID and FAO expert consultations have provided that the FAO-56 PM formulae can be used as the standard to estimate  $ET_0$  in the eqn (1).

$$ET_0 = \frac{0.408 (R_n - G) + \frac{900}{T + 273} (e_s - e_a)}{\gamma (1 + 0.34 U_2)} \quad (1)$$

Where,  $ET_0$  is reference evapotranspiration [ $mm \text{ day}^{-1}$ ],  $R_n$  net radiation at the crop surface [ $MJ \text{ m}^{-2} \text{ day}^{-1}$ ],  $G$  is soil heat flux density [ $MJ \text{ m}^{-2} \text{ day}^{-1}$ ],  $T$  is mean daily air temperature at 2 m height [ $^{\circ}C$ ],  $U_2$  is wind speed at 2 m height [ $m \text{ s}^{-1}$ ],  $e_s$  is saturation vapour pressure [ $kPa$ ],  $e_a$  is actual vapour pressure [ $kPa$ ],  $e_s - e_a$  is saturation vapour pressure deficit [ $kPa$ ],  $\Delta$  is slope of vapour pressure curve [ $kPa \text{ }^{\circ}C^{-1}$ ],  $\gamma$  is psychrometric constant [ $kPa \text{ }^{\circ}C^{-1}$ ].

The expressions for  $\Delta$  and  $R_n$  are given in Eqs. (2) and (3), respectively

$$\Delta = \frac{4098 [0.6108 e^{(\frac{17.27 T}{T + 273.3})}]}{(T + 273.3)^2} \quad (2)$$

$$R_n = [R_a (1 - \rho_g) + \rho_g R_{ns}] - T_a^4 (0.56 + 0.092 \sqrt{e_a}) \quad (3)$$

ET can be estimated using mathematical models, usually relying on reference evapotranspiration ( $ET_0$ ), which is defined in terms of the FAO-56 Penman-Monteith (PM) model as the rate of evapotranspiration from a hypothetical reference crop with an assumed crop height of 0.12 m. (Feng et al 2016).

**Artificial neural network (ANN):** Artificial neural network is a technique used to simulate the evapotranspiration process. It has many parameters e.g. transfer function, activation function, number of iteration etc. In this study different training functions are used for study of different training functions. e.g. TRAINLM, TRAINGDM and TRAINOSS. And their parameters i.e. correlation coefficient and mean square error are compared for finding out the best model out of the three model. An ANN is a signal-processing machine made up of many nonlinear and densely connected processing elements namely neurons. The main operation of the Artificial neural network paradigms is to map a set of input signals to a set of outputs. The inputs are multiplied by their respective weights by which they are transmitted toward the neurons, where they are integrated and the total input is passed by the

activation function to get the final output. The axon-dendrite make contact between end bulbs and the neuro cell it impinges over is called a synapse. The impulse flow in the neuron is (with some conditions when the flow could be bi-directional) from the dendrites through the soma converging at the axon hillock and then down the axon the end bulbs. A neuron typically has many dendrites but only a single axon. Some neurons does not have axons, e.g. amercing cells.

Let  $x_i (i = 1, 2, \dots n)$  are inputs and  $w_i (i = 1, 2, \dots n)$  are respective weights. The net input to the node can be expressed as

$$net = \sum_{i=1}^n x_i w_i \dots(4)$$

The total input is then transferred from an activation function  $f$  and the output  $y$  of the node is computed as-

$$y = f(net) \dots (5)$$

One neuron cannot solve a complex problem so many neurons are used for addressing complex problems. In this structure, along with the input signal layer and the output signal layer, the network also contains at least one intermediate layer or hidden layer. Each layer is totally connected to the previous layer by interconnected weights.

**Performance evaluation of developed models:** The qualitative and quantitative evaluation of developed models was performed to judge the performance of each model between observed and estimated values. In the present study, the correlation coefficient was applied to test the estimation performance of the developed model. The visual observation based on the graphs and comparison of best fit linear equations for various models between measured and estimated values is one of the simplest methods for the qualitative performance assessment of a model. Since, the qualitative comparison may have personal bias, it is not a very accurate decision making process. Therefore, Correlation Coefficient was also used for testing the goodness of fit for the quantitative comparison of the observed and estimated values.

Evapotranspiration estimation models were developed for the study area using three different training functions in Matlab, Levenberg Marquardt, Gradient Descent with Momentum and One Step Secant

**Statistical indices:** The statistical indices used in the study for the evaluation of developed model is correlation coefficient (CC) and mean square error (MSE).

**Coefficient of correlation (R):** The coefficient of correlation is computed by following equation-

$$R = \frac{\sum_{i=1}^N (E_{io} - E_{mo})(E_{ie} - E_{me})}{\sqrt{\sum_{i=1}^N (E_{io} - E_{mo})^2 \sum_{i=1}^N (E_{ie} - E_{me})^2}} \dots(6)$$

**Mean square error (MSE):** In this study performance of various training functions such as Levenberg Marquardt, Gradient Descent with Momentum and One Step Secant are estimated. In statistics the formulae for Mean Square Error is given as equation (7)

$$MSE = \frac{1}{n} \sum_{i=1}^n (y_{oi} - y_{oi})^2 \dots(7)$$

Where  $y_{ti}$  is  $i^{th}$  target value,  $y_{oi}$  is  $i^{th}$  output value and  $n$  is number of observations.

## RESULTS AND DISCUSSION

The statistical parameters of the reference evapotranspiration obtained from cropwat 8.0 are given in Table 1. There is uniformity in the data over 5 years. The range of reference evapotranspiration data is between 0.65 to 6.01 mm/day. The annual standard deviation ranges from 1.277 to 1.403 mm day<sup>-1</sup> and coefficient of variation varies from 0.44 to 0.47. In the year 2013, there is minimum value of evapotranspiration i.e. 0.65 mm day<sup>-1</sup>. The graphical representation of variation of evapotranspiration data in mm/day with respect to days of 5 years is shown in Fig 2. The reference evapotranspiration has the minimum annual average value (2.896 mm/day) and maximum average value is in year 2014 (3.036 mm day<sup>-1</sup>). Average value represents the daily annual average of the reference evapotranspiration data. The results of the developed models in terms of correlation coefficient and mean square error are listed in the Table 1.

**Performance evaluation by correlation coefficient (R):** The performance evaluation of Levenberg Marquardt model was carried out based on qualitative and quantitative evaluation. The visual observation based on the graphical comparison between the observed and estimated values is one of the simplest methods for the performance assessment of the model which are shown in the fig. 3(a), 3(b), 3(c), 4(a), 4(b) and 4(c) respectively. The performance of the model was evaluated by the mean square error graph and best fitted line comparing ordinate and abscissa of observed and estimated graphs. The interpretation of the graphs shows there is a close agreement between the predicted and observed evapotranspiration.

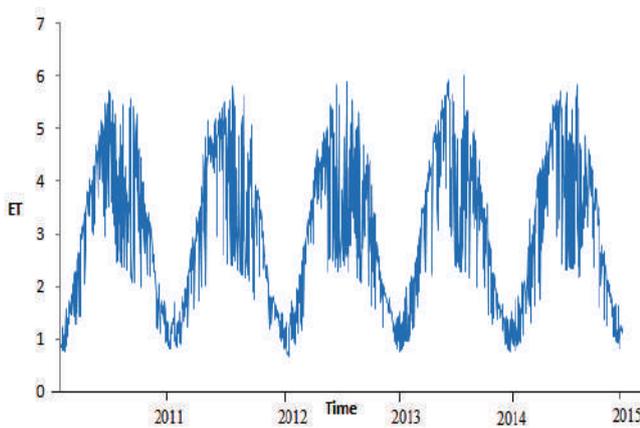
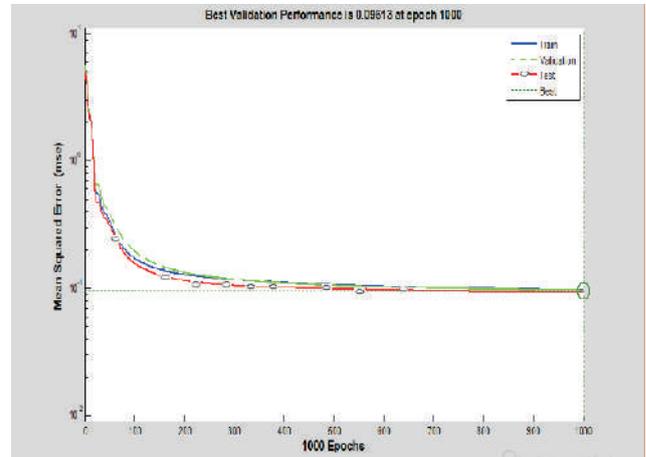
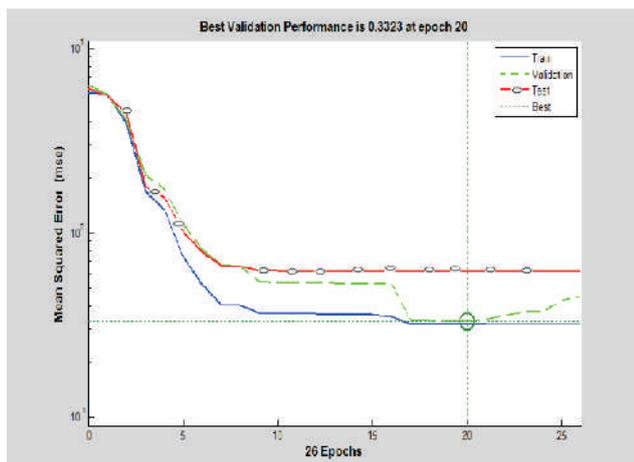
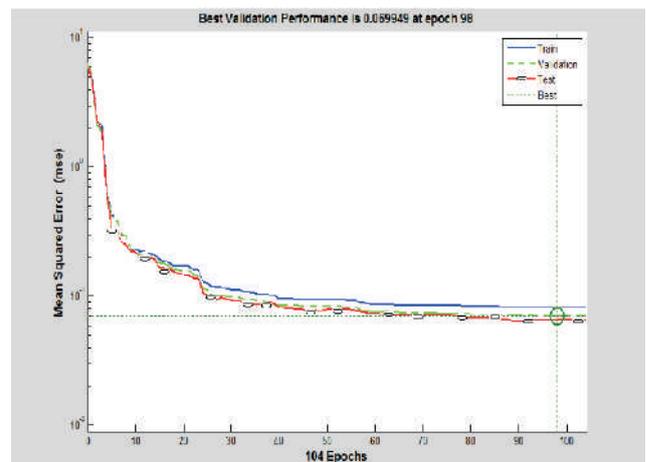
**Quantitative evaluation:** The quantitative performance of models was evaluated by using statistical indices viz. coefficient of correlation and mean square error. For LM model the coefficient of correlation for training, testing and overall is 0.91, 0.83 and 0.90, respectively and mean square error is 0.33. For GDM model the coefficient of correlation for training, testing and overall is 0.97, 0.97 and 0.97, respectively and mean square error is 0.12. For OSS model the coefficient of correlation for training, testing and overall is

**Table 1.** Statistical parameters of reference evapotranspiration

Year	Minimum value (mm/day)	Maximum value (mm/day)	Mean value (mm/day)	S.D. (mm/day)	C.V.
2011	0.74	5.72	2.949	1.330	0.451
2012	0.79	5.80	2.947	1.351	0.458
2013	0.65	5.89	2.896	1.277	0.440
2014	0.74	6.01	3.036	1.444	0.475
2015	0.78	5.84	3.007	1.403	0.466

Training function	R (training)	R (testing)	R (overall)	MSE (saturation)	Epoch (saturation)
Levenberg marquardt	0.91	0.83	0.90	0.33	20
Gradient descent with momentum	0.97	0.97	0.97	0.12	1000
One step secant	0.97	0.98	0.97	0.07	48

**Fig. 2.** Graphical representation of evapotranspiration data over 5 years (2011-15)**Fig. 3b.** Variation of mean square error with respect to Epoch number for GDM**Fig. 3a.** Variation of mean square error with respect to Epoch number for LM.**Fig. 3c.** Variation of mean square error with respect to Epoch number for LM

In fig. 3a top line shows testing MSE, middle line shows validation MSE and bottom line shows training MSE. In fig. 3b top line shows validation MSE, middle line shows training MSE and bottom line shows testing MSE. In fig. 3c top line shows testing MSE, middle line shows train MSE and bottom line shows validation MSE.

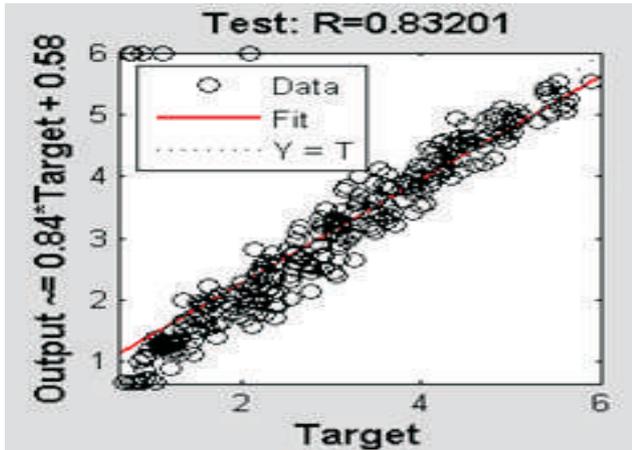


Fig. 4a. Output v/s Target Reference evapotranspiration for Levenberg Marquardt for testing data

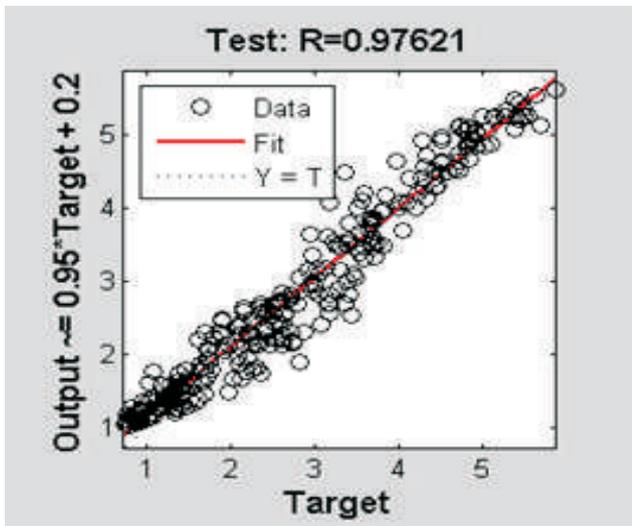


Fig. 4b. Output vs Target Reference evapotranspiration using Gradient Descent with Momentum for testing data

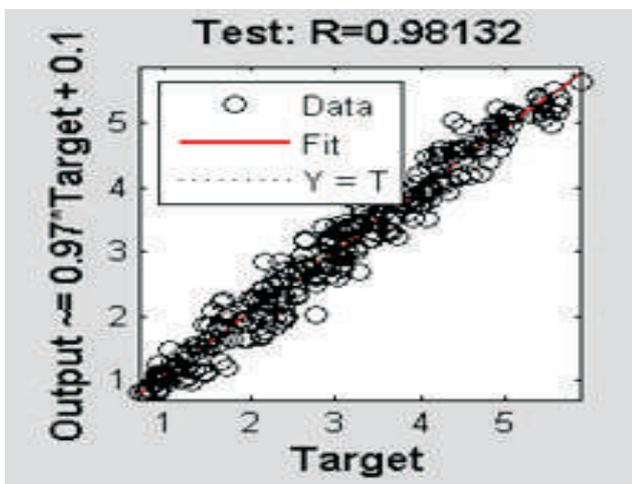


Fig. 4c. Output vs target reference evapotranspiration using One Step Secant for testing data

0.97, 0.98 and 0.97 respectively and mean square error is 0.07. In terms of (MSE) and Epoch values at saturation, it can be concluded that in Levenberg Marquardt (LM) the MSE is high, but as saturation epoch is less, it means learning rate is high. In Gradient Descent with Momentum (GDM) MSE is medium but the saturation epoch is very high. It means learning rate is very slow but it minimizes the errors more efficiently than LM. In One Step Secant (OSS) MSE is very low and saturation epoch is also low i.e. 48. It means that One Step Secant (OSS) has sufficient learning rate and it minimizes errors very efficiently. It can be concluded that One Step Secant (OSS) should be taken as the most efficient model.

## CONCLUSION

The reference evapotranspiration in 5 years varies from 0.65 mm/day to 6.01 mm/day. The correlation coefficients for TRAINLM function is 0.832, for TRAINGDM function is 0.976 and for TRAINOSS function is 0.981 during testing. One Step Secant training function produced the high value of correlation coefficient rather than Levenberg Marquardt. Therefore, this model was considered as the best model. Gradient Descent with Momentum and One Step Secant training function are almost equally fitted.

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Received 16 December, 2017; Accepted 10 February, 2018



# Solar Power Based DC-DC Converter Fed Brushless DC Motor Drive for Agricultural Applications

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**Abstract:** The proposed research involves, a design solar power based dc-dc converter fed brushless dc motor drive for agricultural applications. It consists of step up and step down converter, DC-link module. Compared with conventional and two converters, the designed system results in reduction of voltage tension across the switches, compact power switches, DC source reckoning and reduced inrush current. DC-link switching is achieved by reduced ripple voltage which results in improved quality of obtained output power. Reduction in DC source and switch count makes the system more cost effective, and more useful agriculture by coupling water pwm with motor. A simulation of DC-DC converter is developed and its performance is analysed for various operating parameter conditions.

**Keywords:** B4 Inverter, Buck Boost converter, dsPIC Controller, DTC, Permanent Magnet Brushless dc Motor, Simulation

In recent times, permanent magnet brushless DC (BLDC) motors are extensively utilized by several industries like medical, electric traction, HVAC industry, aircrafts, military equipment, road vehicles, hard disk drive, etc., because of their better efficiency, high power density, consistency and extremely uncomplicated to control. One of the most significant categories of instantaneous electromagnetic torque controlled AC drives employed for high-performance applications is Direct Torque Control (DTC) drives (Liu et al 2005). DTC is a kind of hysteresis or bang-bang control for the purpose of controlling the torque (and as a result speed) of electric motors. The fundamental conception that functions the DTC of AC drive, as its name indicates, is to direct the electromagnetic torque and also the flux linkage directly and autonomously with the help of six or eight voltage space vectors given in lookup tables. DTC schemes have been extensively employed in the process of squirrel cage induction machine drives. They permit a straight control of the electromagnetic torque and the stator flux by means of the application of appropriate groupings of the control signals of the inverter switches. Numerous DTC schemes in accordance with the analytical techniques have been formulated until now, by taking conventional inverters (also known as B6-inverters) (Taheri et al 2012, Jidin et al 2012, Metidji et al 2012, El Badsy et al 2013, Ziaeinejad et al 2013, Zhang et al 2012) into account, in addition to unconventional inverters (El Badsy et al 2013, Blaabjerg et al 1997).

The conventional DTC model of B4 inverter fed BLDC

motor is illustrated in Fig. 1. Given that, a variable input power supply like PV panel is employed here, there is a requirement to incorporate a converter with the intention of obtaining the regulated supply voltage. For these functions, various converters, for instance, boost, buck, buck boost, cuk, sepic, zeta etc have been employed in the literature. However, the most important drawback with these converters for a DTC of B4 inverter fed BLDC is the incidence of voltage imbalance across the capacitors. This voltage imbalance is primarily because of the DTC switching model to the BLDC motor. This setting is completely described with a conventional type buck boost converter fed BLDC motor as illustrated in Fig. 1.

When switch ( $S_1$ ) is in "ON" condition, the current in inductance ( $L_1$ ) begins to increase (Charging). In contrast, during switch ( $S_1$ ) in "OFF" condition, the energy in inductance ( $L_1$ ) begins to dropping (discharging). This energy in the inductance is transmitted to the voltage balancing capacitors ( $C_{01}$ ) and ( $C_{02}$ ). At some point when these capacitors are about to discharge in accordance with the switching pattern of the DTC, it ends in voltage imbalance because of variation in time period of discharging. This voltage imbalance is a most important complication since it has an effect on the torque ripples in the BLDC motor are shown in (Table 1).

## MATERIAL AND METHODS

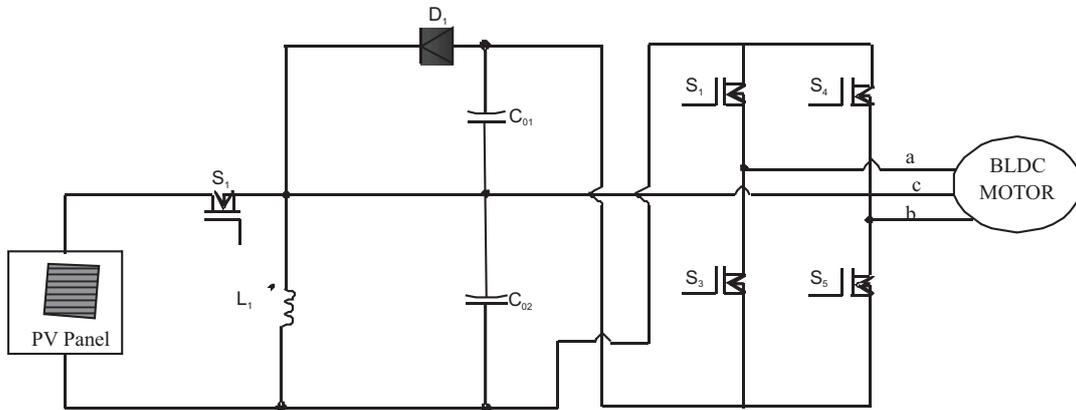
The proposed system model for DTC of B4-Inverter-Fed BLDC Motor Drives is given Fig. 2. The system model includes front end modified voltage balancing converter and

**Table 1.**

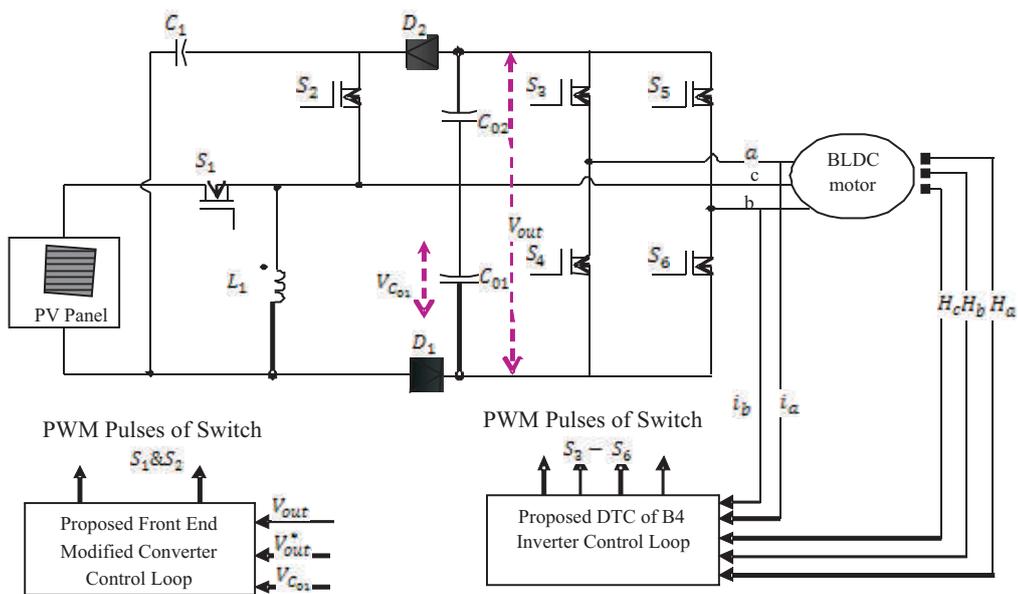
$S_1$	$S_2$	$S_3$	$S_4$	Status	
				$V_{c01}$	$V_{c02}$
1	0	0	0	$V_{ac}/2$	$V_{ac}/2$
0	1	0	0	$V_{ac}/2$	$V_{ac}/2$
0	0	1	0	$V_{ac}/2$	$V_{ac}/2$
0	0	0	1	$V_{ac}/2$	$V_{ac}/2$
1	0	0	1	$V_{ac}/2$	$V_{ac}/2$
0	1	1	0	$V_{ac}/2$	$V_{ac}/2$

the rear end B4 inverter fed BLDC motor. The front end modified converter includes intermediary capacitor  $C_{11}$ , power switches  $S_1$  &  $S_2$ , input inductance  $L_1$ , power diodes  $D_1$  &  $D_2$  and voltage balancing capacitors  $C_{01}$  &  $C_{02}$ . On the other

hand, the rear end includes a B4 inverter ( $S_3$ - $S_6$ ) and a BLDC motor. In the midst of the unconventional inverters, it is easy to differentiate the B4-inverter which results from the reorganization of the B6-inverter in the scenario of a switch/leg breakdown. These kind of reorganization is a fundamental requirement in certain category of applications, in particular electric and hybrid propulsion systems, in case of the vehicle consistency is taken into account (Lee et al 2011, Stirban et al 2012). Managing the BLDC motor control schemes, it is relatively in general considered that they are completely based on the current and torque control techniques (Fang et al 2012, Joice et al 2013, Grenier et al 1995). One of the most popular is a generalized harmonic injection to discover optimal current waveforms by reducing the torque ripple (Sung et al 2000). In order to handle this voltage imbalance problem, a modified converter is required



**Fig. 1.** Conventional Buck Boost Converter based DTC model of B4 inverter fed BLDC motor



**Fig. 2.** Proposed modified converter based DTC model of B4 inverter fed BLDC motor

which is the major focus of this research work. Comparison carried out conduction of switches for B4 and B6 inverter for the proposed DOBB fed BLDC Motor Drive are show in (Table 2).

**Table 2.** Comparison of conduction of switches for B4 and B6 inverter for the proposed DOBB fed BLDC Motor Drive

Sector	Conduction of switches for B6-Inverter	Conduction of switches for B4-Inverter
0-60	Q1, Q6	Q1, Q4
60-120	Q2, Q3	Q2
120-180	Q3, Q6	Q4
180-240	Q4, Q5	Q3
240-300	Q1, Q4	Q1
300-360	Q2, Q5	Q2, Q3
Total number of switches conduct at 0-360°	12	8
Switching losses for 300 Watt system	2.48 Watt	1.36 Watt

On the other hand, since the torque is not directly controlled, a fast dynamic may not be accomplished. In addition, the implementation of these schemes needs costly position sensors. In (Ozturk et al 2011), hysteresis current controllers are employed for the purpose of driving BLDC motors. On the other hand, the proposed control scheme needs quite a lot of transforms for the purpose of synthesizing the *abc*-frame optimum reference currents, leading to a tricky control scheme with no direct control of the torque. In recent times, several DTC schemes have been effectively put into practice in B6-inverter-fed BLDC motor drives (Zhu et al 2012, Masmoudi et al 2013, Ozturk et al 2013). This DTC scheme utilizes a vector selection subtable that allows the independent control of the electromagnetic torques increased through the phases linked to the inverter legs at some stage of their simultaneous conduction. On the other hand, it has been observed in (Jiancheng et al 2012, Rajankumar et al 2017) that the two-phase conduction mode is penalized through high torque ripple at some stage in sector-to-sector commutations. In order to overcome this disadvantage, the three-phase conduction mode has been considered provisionally at some stage in sector-to-sector commutations. Mourad Masmoudi et al formulated a scheme in the scenario of B4-inverter-fed BLDC motor drives under DTC (Mourad Masmoudi et al 2014, Sathishkumar et al 2016, Rajankumar et al 2016). The DTC of BLDC motor results in voltage imbalance state across capacitors  $C_{01}$  and  $C_{02}$  which consecutively results inelevated torque ripples. With the intention of managing this complication, a modified converter

is incorporated with the B4 inverter in the front end. The method of managing the charging and discharging time period of capacitors  $C_{01}$  and  $C_{02}$  in accordance with the (ON/OFF) position of the modified converter switches  $S_1$  &  $S_2$ . The operation of the converter is categorized as three modes which are clearly given in the following section.

#### Mode of Operation

**Mode 0:** When switch ( $S_2$ ) is in "ON" condition and switch ( $S_1$ ) is in "OFF" condition, current in inductance ( $L_1$ ) drops (discharging). As a result, the intermediary capacitor ( $C_1$ ) gets (charging) energy from an input inductor ( $L_1$ ). Consequently, voltage across the intermediary capacitor  $C_1$  boosts as given in Fig. 3.

**Mode 1:** When switch ( $S_1$ ) is in "ON" condition, current in supply voltage drops (discharging). Consequently, the energy is transmitted to the inductance ( $L_1$ ) (charging). Therefore, voltage across the intermediary capacitor  $C_1$  boosts as given in Figure 3. Simultaneously, current in the capacitor  $C_1$  and the supply current  $V_{dc}$  drops (discharging). As a result, the energy is transmitted to the capacitor ( $C_{02}$ ) (charging) with the help of diode  $D_2$ . Consequently, voltage across the intermediary capacitor  $C_{02}$  boosts as given in Fig. 3.

**Mode 2:** When switches ( $S_1$ ) and ( $S_2$ ) is in "OFF" condition, current in inductance ( $L_1$ ) drops (discharging). As a result, the intermediary capacitor ( $C_1$ ) gets (charging) energy from input inductor ( $L_1$ ) with the help the diode  $D_1$ .

**Front end converter control loop:** Given that the major contribution of this research work is based on the converter, this work chooses to utilize a conventional Proportional Integral (PI) for the purpose of a control loop feedback mechanism. In case of industrial process, a PI controller tries to accurate that error among a measured process variable and preferred set point by means of calculating and subsequently provide accurate output that can regulate the process consequently.

The actual voltage in the capacitors ( $V_{dc} = V_{c01} + V_{c02}$ ) and the set voltage  $V_{ac}$  is deducted and the error is provided as input to the PI controller. At this point, the set voltage  $V_{dc}$  is taken as 540 V.

$V_{c01}$  = voltage across the capacitor  $C_{01}$ ,  $V_{c02}$  = voltage across the capacitor  $C_{02}$

The PI controller computation engages two distinct modes, they are, proportional mode and integral mode. In case of the proportional mode, the reaction to the current error is determined, however, in case of the integral mode, the reaction based recent error is determined. The weighted sum of the two modes output as corrective action to the control element. PI controller is extensive employed in

industry because of its simplicity in design and uncomplicated structure. PI controller algorithm can be executed as follows,

$$\text{Output}(t) = K_p \text{err}(t) + K_i \int \text{err}(\tau) d\tau$$

Where  $\text{err}(t) = \text{set voltage} - \text{actual voltage}$

The output of the PI controller which is the controlled error is evaluated against the triangular carrier signal of frequency 5 KHz to produce PWM pulses of switch  $S_1$ . In the same way, with the aim of controlling Switch  $S_2$ , actual voltage taken here is  $V_{dc}/2 = V_{co1}$ . The output of the PI controller which is the controlled error is evaluated against the triangular carrier signal of frequency 10 KHz to produce PWM pulses of switch  $S_2$  as illustrated in Fig 3.

Here, introduced a new DTC strategy which shows the sign of a potential of dropping the torque ripple at some stage in sector-to-sector commutations. These have been concentrated by Zhu and Leong (2012) considering the scenario where the BLDC motor is supplied by a B6-inverter. They formulated a scheme consisting in the application of active voltage vectors in line with the three-phase conduction mode, at the commencement of every sector with the aim of forcing the current in the turned-off phase to flow through a controllable IGBT rather than an uncontrollable freewheeling diode. Therefore, the rising rate  $|di/dt|$  of the current in the turned off phase is controlled in an effort to make it resembling the one of the current in the turned-on phase. The high-speed operation with the DC-link voltage  $V_{dc}$  being lesser than four times the maximum value  $E$  of the back EMF waveform ( $V_{dc} < 4E$ ). With this situation, the following drawbacks have been observed:

The rising rates ( $|dia/dt|$ ,  $|dib/dt|$ , and  $|dic/dt|$ ) of the phase currents rely on three variables, specifically: i) the DC-link voltage  $V_{dc}$ , ii) the back-EMF peak value  $E$ , and iii) the self-inductance  $L$ . As a result, the rising and the falling times  $\Delta t$  of the phase currents rely on their maximum value  $I$  which is openly associated with the load torque  $T_l$ . It has been observed that, even though at high-speed operation ( $V_{dc} < 4E$ ), an unbalanced phenomenon is related with the declining of the electromagnetic torque at some stage in sector-to-sector commutations, particularly for low values of the peak current  $I$  and the self-inductance  $L$ . In addition, it has been found that, at some stage in torque acceleration or deceleration, the rising and falling times  $\Delta t$  of the phase currents are variables which have an effect on the electromagnetic torque by outstanding dips.

The previously explained scheme necessitates an instantaneous measurement of the  $V_{dc}$ , particularly in electric and hybrid propulsion systems where the DC-bus is accomplished by means of a battery pack. Hence, a different scheme is formulated for the purpose of keeping away from

the previously described constraints. It includes the replacement of the two-level torque controller with a four-level one. In actual fact, the positive high level  $c\tau = +2$  of the torque hysteresis controller is methodically triggered when the torque drops at some point in sector-to-sector commutations in the scenario of an anticlockwise rotation ( $T_{em} > 0$ ), while its negative high level  $c\tau = -2$  is methodically triggered when the torque drops at some point in sector-to-sector commutations in the scenario of a clockwise rotation ( $T_{em} < 0$ ). The low level  $c\tau = \pm 1$  are applied at the time of the complete cycle not including the torque dips taking place at some stage in sector-to-sector commutations. With the reference phase currents illustrated in Fig. 1, it should be emphasized that the proposed scheme is ineffective during the commutations from Sector I to Sector II and from Sector IV to Sector V in the scenario of an anticlockwise rotation, and from Sector III to Sector II and from Sector VI to Sector V in the scenario of a clockwise rotation, owing to the truth that  $|dic/dt|$  is out of control. With this, the proposed DTC strategy shows the sign of a capability of reducing the torque ripple at the time of sector-to-sector commutations without any dependence of  $V_{dc}$ ,  $I$ ,  $\Delta t$ , and  $L$ . The result and transformations in the implementation scheme concern just the blocks surrounded by the dashed line in Fig. 7. These turn to be as illustrated in Fig. 8. By considering both anticlockwise and clockwise rotations, the proposed vector selection subtables are given in Tables 3 and 4 respectively.

The performance of the Proposed Modified Converter based DTC model of B4 inverter fed BLDC motor is simulated in MATLAB/Simulink environment using the Sim-Power-System toolbox. The performance evaluation of the proposed system is categorized in terms of the voltage balancing performance of the front end Converter as well as the sudden change in torque and speed in the rear end B4 Inverter. The parameters associated with the proposed system such as voltage across the balancing capacitors  $V_{co1}$  and  $V_{co2}$ , Expected voltage across the balancing capacitors  $V^*_{co1}$  and  $V^*_{co2}$  are analyzed for the proper functioning of the front end Converter. The conventional buck boost converter based DTC model of B4 inverter fed BLDC motor response which is termed as 'Exist'. It is observed that, the existing buck boost converter model results in voltage unbalanced condition across the capacitors  $co_1$  and  $co_2$ . This voltage unbalancing condition results in higher torque and speed ripples. The capacitor voltages  $V_{co1}$  and  $V_{co2}$ , are varied sequentially to attain the respective torque and speed ripples (Table 5)

From the Table 5, it is clearly observed that, an efficient voltage balancing capacitor is essential to handle this voltage unbalancing condition. The proposed modified converter

based DTC model of B4 inverter fed BLDC motor is designed to handle this problem and its response is termed as 'Proposed' in the simulated result. The specifications of the BLDC motor for this simulation study is given below.

BLDC Motor Rating: four poles, Prated (rated power) = 251.32 W, Vrated (rated dc link voltage) = 200 V, Trated (rated torque) = 1.2 N·m,  $\omega$  rated (rated speed) = 2000 r/min, Kb (back EMF constant) = 78 V/kr/min, Kt (torque constant) = 0.74 N·m/A, Rph (phase resistance) = 14.56  $\Omega$ , Lph (phase inductance) = 25.71 mH, and J (moment of inertia) =  $1.3 \times 10^{-4}$  N·m/A<sup>2</sup>. Back EMF constant = 78 V/kr/min; thus a minimum of 78 vpeak\*4=312v for b4 inverter is required. Here, 540 V is considered as Vout.

### CONCLUSION

In this proposed research presents in the dsPIC microcontroller (dsPIC30F4011) based 120 degree mode is used for gate pulse generation in the B4 Inverter fed brushless DC Motor drive. Brushless DC drives which is preferable for compact, low maintenance and high reliability system in order to reduce the mechanical strength so it proposed and convenient results were carried out. In this scheme, the Pulse width modulation is applied to switches of the B4 Inverter, This Pulse width modulation scheme can eradicate the offset voltage in the back Electromotive force signal caused by the voltage drop of the Insulated bipolar transistor and also increase system efficiency by reducing the conduction loss is achieved compared to conventional converter. The simulation results are verifying the feasibility of the system. The concept of the capacitor voltage balancing is also done to obtain equal voltage across the capacitors. Since converter used Sensorless control operation no hall sensors, therefore, the system becomes robust, optimized design of the Brushless DC Motor achieved higher efficiency and better speed, current were formulated.

**Table 3.** Vector selection subtable for BLDC motor vector selection subtable adopted to reduce the distortion of the BLDC motor phase current in sectors II and V

$C\tau_a$	+1		-1	
	+1	-1	+1	-1
Sector II	$U_3$ (0110)	$U_4$ (0101)	$U_2$ (1010)	$U_1$ (1001)
Sector V	$U_1$ (1001)	$U_2$ (1010)	$U_4$ (0101)	$U_3$ (0110)

**Table 4.** Vector selection subtable for sector-sector commutations vector selection subtable during setor-to-sector communications in the case of a clockwise rotation

$C\tau$		-2
Sector II	Sector I	$U_1$ (1001)
Sector I	Sector VI	$U_4$ (0101)
Sector V	Sector IV	$U_3$ (0110)
Sector IV	Sector III	$U_2$ (1010)

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**Table 5.** Torque and speed ripples evaluation

$V_{out}$	$V_{C01}$	$V_{C02}$	Conventional circuit evaluation					
			Higher Torque Value HTV)	Lower Torque Value LTV)	Torque Ripple (TR) (TR=HTV-LTV)	Higher Speed Value(HSV)	Lower Speed Value (LSV)	Speed Ripple (SR) (SR=HSV-LSV)
540 V	270 V	270 V	1.4 Nm	0.95 Nm	0.45 Nm	2005 Rpm	1980 Rpm	25 Rpm
540 V	260 V	280 V	1.43 Nm	0.9 Nm	0.5 Nm	2008 Rpm	1977 Rpm	31 Rpm
540 V	250 V	290 V	1.47 Nm	0.88 Nm	0.59 Nm	2012 Rpm	1974 Rpm	38 Rpm
540 V	220 V	320 V	1.55 Nm	0.87 Nm	0.68 Nm	2015 Rpm	1973 Rpm	42 Rpm
540 V	200 V	340 V	1.61 Nm	0.87 Nm	0.74 Nm	2017 Rpm	1972 Rpm	45 Rpm
540 V	170 V	370 V	1.72 Nm	0.84 Nm	0.88 Nm	2021 Rpm	1969 Rpm	52 Rpm
540 V	140 V	400 V	1.93 Nm	0.6 Nm	1.33 Nm	2028 Rpm	1955 Rpm	73 Rpm
540 V	100 V	440 V	2.5 Nm	0.2 Nm	2.3 Nm	2032 Rpm	1935 Rpm	97 Rpm

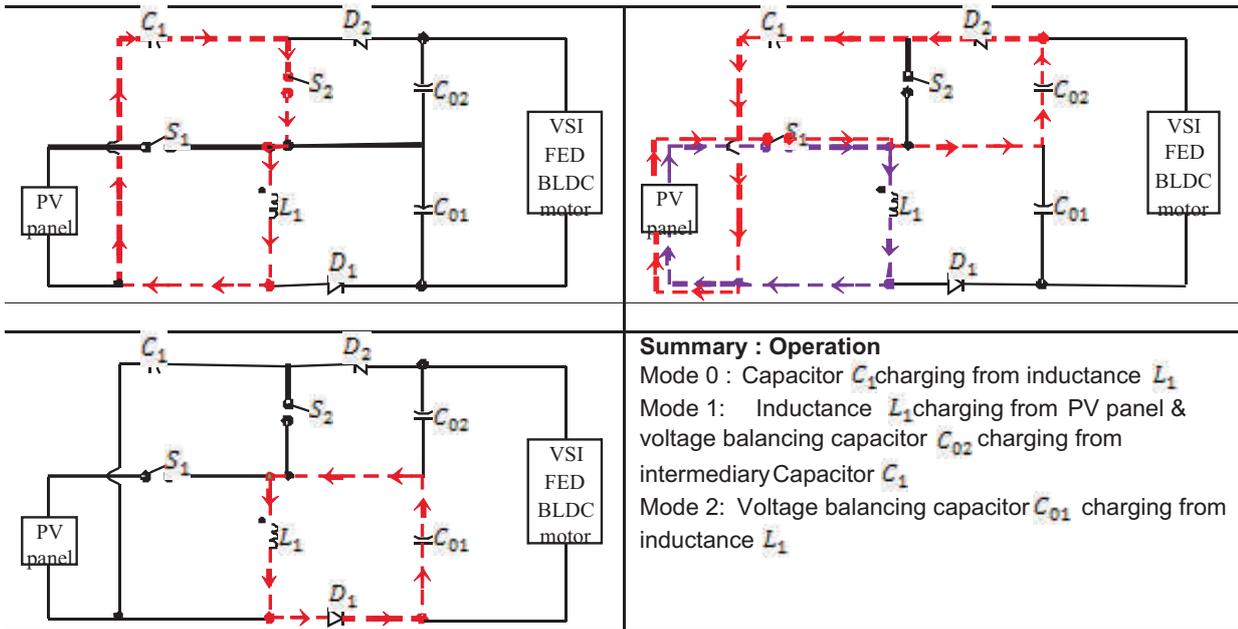


Fig. 3. Modes of operation

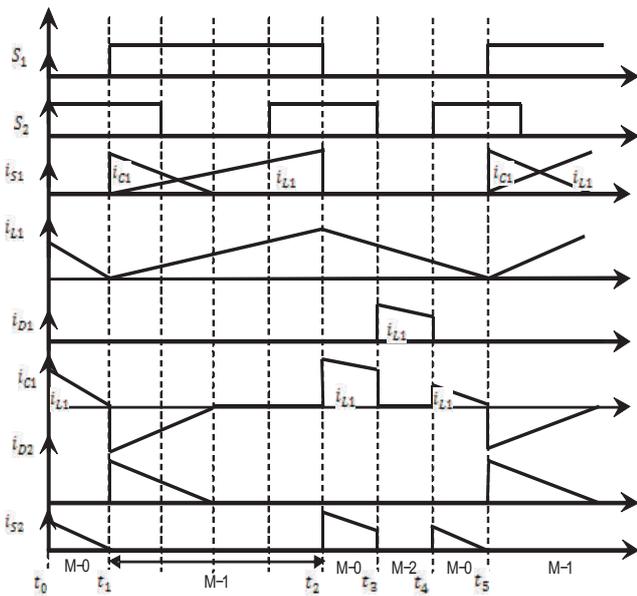


Fig. 4. Theoretical analysis

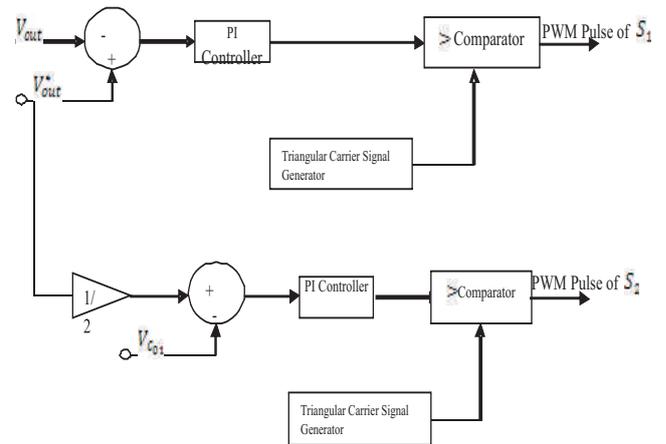


Fig. 5. Proposed front end modified converter control loop

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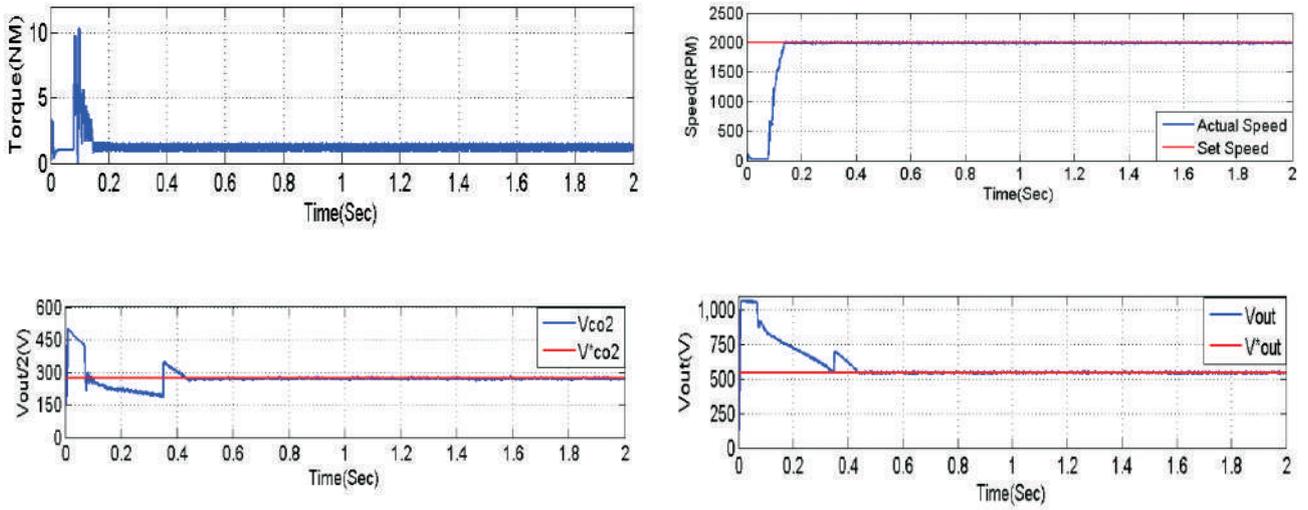


Fig. 6. Performance of BLDC motor

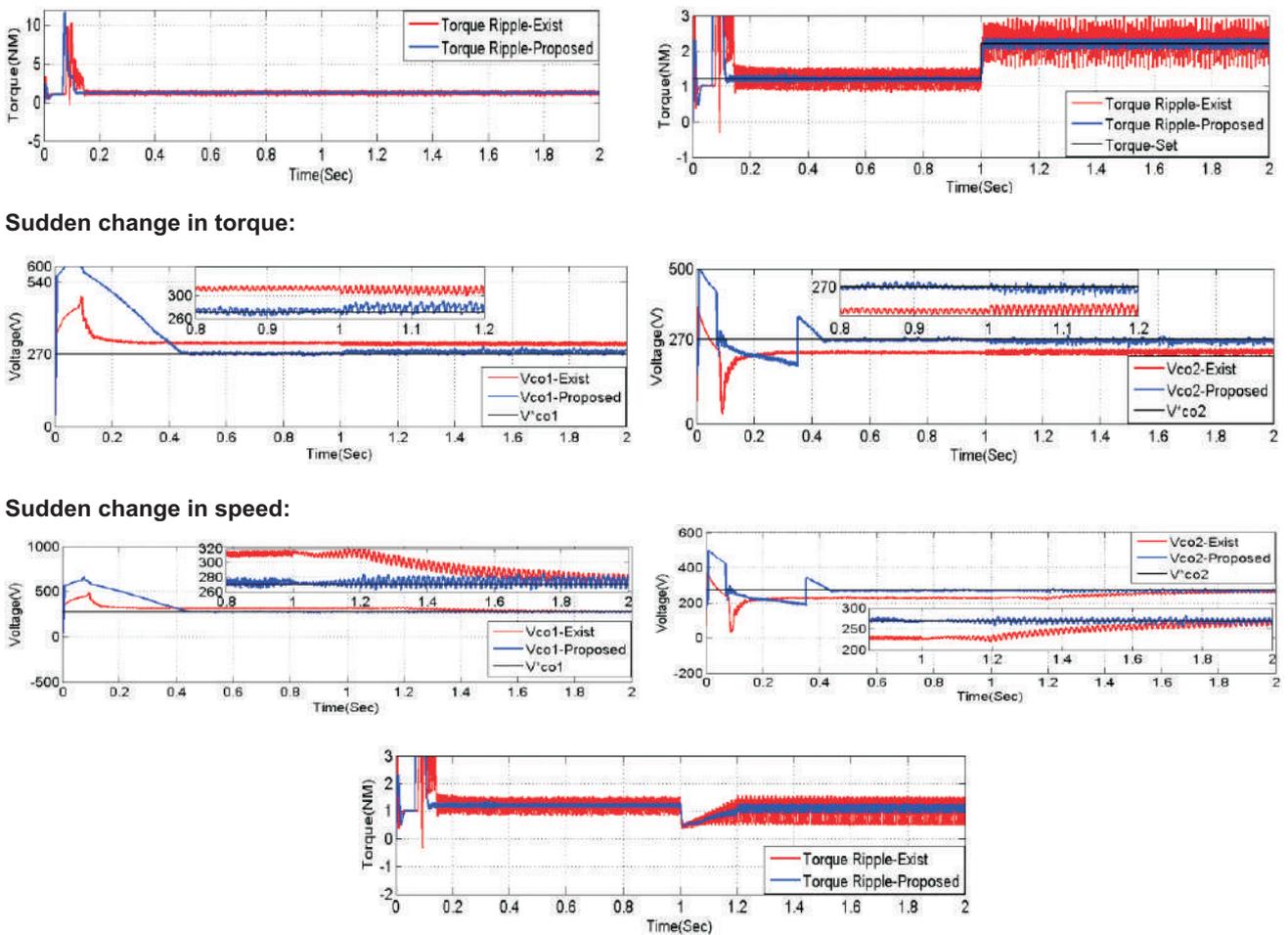


Fig. 7. Performance of parameters

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## Seasonal Variations in Physico Chemical Characteristics of Dal Lake, Kashmir

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**Abstract:** The present paper deals with the assessment of different physico chemical parameters of Dal lake, Kashmir during December 2011–November 2013. Transparency varied from 0.2 m to 1.5m and was maximum in summer after the melting of snow. Conductivity varied from 100 to 592 $\mu$ S/cm and was maximum in spring and minimum in summer in both the years. pH values varied from 7.2 to 9.5 and it showed an increase with increasing water temperature indicating a positive correlation with the latter. Dissolved oxygen was recorded higher in spring and lower in summer. High alkalinity indicated productive nature of lake. Total hardness was due to the source of  $\text{Ca}^{++}$  and  $\text{Mg}^{++}$  owing to its origin to the lacustrine deposits in the valley. The lake is calcium rich water. Ammonical and nitrate nitrogen was maximum in winter due to slower metabolic processes. On the basis of phosphorus range Hazaratbal basin and Brarinumbal basin of Dal lake fall under hyper eutrophic category. Results indicated that Brarinumbal basin differ from other basins of the Dal Lake tremendously in nature as it is undergoing fast eutrophication due to pollution caused by domestic sewage, organic wastes and agricultural run off which has enriched the lake water.

**Keywords:** Conductivity, Calcium, Dissolved oxygen, hyper eutrophic, Phosphorus

Nutrient supply due to anthropogenic activities such as sewage, fertilizer run off from agricultural fields changes the lake ecosystem causing eutrophication. Continuous eutrophication results from autotrophic production of internal organic matter by primary producers from nutrients available in the lake derived from external sources anthropogenic activities in the catchment. Discharge of sewage into water body is a common way that various nutrients enter the aquatic ecosystem resulting in the pollution of these systems (Adeyemo 2003). The hydrogeochemical characteristics of water body are not constant and fluctuate seasonal variation as well as degree of pollution (Prasad 2006). A physico chemical approach to monitor water quality gives the causes and levels of pollutants in the water body. The trophic status of water body is determined by physico chemical features of the lake, therefore a knowledge of important parameters is essential for understanding and functioning of the lake ecosystems. In order to gain insight into the changing environment of the lake a study was conducted during 2011 – 2013 with objective to assess the changes in trophic status with respect to the physico chemical parameters of the lake.

### MATERIAL AND METHODS

To study the status of water quality, the Dal lake was visited every month starting from December, 2011 through November 2013 for collection of water samples between 9 to 12 a.m from each sampling site. Temperature of both air and

water was measured. The depth was determined with a weighted graduated non-stretchable line, transparency was by a 20 cm diameter Secchi disc painted black on under surface and white and black on upper surface. The pH and conductivity were measured with the help of portable pH meter (HANNA Model –PHEP) and conductivity meter (HANNA Model – DIST –3). Dissolved oxygen content was estimated by Iodometric Azide Modification Method of Winkler (APHA 1998). Free carbon dioxide and alkalinity were determined by Titrimetric method (Mackereth et al 1978). Concentration of chloride was determined by silver nitrate method (APHA, 1998). Total hardness, calcium and magnesium were determined by EDTA titrimetric method (APHA, 1998). Phosphate (stannous chloride method), nitrate (salicylate method) and ammonia (phenate method) were analyzed with the help of Systronics 106 Spectrophotometer in accordance with CSIR (1974) and (Mackereth et al 1978).

**Study Area:** Dal lake is a, shallow urban water body situated at an altitude of 1583 m (a.s.l) within the geographic coordinates of 34°4'56"–34°08'57"N and 74°49'48"–74°52'51"E at a distance of about 12 km to the North east of the Srinagar city. It has a total area of 11.5 km<sup>2</sup>, with the maximum depth of 1.5 m. The lake is open drainage type and receives water from (1) TelbalNallah (Dachigam Nallah) and (2) Bot kol. The lake is divisible into five basins, (Fig. 1). Gagribal basin in the south – east, Lokut –in the east with a small island called

Rupa-Lank in the middle, Hazaratbal basin in the north with a small island called Sona –Lank in the middle. This basin receives Telbal stream on its north side and is connected by a narrow channel at Ashaibagh with the 4<sup>th</sup> basin of the lake and the Nageen basin. On the western side the Gagribal basin is connected with the 5<sup>th</sup> basin called Brarinumbal basin through the Nowpora channel. The lake is infested with many macrophytes at many places like *Myriophyllum spicatum*, *Ceratophyllum demersum*, *Potamogeton lucens* and *Nelumbo nucifera*

Four study sites which represented various microhabitats were selected in this lake,

**D1:** towards the north–west of the lake at 34°08'41fN and 74°50'38fE, adjacent to the place where Telbal Nallah enters the lake.

**D2:** in Hazaratbal basin at 34°07'28fN and 74°51'04fE. This area is characterized by submerged macrophytes especially *Ceratophyllum demersum*.

**D3:** in Lokut Dal, at 34°05'37fN and 74°52'15fE. It receives heavy amount of waste from Centaur hotel .

**D4:** in Brarinumbal basin at 34°05'18.6fN and 74°49'58fE. It is located close to human habitation therefore highly eutrophic as raw sewage are discharged into it.

## RESULTS AND DISCUSSION

**Temperature:** Water surface is directly exposed to solar radiation and accordingly the monthly fluctuations of water temperature followed closely those of air temperature. Surface water temperature of all the four sites showed

maximum values in summer and minimum in winter (Fig. 1), During the first year it ranged from 3.9°C (January) at site D1 to 30.5°C (July) at site D3 and D4, while in the second year it varied from 4.2°C (January) at site D1 to 30.4°C (July) at site D2 and D3.

**Transparency:** Significant seasonal variations in the Secchi transparency were recorded with increasing trend from March, attaining maximum values in June and July and decreasing from August onwards (Fig. 2). During the first year it varied from 0.2 m (January, February, November) at site D<sub>1</sub> and D<sub>4</sub> to 1.5 m (July) at D<sub>3</sub>. During the second year the range was between 0.2m (January, February) at site D<sub>1</sub>, D<sub>4</sub> to 1.5 m (July) at the site D<sub>3</sub>.

**Depth:** Depth of Dal lake varied from place to place and also from season to season (Fig. 3). In the first year it varied from 0.5m (February) at site D<sub>4</sub> to 2.4m (June) at site D<sub>1</sub> and D<sub>2</sub>, while in the second year it ranged from 0.4m (February) at site D<sub>4</sub> to 2.3m (June) at site D<sub>1</sub>, D<sub>2</sub>, D<sub>3</sub>. Maximum values were recorded in summer and minimum in winter.

**Conductivity:** The conductivity of water showed variations between 100 (August) at site D<sub>3</sub> and 592µS/cm (May) at site D<sub>4</sub> during the first year and 154 (July) at site D<sub>2</sub> and 581µS/cm (April) at site D<sub>4</sub> during the second year (Fig. 4). The difference in conductivity values between the site D<sub>4</sub> and site D<sub>1</sub>, D<sub>2</sub>, D<sub>3</sub> was found to be statistically significant (Table 1). Maximum conductivity was in spring and minimum in summer in both the years.

**pH:** The pH was maximum in summer and the minimum in

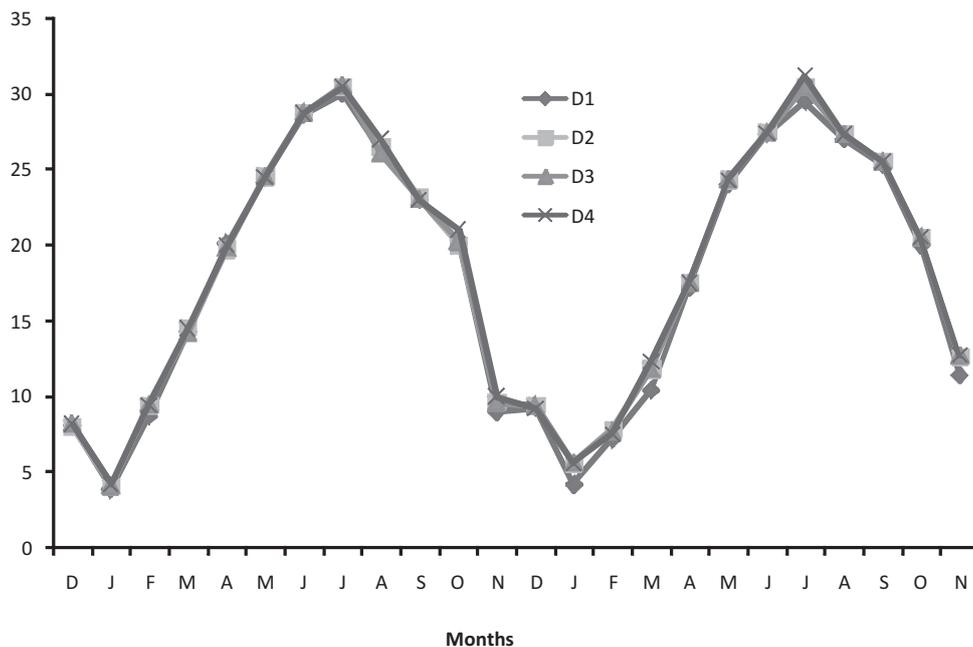


Fig. 1. Variations in water temperature in Dal lake

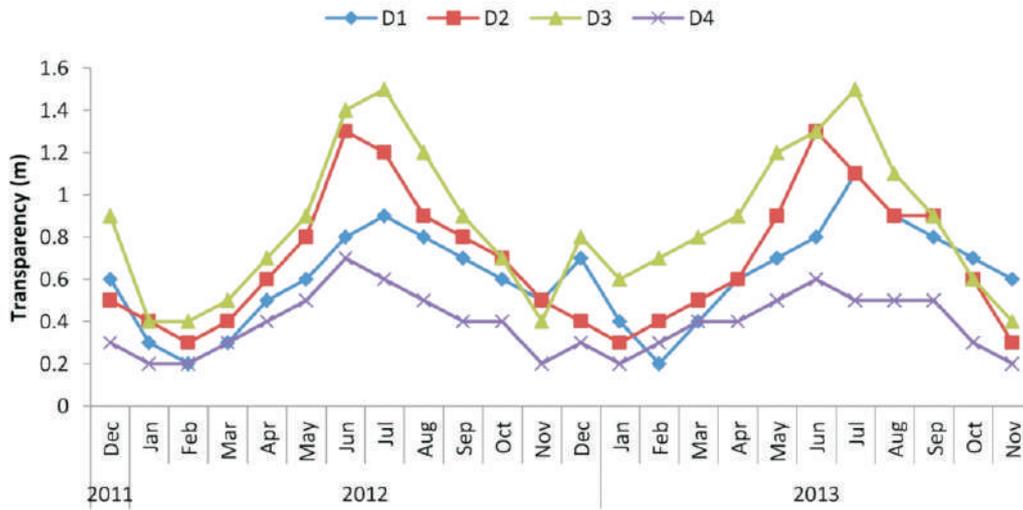


Fig. 2. Variations in transparency in Dal lake

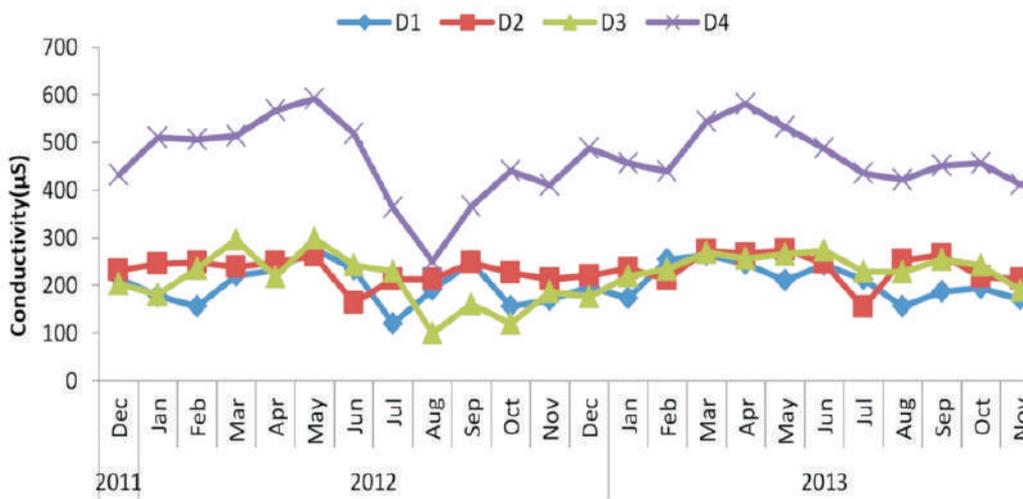


Fig. 3. Variations in depth in Dal lake

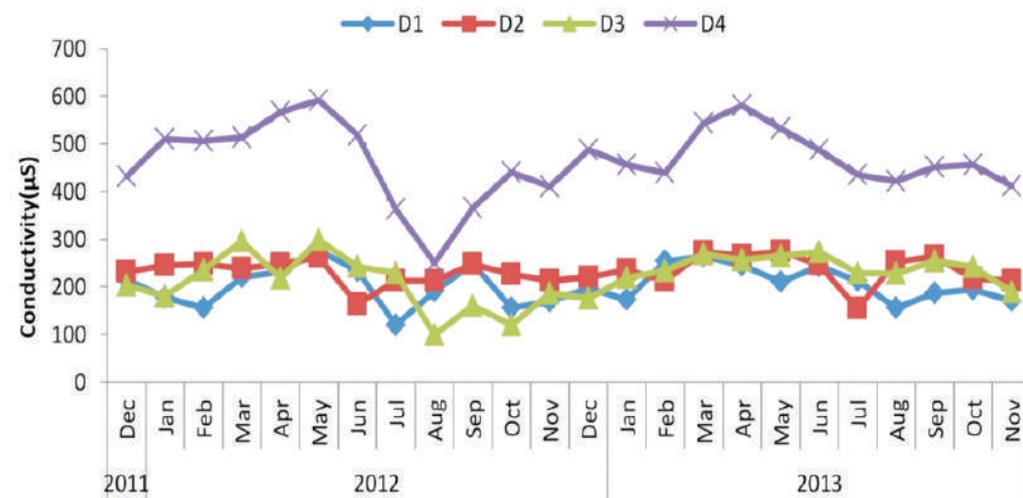


Fig. 4. Variations in conductivity in Dal lake

**Table 1.** Physico-chemical parameters between different sites of Dal Lake

Parameter	Site	D1	D2	D3	D4	p-value
Water temperature	D1	-	0.87	0.87	0.82	0.99
	D2	0.87	-	0.99	0.95	
	D3	0.87	0.99	-	0.95	
	D4	0.83	0.95	0.95	-	
Dissolved oxygen	D1	0.85	-	0.86	0.00	0.00
	D2	0.85	-	0.72	0.00	
	D3	0.86	0.72	-	0.00	
	D4	0.00	0.00	0.00	0	
Conductivity	D1	-	0.066	0.27	0.00	0.00
	D2	0.06	0	0.45	0.00	
	D3	0.27	0.45	-	0.00	
	D4	0.00	0.00	0.00	-	
Hydrogen ion concentration	D1	-	0.18	0.13	0.01	0.00
	D2	0.18	-	0.87	0.00	
	D3	0.13	0.87	-	0.00	
	D4	0.001	0.00	0.00	-	
Carbon dioxide	D1	-	0.18	0.09	0.00	0.00
	D2	0.18	-	0.092	0.00	
	D3	0.097	0.092	-	0.00	
	D4	0.00	0.00	0.00	-	
Chloride	D1	-	0.42	0.85	0.00	0.00
	D2	0.42	-	0.54	0.00	
	D3	0.85	0.54	-	0.00	
	D4	0.00	0.00	0.00	-	
Ammonical nitrogen	D1	-	0.00	0.00	0.00	0.00
	D2	0.00	-	0.50	0.00	
	D3	0.00	0.50	-	0.00	
	D4	0.00	0.00	0.00	-	
Total phosphate phosphorus	D1	-	0.00	0.00	0.00	0.00
	D2	0.00	-	0.84	0.00	
	D3	0.00	0.84	-	0.00	
	D4	0.00	0.00	0.00	-	

The difference is significant at 0.05 level

winter (Fig. 5). It varied from 7.2 (January) at site D<sub>2</sub> to 9.4 (July) at D<sub>2</sub> site during the first year, while during the second year it varied from 7.2 (January) at site D<sub>3</sub>, D<sub>4</sub> to 9.7 (June) at site D<sub>2</sub> and D<sub>4</sub>. The difference in pH values of site D<sub>4</sub> in comparison to the other sites was statistically significant (Table 1).

**Dissolved oxygen:** The oxygen concentration was maximum in spring (Fig. 6). Its concentration varied during the first year from 1.3mg l<sup>-1</sup> (July) at site D<sub>4</sub> to 13.8 mg/l (March) at site D<sub>1</sub>, while during the second year it varied from 2.4 mg l<sup>-1</sup> (August) at site D<sub>4</sub> to 12.5 (April) at site D<sub>2</sub>. The oxygen content at site D<sub>4</sub> was different from the other three

sites, the difference being statistically significant (Table 1).

**Free carbon dioxide:** Perusal of the data of the lake showed absence of carbon dioxide at site D<sub>2</sub> and D<sub>3</sub> from March to September during both the years (Fig. 7). At site D<sub>1</sub> it ranged from 6.7 (July) to 8.7 mg l<sup>-1</sup> (February) and 7.3 (June) to 8.5 mg l<sup>-1</sup> (December) in the two successive years respectively. Similarly it ranged at site D<sub>4</sub> from (July) to 41mg/l (November) and 17 (May) to 54 mg l<sup>-1</sup> (October) in the two years respectively. From spring concentration of carbon dioxide showed decreasing trend reaching the minimum value in summer; in autumn it showed a slight increasing trend and attained the maximum value in winter. The difference in carbon dioxide content between site D<sub>4</sub> and other three sites was statistically significant (Table 1).

**Total alkalinity:** Total alkalinity fluctuated from 54 (September) at site D<sub>3</sub> to 297 mg l<sup>-1</sup> (August) at site D<sub>4</sub> during the first year while during the second year it ranged from 107 (December) at site D<sub>3</sub> to 285 mg l<sup>-1</sup> (July) at site D<sub>4</sub> (Fig. 8a, 8b). Alkalinity showed increasing trend in winter and minimum in summer. Throughout the study period carbonates were totally absent at site D<sub>1</sub> and site D<sub>2</sub> and thus alkalinity was due to bicarbonates of calcium and magnesium. At site D<sub>2</sub> and D<sub>3</sub> carbonates were present from March to September, and thus alkalinity was due to bicarbonates and carbonates. At site D<sub>2</sub> carbonates ranged from 5 to 44 mg l<sup>-1</sup> and 9 to 26 mg l<sup>-1</sup> in the two years respectively while at site D<sub>3</sub> it ranged from 7 to 40 mg/l and 6 to 26 mg l<sup>-1</sup> in the two years respectively.

**Total hardness:** In the lake total hardness during the first year study fluctuated from 83 (August) at site D<sub>2</sub> to 438 mg l<sup>-1</sup> (July) at site D<sub>4</sub>, while during the second year it ranged from 85 (February) at site D<sub>2</sub> to 374 mg l<sup>-1</sup> (July) at site D<sub>4</sub> (Fig. 9). Hardness values in the lake were high in summer and low in winter. Calcium hardness showed a range of 34 (February) at site D<sub>2</sub> to 167 mg l<sup>-1</sup> (June) at site D<sub>4</sub> in the first year while as in the second year it fluctuated from 34 (February) at site D<sub>1</sub> to 145 mg/l (March) at site D<sub>4</sub> (Fig. 10). Calcium hardness was low in winter and high in spring and summer. Magnesium hardness fluctuated in the first year from 6 (February/April) at site D<sub>4</sub>, D<sub>2</sub> to 80 mg l<sup>-1</sup> (July) at site D<sub>4</sub> and from 4 (February) at site D<sub>2</sub> to 69 mg l<sup>-1</sup> (July) at site D<sub>4</sub> in the second year (Fig. 11). Magnesium hardness was low in winter, high in spring, summer and autumn, attained maximum concentration in summer.

**Chloride:** The chloride concentration of the lake ranged from 10 (November) at site D<sub>2</sub> to 62 mg l<sup>-1</sup> (April) at site D<sub>4</sub> in the first year while in the second year it ranged from 17 (May, November.) at site D<sub>1</sub>, D<sub>3</sub> to 67 mg l<sup>-1</sup> (January) at site D<sub>4</sub> (Fig. 12). No definite trend in seasonal variation was recorded here. The difference between the site D<sub>4</sub> and D<sub>1</sub>, D<sub>2</sub>, D<sub>3</sub> was

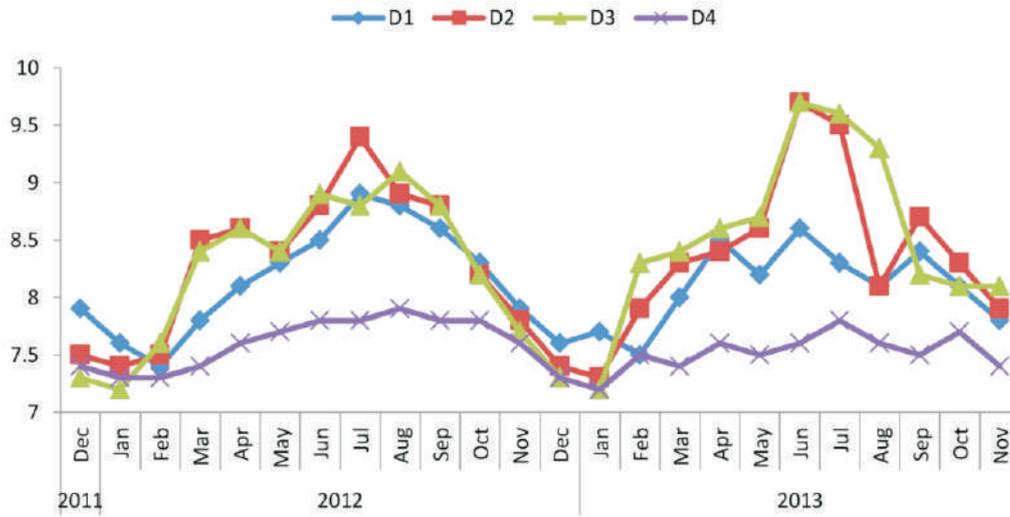


Fig. 5. Variations in pH in Dal lake

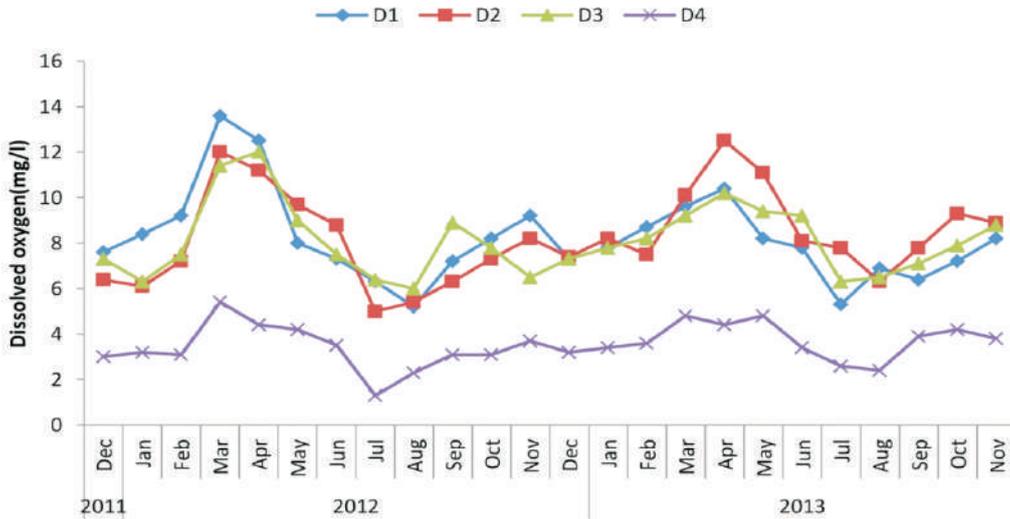


Fig. 6. Variations in dissolved oxygen in Dal lake

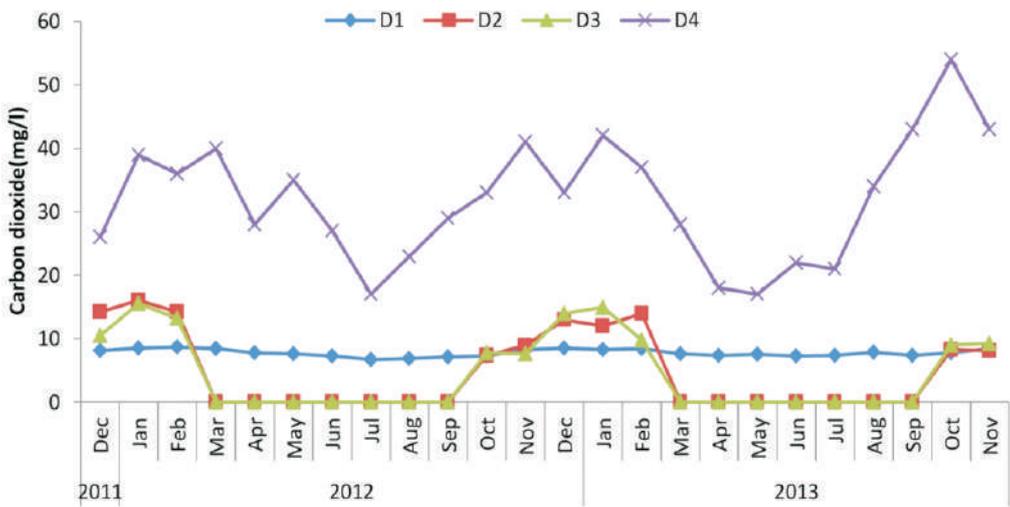


Fig. 7. Variations in carbon dioxide in Dal lake

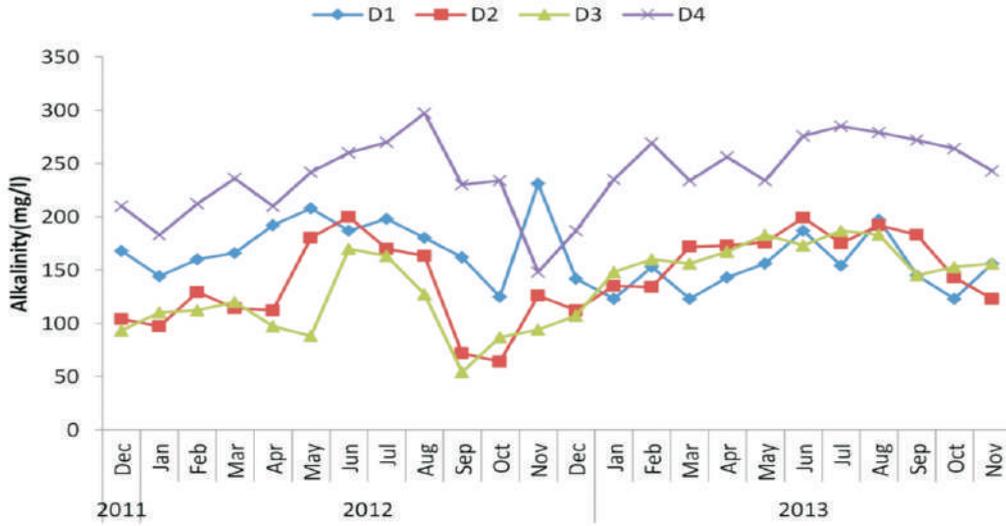


Fig. 8a. Variations in alkalinity in Dal lake

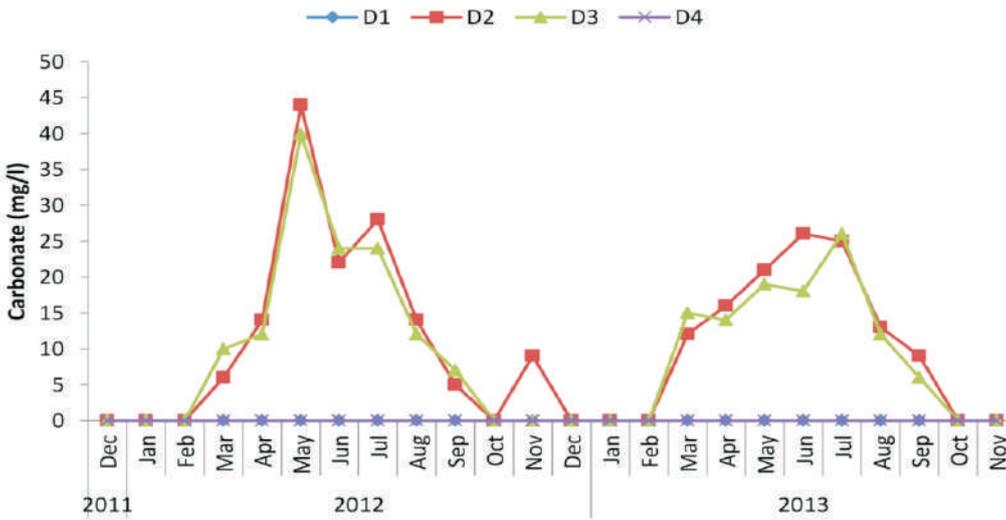


Fig. 8b. Variations in carbonates in Dal lake

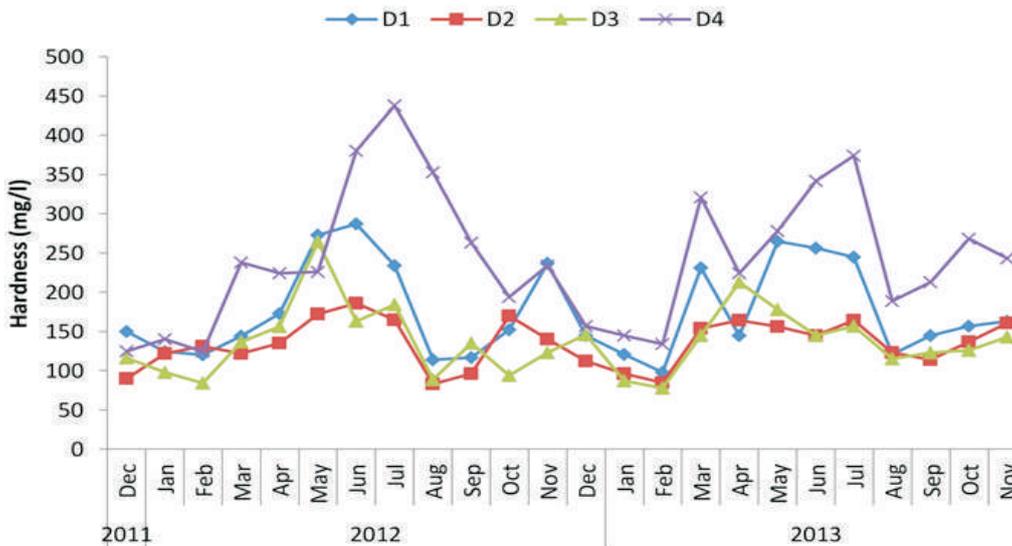


Fig. 9. Variations in hardness in Dal lake

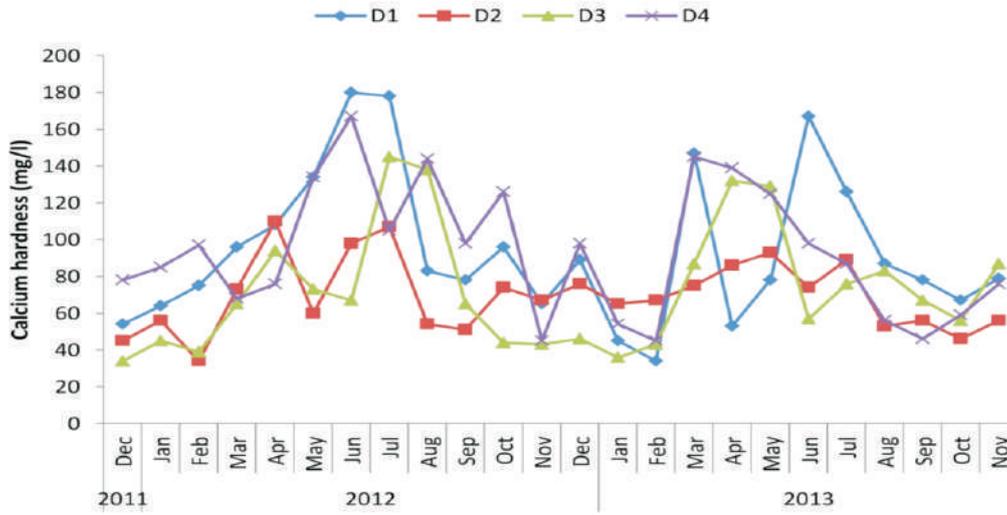


Fig. 10a. Variations in calcium hardness in Dal lake

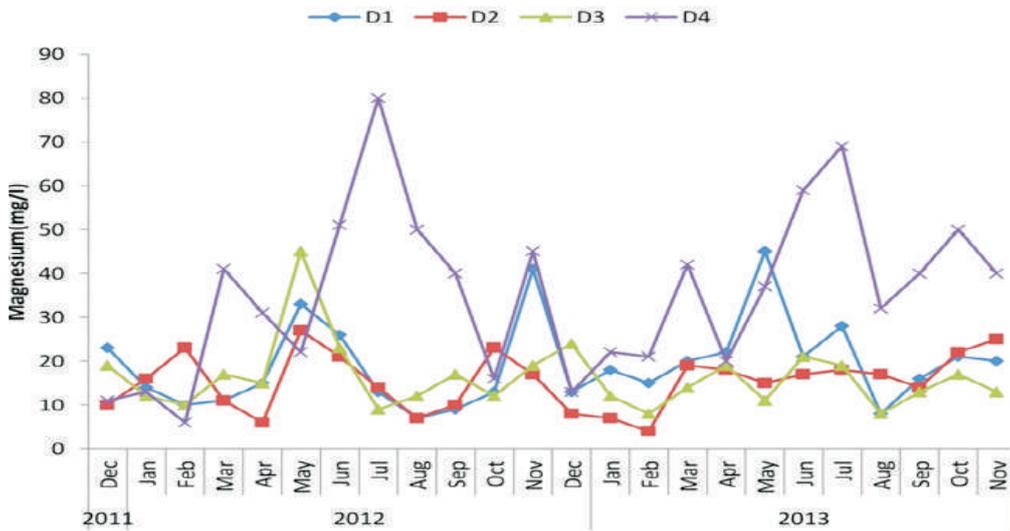


Fig. 10b. Variations in magnesium hardness in Dal lake

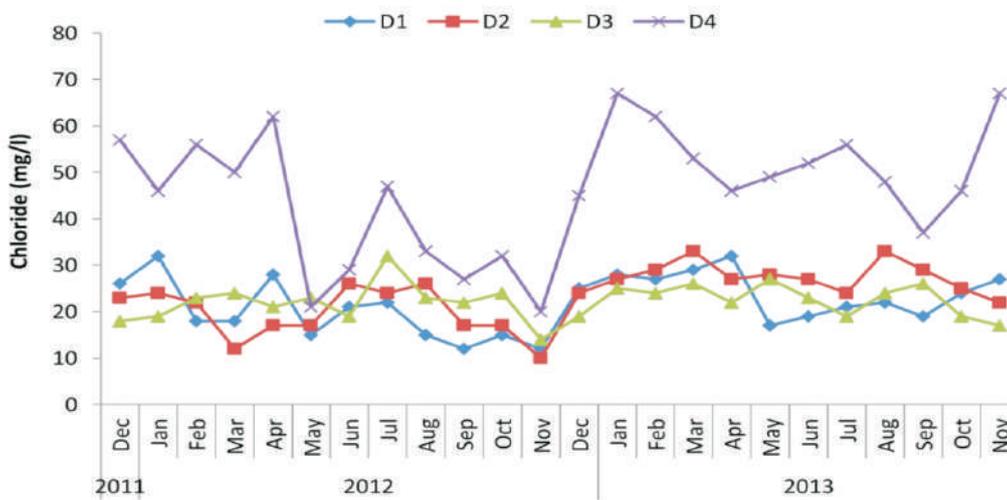


Fig. 11. Variations in chloride in Dal lake

statistically significant (Table 1).

**Ammonical nitrogen:** Data pertaining to ammonical nitrogen in the lake (Fig. 13) ranged from 44 (August) at site D<sub>2</sub> to 1263  $\mu\text{g l}^{-1}$  (January) at site D<sub>4</sub> during the first year while during the second year it ranged from 89 (August) at site D<sub>2</sub> to 1124  $\mu\text{g l}^{-1}$  (November) at site D<sub>4</sub>. During both the years a decreasing trend was recorded from spring to summer resulting minimum concentration in summer. From autumn it showed increasing trend attaining maximum concentration in winter.

**Nitrate nitrogen:** The nitrate nitrogen content (Fig. 14) fluctuated from 87 (July) at site D<sub>2</sub> to 893  $\mu\text{g l}^{-1}$  (October) at site D<sub>1</sub> during the first year and from 58 (July) at site D<sub>2</sub> to 698  $\mu\text{g l}^{-1}$  (November) at site D<sub>1</sub> during the second year. Concentration of nitrate nitrogen was high in autumn and winter, decreased from spring and attained minimum in summer. Site D<sub>4</sub> showed a significant difference with D<sub>1</sub>, D<sub>2</sub>, D<sub>3</sub>.

**Total phosphate phosphorus:** Total phosphate phosphorus in the lake ranged during the first year from 148 (February) at site D<sub>2</sub> to 1663  $\mu\text{g l}^{-1}$  (May) at site D<sub>4</sub> while during the second year it showed fluctuations from 135 (February) at site D<sub>2</sub> to 1470  $\mu\text{g l}^{-1}$  (July) at site D<sub>4</sub> (Fig. 15). High concentration was recorded in warmer months in spring and summer and minimum in autumn and winter. The difference in between the sites D<sub>4</sub> and D<sub>1</sub>, D<sub>2</sub>, D<sub>3</sub> was statistically significant.

The present data recorded maximum transparency in summer in Dal lake. The melting of snow in the higher altitudes of the valley starts in march and the rate of melting increases with advance in spring and most of the snow on hills is completely melted by the end of June. It is this period when the depth of the water bodies reached the peak values and the transparency shot up. The low transparency recorded in Brarinumbal basin is related with sewage disposal, domestic effluents and agricultural runoff bringing large quantities of silt into the lake. The maximum transparency at Hazratbal basin and Gagribal basin

corresponded with higher depth. Depth of lake is related to precipitation, melting of snow (Yousuf et al 2007). The depth was low in winter / autumn and high in spring / summer. The depth had a direct effect on transparency and a positive correlation was recorded between the two. During spring/summer melting of snow led to increase in volume of water and in close association with it the transparency also recorded the highest values. Electrical conductivity of water varies with temperature. Conductivity of lake water is of definite geochemical interest and depends generally upon the geological character of the rocks and subsoils in the catchment area and the basin. However, human interference in the catchment may overshadow the contribution of geology. A similar phenomenon seems to be operating in the present lakes. The high electrical conductivity values in Dal lake in spring particularly in Brainumbal basin is attributable to the inflow of domestic sewage and agricultural runoff. Dissolved oxygen concentration was higher in spring, while the lowest values were observed in summer. A non-significant correlation ( $r = -0.127$ ), between temperature and oxygen indicates that concurrent with photosynthetic activity, organic decomposition also takes place, leading to utilization of oxygen content, thereby reducing the oxygen (Table 2). Raina et al (2004) s also reported lower dissolved oxygen in summer months due to higher rate of decomposition of organic matter in high temperature. In case of the Brarinumbal basin of the Dal lake the dissolved oxygen was always very low due to high biological oxygen demand as a result of presence of significant quantities of decomposing organic matter throughout the year.

Hydrogen ions concentration showed an increase with increasing water temperature indicating a positive correlation with the latter. A significant positive correlation was recorded between water temperature and pH ( $r = 0.670$ ). In summer maximum pH values may be attributed to increased photosynthetic activity which is accelerated by rising temperature and prolonged photoperiod. High pH values in summer results from rapid removal and assimilation of dissolved carbon dioxide from the water. During winter low

Parameter	Air temp	Water temp	Depth	Transparency	pH	Oxygen	Carbon dioxide
Air temp	1	0.956**					
Water temperature	0.956**	1					
Depth	0.344**	0.376**	1				
Transparency	0.671**	0.685**	0.685**	1			
pH	0.672**	0.670**	0.683**	0.815*	1		
Oxygen	-155	-127	-664**	0.181	0.358**	1	
Carbon dioxide	-275	-266**	-275**	-664**	-679**	-705**	1

\* and \*\* = Correlation is highly significant at  $p < 0.05$  and  $< 0.01$

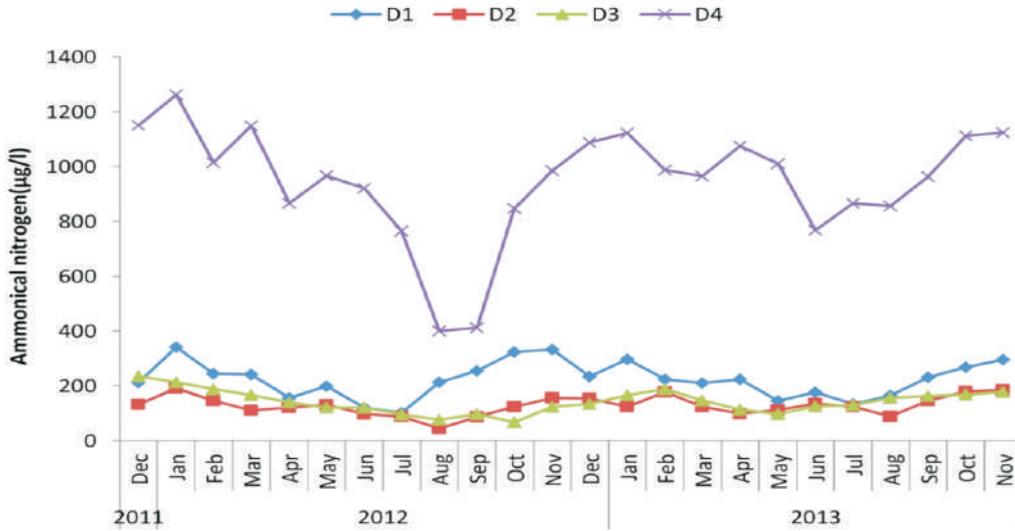


Fig. 12. Variations in ammonical nitrogen in Dal lake

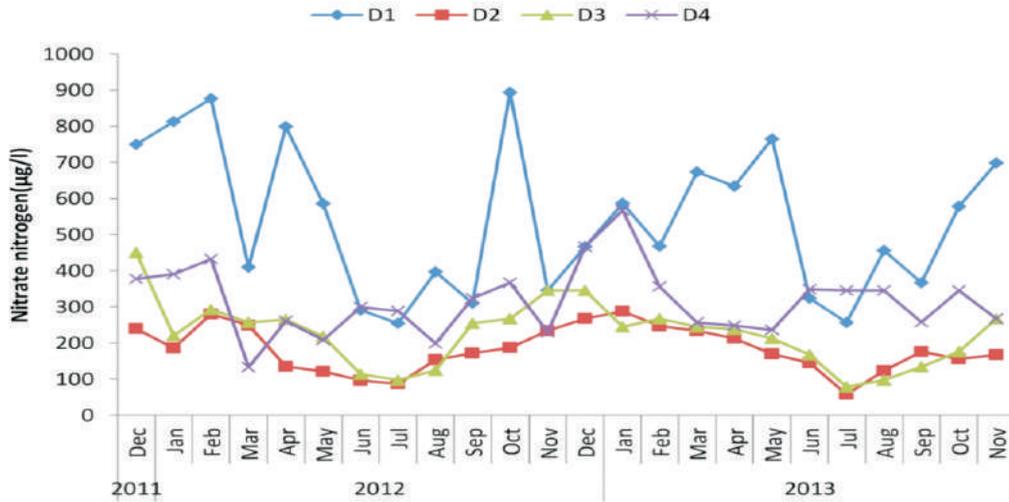


Fig. 13. Variations in nitrate nitrogen in Dal lake

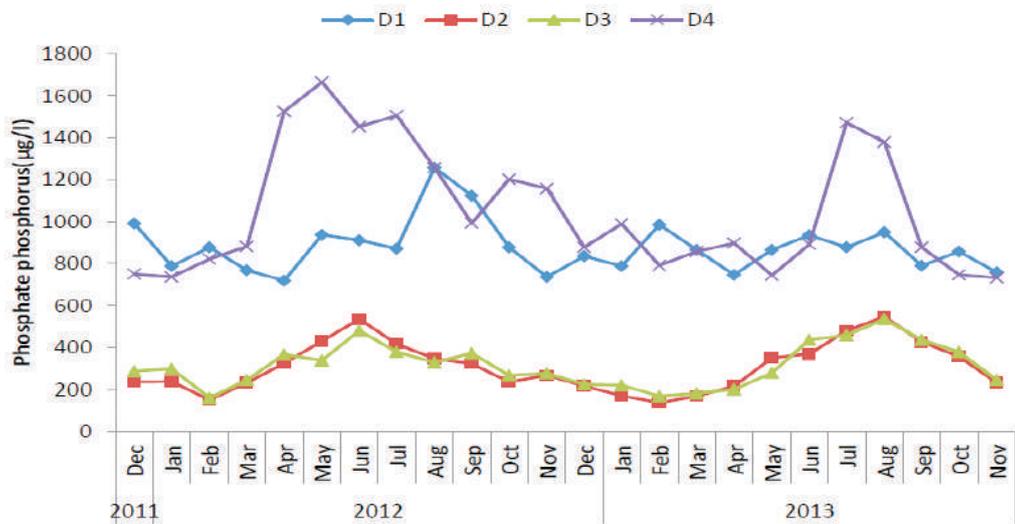


Fig. 14. Variations in phosphate phosphorus in Dal lake

photosynthetic activities and the dominance of decomposition over photosynthesis results in the liberation of carbon dioxide which causes lowering of pH (Kinnear and Garnett 1999). Low pH values often occur in natural waters rich in dissolved organic matter (Wetzel 2001). A negative correlation significant was recorded between carbon dioxide and pH ( $r = -0.679$ ). The concentration of carbon dioxide was high in winter and low in summer. This is due to high photosynthetic activity of macrophytes which consume carbon dioxide during summer and during winter low or no photosynthesis occurs, with the result carbon dioxide liberated as a by-product in the respiration of animals and plants gets accumulated in water in large quantities. At site D<sub>2</sub> (Hazratbal basin), site D<sub>3</sub> (Gagribal basin) carbon dioxide remained absent during spring and summer. A major cause of the loss of aggressive CO<sub>2</sub> is photosynthetic utilization of carbon dioxide by phytoplankton and submersed macrophytes during the larger hours of sunshine. The higher concentration of carbon dioxide in Brarinumbal basin seems to be related to the continuous oxidation of large quantities of organic matter existing therein inhibiting the conversion of bicarbonates to carbonates. The total alkalinity values have been used to differentiate soft and hard water bodies. According to Sorensen (1948) and Moyle (1949) lakes having total alkalinity values up to 40mg l<sup>-1</sup> are considered "Soft", those with 40-90 l<sup>-1</sup> as "Medium hard" and those with values over 90 mg l<sup>-1</sup> as "Hard type". When this classification is applied for the present lake, it becomes clear Dal lake is a typical "hard water". The total alkalinity values in the lake were high indicating the productive nature of lakes.

Hardness of water is not a pollution parameter but indicates water quality in terms of polyvalent cations Ca<sup>++</sup> and Mg<sup>++</sup> dissolved in water and expressed as calcium carbonate (Shinde et al 2010). The total hardness in the lake was high indicating hard water nature which seems to be related to the source of Ca<sup>++</sup> and Mg<sup>++</sup> owing to its origin to the lacustrine deposits in the valley. Brarinumbal basin showed comparatively high hardness values, as they receive large amounts of detergents, domestic wastes which seem to be the main factors for its hardness. Calcium accounted for most of the hardness in the lake and is generally the dominant cation in Kashmir lakes because of predominance of lime rich rocks in their catchment areas. Chloride content in the Brarinumbal basin of Dal lake showed very high concentration, which clearly indicates the higher level of pollution due to the entry of organic wastes of animal nature entering the water body. Concentration of ammonical nitrogen was minimum in summer, which is attributed to immediate utilization by plankton and other plants without consumption of any extra energy for chemical reduction

through adsorption and maximum concentration in winter may be due to slower metabolic processes as development of plant life is low and accumulation of degradation products (decomposition). Pandit and Yousuf (2002) classified Kashmir Himalayan lakes on the basis of phosphorus range for total phosphorus, oligotrophic < 10µg, mesotrophic 10 – 30µg, eutrophy 30 -100 µg, hypertrophy > 100µg. As per this classification Hazaratbal basin and Brarinumbal basin of Dal Lake falls under hyper eutrophic category

## CONCLUSION

The physico-chemical parameters of the water body reveal that Dal lake has passed through eutrophication particularly Brarinumbal basin. During spring/summer melting of snow on the mountains in the neighborhood led to increase in volume of water and in close association with it, the lake water showed higher transparency values. Higher conductivity in the lake under study was attributable to continuous entry of sewage from human settlements, run off from agricultural lands. Dissolved oxygen in the lake showed seasonal variation with higher values during spring season and during this time the plant community also starts bloom leading to release of large quantities of dissolved oxygen. Hydrogen ion concentration in the lake depicted alkaline nature of water. Higher values of carbon dioxide in Brarinumbal basin seems to be related to the continuous oxidation of large quantities of organic matter inhibiting conversion of bicarbonates to carbonates. High concentration of chloride ion in Brarinumbal basin of Dal lake indicated high level of pollution due to sewage and entry of organic waste. The present lake can be categorized as hypertrophic on the basis of total phosphorus. The high concentration of ammonical and nitrate nitrogen during winter is due to low metabolic activities and accumulation of degradation products.

## ACKNOWLEDGEMENT

I am very much thankful to UGC, for providing me this opportunity to pursue my Ph.D. under FIP.

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# Meteorological Drought Assessment for Agricultural Planning at Mungeli District of Chhattisgarh Plain

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**Abstract:** In rainfed agriculture regions, drought analysis plays a better role for suitable crop planning by predicting the occurrence of drought. In this respect, an attempt has been made to evaluate drought reoccurrence patterns of fortnightly, monthly, seasonal and annual rainfall according to the severity, based on 39 years (1978-2016) data of Mungeli, Chhattisgarh. The occurrence of mild, moderate, severe and extreme drought situation were maximum 28.21, 25.64, 20.51 and 25.64 percent in 4, 5, 3 and 8 fortnight, respectively. The mild and moderate drought occurs in June to October. The maximum percentage of monthly extreme drought (74.36 %) occurs in December and followed by November (58.97%). The possibilities of occurrence of yearly no drought, mild drought and moderate drought are 43.59, 51.28 and 5.13 percent respectively and no year receives severe drought and extreme drought condition. So there were a drought in every 2<sup>nd</sup> or 3<sup>rd</sup> year. Therefore, it is a need of water harvesting at the time of monsoon season so that at least one or two supplemental irrigations can be done in *Kharif* season when dry spell occur or it can be used for *Rabi* season.

**Keywords:** Meteorological drought, Drought analysis, Dry spell, Rainfall analysis, Drought occurrence

Rainfall play a major role in rainfed agriculture and the distribution pattern of rainfall varies region to region and year to year. Rice is the main crop of the state and the productivity is very low (1.34 t ha<sup>-1</sup>) as compared to the national average (1.88 t ha<sup>-1</sup>). The state receives fairly high amount of rainfall, 1200 to 1600 mm annually. But the shortage of water at critical growth stages is often experienced due to uneven distribution of rainfall resulting in frequent terminal droughts in wide spread areas leading to large scale migration of farm labourers and farmers to other potential areas. Rainfall is an important factor that decides the severity of drought in a particular region (Khardiwar 2016). Drought is one of the major disasters, which not only affects production of agriculture directly but also other agro-based industries. It is a climatic anomaly which supply deficient soil moisture of the crop. Such a deficiency may result from less rainfall, erratic rainfall distribution, excessive water need or combination of all these factors. Occurrence of drought is a recurring phenomenon in different parts of rain shadow area of Chhattisgarh plains viz., Mungeli, Kawardha, Bemetara and Rajnadgaon. In the recent years with large scale utilization of water resources, there is a need for judicious use of water for proper agricultural management and to minimize drought risk. Among the various soil tracks in India dry farming region face the greatest drought hazard and characterized by low and uncertain crop yields (Khardiwar et al 2013). The

meteorological drought analysis is mostly done based on point rainfall data as reported by several researchers earlier. Pali and Thakur (2015) analyzed the rainfall data for agricultural planning to overcome the problem of continuous maximum dry days. The rainfall data analyzed for drought using the weekly, monthly, seasonal and yearly rainfall of Pantnagar, Ranchi, Barapani and Raipur respectively by various researchers (Ray et al 2012a, b, 2013a, b, Rajpoot and Kumar 2013, Bhelawe, 2015). Looking to enhance the productivity of crops in drought situation, the current study was planned to work out the occurrence of meteorological drought at Mungeli region using daily rainfall data.

## MATERIAL AND METHODS

The study area, Mungeli is located at 22° 04' N latitude, 81° 38' E longitude and at an altitude of 301 m above the mean sea level. The rainfall is mainly concentrated in four rainy season months from mid-June to mid-October and varies from 692 to 1671 mm per annum. Average annual rainfall of the study area is 1080.0 mm. The pattern of rainfall with reference to the amount of rainfall and number of rainy days at Mungeli were analyzed from historic daily rainfall records (1978-2016). The monthly rainfall, seasonal rainfall (i.e. June to September – monsoon; October to December – post monsoon; and January to May – pre monsoon) and yearly rainfall were analyzed. The average monthly, seasonal and yearly rainfall

values were worked out. The variation of rainfall in each month, season and year from the mean was determined and the mean deviation for the seasons was calculated. The fortnightly, monthly, seasonal and yearly intensity of drought was determined using the criteria suggested by IMD (1971) which is based on the percentage deviation of rainfall from its long term mean and it is given by (Eq.1).

$$D_i = \frac{P_i}{\mu} - 100 \dots\dots(1)$$

Where Di is the percentage deviation from the long-term mean,

Pi is the annual rainfall, mm and; μ is the long term mean of the annual rainfall, mm

Drought codification based on percentage departure of rainfall from normal is presented in Table 1. The percentage of deviation (Di) is then used to categories the drought. On the basis of percentage deviation drought conditions are dividing into five categories as No drought, Mild drought, moderate drought, severe drought and extreme drought.

**RESULTS AND DISCUSSION**

The past 39 years rainfall data have been analyzed and

**Table 1.** Category of drought codification based on percentage deviation of rainfall from normal value (IMD, 1971)

Percentage departure of rainfall from normal	Intensity of drought
0.0 or above	No drought
0.0 to -25	Mild drought
-25.0 to -50.0	Moderate drought
-50.0 to -75.0	Severe drought
-75.0 or less	Extreme drought

its fortnightly, monthly, seasonally and annually occurrence of drought was predicted using the equation of percentage deviation. This prediction would help to optimize choice of crops, sowing date and irrigation scheduling of different crops to be cultivated and efficient use of rainwater in *rainfed* areas for getting maximum production

**Fortnightly drought analysis:** In fortnightly drought analysis mainly considered the monsoon season weeks (24<sup>th</sup> to 39<sup>th</sup>) and it was observed that the occurrence of fortnightly drought repeat itself in every 2<sup>nd</sup> or 3<sup>rd</sup> year and chances of occurrence of mild drought and severe droughts is less in comparison to disastrous droughts (Table 2). The occurrence

**Table 2.** Fortnightly drought occurrence percentage

Fortnight (SMW)	No drought	Mild drought	Moderate drought	Severe drought	Extreme drought
1 (24+25,)	41.03	15.38	12.82	17.95	12.82
2 (26+27)	51.28	15.38	10.26	15.38	7.69
3 (28+29)	46.15	17.95	15.38	20.51	0.00
4 (30+31)	43.59	28.21	17.95	0.00	10.26
5 (32+33)	41.03	23.08	25.64	10.26	0.00
6 (34+35)	41.03	23.08	17.95	10.26	7.69
7 (36+37)	41.03	7.69	20.51	17.95	12.82
8 (38+39)	38.46	5.13	12.82	17.95	25.64

**Table 3.** Monthly drought occurrence percentage

Month	No drought	Mild drought	Moderate drought	Severe drought	Extreme drought
January	35.90	2.56	5.13	10.26	46.15
February	38.46	0.00	10.26	7.69	43.59
March	43.59	5.13	0.00	2.56	48.72
April	30.77	5.13	7.69	12.82	43.59
May	35.90	5.13	7.69	2.56	48.72
June	51.28	12.82	10.26	25.64	0.00
July	48.72	30.77	12.82	7.69	0.00
August	48.72	33.33	17.95	0.00	0.00
September	46.15	15.38	17.95	15.38	5.13
October	33.33	10.26	17.95	20.51	17.95
November	30.77	0.00	5.13	5.13	58.97
December	25.64	0.00	0.00	0.00	74.36

**Table 4.** Seasonal drought occurrence percentage

Season	No drought	Mild drought	Moderate drought	Severe drought	Extreme drought
Winter	46.15	2.56	15.38	15.38	20.51
Summer	33.33	25.64	10.26	10.26	20.51
Monsoon	51.28	41.03	7.69	0.00	0.00
Post monsoon	33.33	10.26	12.82	28.21	15.38

of mild, moderate, severe and extreme drought situation were maximum 28.21, 25.64, 20.51 and 25.64 per cent in 4, 5, 3 and 8 fortnight respectively. Occurrence of no drought condition varies from 38.46 to 51.28 percent in the monsoon season.

**Monthly drought analysis:** Out of 39 years period, minimum percentage of no drought situation occurrences in the December and maximum percentage (51.28) observed in June (Table 3). The study revealed that mild and moderate drought situation occurs in June to October. It can be observed that maximum percentage (74.36) of extreme drought occurs in December and followed by November (58.97).

**Seasonal drought analysis:** The monsoon season receives 51.28, 41.03, 7.69 and 0.0 percent no , mild , moderate, severe and extreme drought conditions respectively (Table 4). In post monsoon 33.33, 10.26, 12.82, 28.21 and 15.38 percent are occurrences of no, mild, moderate, severe and extreme drought, conditions respectively. The study reveals that maximum percentage of severe drought (28.21) occurs in post monsoon season and followed by 15.38 percent in winter season. Extreme drought condition were observed 20.51% in winter and summer season. Hence this would be helpful for collection of surface runoff during this rainy season and efficient use of harvested rainwater during the subsequent dry spell in monsoon season and irrigation of winter, summer season

**Annual drought analysis:** Long term data of annual rainfall of 39 years (1978-2016) at Mungeli indicates that rainfall in the region is highly variable (Table 5). The average annual rainfall of Mungeli is worked out to 1080 mm. Out of 39 years period, 17 (43.59%) years receives no drought condition, 20 (51.28%) years receives mild drought conditions, 2 (5.13%) years receives moderate drought conditions and no year receives severe drought and extreme drought condition. Thus according to analysis, it shows that there were a drought in every 2<sup>nd</sup> or 3<sup>rd</sup> year.

### CONCLUSION

The drought analysis of the study area shows that there were a drought in every 2<sup>nd</sup> or 3<sup>rd</sup> year thus some major steps are needed for assuring the irrigation of rainfed crops. The farmers of this region growing rain-fed crops during monsoon

**Table 5.** Drought categorization on yearly basis

Year	Annual rainfall (mm)	Mean rainfall (mm)	Deviation (%)	Intensity of drought
1978	1168	1080	8.10	No drought
1979	1057	1080	-2.12	Mild drought
1980	1206	1080	11.69	No drought
1981	974	1080	-9.79	Mild drought
1982	868	1080	-19.67	Mild drought
1983	980	1080	-9.27	Mild drought
1984	1218	1080	12.81	No drought
1985	1073	1080	-0.61	Mild drought
1986	1210	1080	12.01	No drought
1987	1018	1080	-5.71	Mild drought
1988	1008	1080	-6.71	Mild drought
1989	1029	1080	-4.71	Mild drought
1990	1211	1080	12.12	No drought
1991	933	1080	-13.66	Mild drought
1992	709	1080	-34.40	Moderate drought
1993	1036	1080	-4.12	Mild drought
1994	1341	1080	24.18	No drought
1995	1166	1080	7.93	No drought
1996	864	1080	-19.98	Mild drought
1997	1143	1080	5.83	No drought
1998	1270	1080	17.56	No drought
1999	910	1080	-15.76	Mild drought
2000	693	1080	-35.87	Moderate drought
2001	1256	1080	16.26	No drought
2002	1130	1080	4.63	No drought
2003	1671	1080	54.71	No drought
2004	1416	1080	31.10	No drought
2005	1270	1080	17.55	No drought
2006	909	1080	-15.80	Mild drought
2007	1210	1080	12.06	No drought
2008	834	1080	-22.77	Mild drought
2009	874	1080	-19.12	Mild drought
2010	893	1080	-17.31	Mild drought
2011	993	1080	-8.06	Mild drought
2012	1078	1080	-0.18	Mild drought
2013	1374	1080	27.25	No drought
2014	1250	1080	15.74	No drought
2015	981	1080	-9.15	Mild drought
2016	898	1080	-16.85	Mild drought

and most of them depend on monsoon. Therefore, it is a need of water harvesting at the time of monsoon season so that at least one or two supplemental irrigations can be done in *Kharif* season when dry spell occur or it can be used for *Rabi* season.

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Received 10 November, 2017; Accepted 31 January, 2018



## Impact of Homesteads Bamboo Nurseries on the Livelihood- A Case from North and West Tripura, India

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**Abstract:** Tripura is facing scarcity of bamboo due to large-scale flowering and farmers preference to take up rubber plantation. The Centre for Forest-based Livelihoods and Extension (CFLE), Agartala had taken up a participatory programme to grow and multiply bamboos in several hamlets of Tripura. The present study focused on the socio-economic benefits derived from bamboo plantation in Tripura state, by assessing the adaptability of propagation techniques as a livelihood activity and its impact on the growers. By analyzing bamboo potential it was visualized that, it can provide ample scope for the development of rural livelihood and is a lucrative business from which rural people could adopt to come out of the poverty trap. Community Livelihood Nurseries (CLNs) on homesteads have been initiated by different groups in study area by providing mother plants and training/technical support. Field survey showed that among the 75 Bamboo growers 78.67% have planted bamboo for the purpose of self-use and selling, 18.67% for processing and selling and 2.67% for self-use and all other purposes. Bamboo contributed about 57.79% annual income in poor, 26.27% in medium and about 14.28% in rich categories of HHs. CLNs activities has got place as an important livelihood option in their day today activities.

**Keywords:** Bamboo Livelihood Nursery, Homestead bamboo, Propagation

Bamboo is an important group of non-wood forest plant gifted by nature to mankind in tropical and subtropical regions of the world. It is the single most important item of forest produce used by rural communities from the cradle to the coffin. Due to its high utility which is closely interwoven with the life of the people, it is commonly known as the Poor man's timber, "Green gold of the forest" and "Friend of the people (Rao et al 1987). World-wide, bamboo is slowly but steadily gaining importance as material for sustainable development.

North Eastern India is the important bamboo growing area in India having very high diversity of bamboo species, where about 19 genera and 78 species are recorded (Hore 1998). The soil and climate provide tremendous scope for the growing of bamboo naturally in the hilly terrain of the area. The region shows a strong base and culture of use of bamboo resources. There exists a wealth of indigenous knowledge on utilization and management of bamboo which go side by side with its traditional use.

The state of Tripura resides at the far north-eastern corner of India. Bamboo is extensively used by tribal and rural people of Tripura and plays an important role in employment generation and socio-economic upliftment in rural sector. Tripura is facing a scarcity of bamboo because of large-scale flowering and resultant death of the plants, especially the local Muli species; and farmers preference to take up rubber plantation for higher economic returns. The Centre for

Forest-based Livelihoods and Extension (CFLE) in Agartala has taken up a participatory programme i.e. eco-restoration of resources for forest-based livelihood security, to grow and multiply bamboos in several hamlets of Tripura.

The present study focused on the socio-economic benefits derived from bamboo plantation by poor rural producers in Noagaon and Kanchanpur village of Tripura Northeast India to analysis the socio-economic benefits in bamboo sector, to enable rural small/poor producers increase production volumes in bamboo based activities and realize greater value and market share, to organize the sustainable production of raw materials inputs in required quantities, to enable higher quality and standards of production (of inputs and final products) and meet market demands, and to create a more favorable policy environment for the bamboo small entrepreneurs in Tripura. With this in mind, the present study assessed the adaptability of propagation techniques as a livelihood activity and the impact on socio-economic status of the growers.

### MATERIAL AND METHODS

The research was started by identifying the livelihood potential of bamboo nurseries. During the preparation, various ideas about the topic were taken from different bamboo experts and professionals by direct contact, telephone conversation and Emails. Series of discussion

with advisor and co advisor encouraged critical thinking on concepts used in this research. Household (HH) survey questionnaires and checklist for focused group discussion, key informant survey and wealth ranking was developed and finalized after the discussion. Discussion with local facilitators and stakeholders helped in planning the field work. Tree field visit was carried out and questionnaire and checklists were pretested before the actual field work and corrected for actual field survey. Data were collected using various methods. After completing field work, first hand information was discussed with local leaders. Post-field visit was also carried out for taking some missing data. Compilation of data, analysis of the data, reporting of the results & discussions with the advisor led to the conclusions and recommendations. (Fig. 4)

**Survey for primary data:** It was collected using following tools:

**Reconnaissance survey:** It was carried out to identify the general feature and existing situation of bamboo production and market of the study area. During that period rapport building with local people, society's members, and other concerned persons was also done.

**Direct field observation:** It was conducted in the Community Livelihood Nurseries (CLNs) to get general idea about the status of bamboo production, present situation and market of bamboo culm and its products, user's socio-economic status, and to triangulate the information gathered.

**Structured questionnaire:** Questionnaire survey was used as a tool in socio-economical studies to assess the socio-economic status, to evaluate their attitudes towards conservation. However, the questionnaire survey was well designed to achieve the objectives, and was supported with supplementary field data. In this type of survey, households were used as a unit of analysis because it is essential to understand how local people support their livelihood and to assess their dependence on the bamboo nurseries in relation to socio-economic factors. The survey helped to record the bamboo species available in the study area, source of collection, uses of Bamboo species, products made from bamboo, the problems associated with marketing and the condition of sellers.

The survey was held in the month of January –February 2016, in an informal way by some open ended and maximum closed ended questions to know the Details of Householders, Data of Bamboo Nurseries, Livelihood potential of Bamboo Nurseries, Ranking of priority species, Other Livelihood option and income details etc.

**Group interaction:** Group discussion was done with the villagers for participatory well-being ranking and to collect the information about the market condition and local price of

bamboo and its products. During that time the opportunities and constraints in production and marketing of bamboo and its products were also discussed among the participants. People of different communities were taken as focus group for discussion. During that discussion the marketing situation of bamboo products, the contribution of bamboo in their socio-economic condition and the price and demand supply trend were discussed.

**Survey for secondary data:** Secondary data were collected from related published and unpublished documents, office records and materials, internet and other essential materials. Additional information was also gathered to meet the objectives of the study from various published and unpublished research reports, journals, magazines, literatures, internet searched articles etc.

**Field verification:** Field verification of primary data and recording of updated information was done by Consultation of official documents available with bamboo Grower societies. Visits were undertaken to different nurseries to interact with the owners of different bamboo nurseries to collect valuable information about different bamboo species available in the study area.

**Analysis of facts and local issues through spot analysis:** To analyse the condition of Community Livelihood Nurseries the issues and facts were identified. Information about the Bamboo Nursery activities and many problems related to the activity were collected through spot analysis. Then the data were analyzed to get the result and interpreted logically.

## RESULTS AND DISCUSSION

The study area viz., Noagaon and Kanchanpur was assessed for its Bamboo diversity and was seen that these areas were rich in bamboo. Bamboo Nurseries were raised since 2013 considering it as a livelihood potential. Peoples of that area were not using bamboo resources because of other livelihood potential, lack of information, poor market availability, lack of technical knowhow etc. But from 2013, after intervention of CFLE (Centre for Forest based Livelihood Nurseries and Extension) through on site and on station training and demonstration bamboo has become a livelihood potential of those areas.

**Year wise scenarios of livelihood potential of bamboo nurseries:** In 2013 Bamboo Nursery was not taken as a livelihood potential in Noagaon and Kanchanpur and people were not at all interested for doing Bamboo Nurseries as they didn't have the technical knowhow in addition to poor market availability and lack of availability of plant material. In order to secure sustainable livelihood alternatives through restoration of dependable resources, the Centre for Forest-based Livelihoods and Extension (CFLE) at Agartala initiated plan to

boost bamboo plantation in Noagaon and Kanchanpur. Training and demonstration session were organized to encourage and motivate people for developing Bamboo Nurseries as a livelihood option. In a bid to encourage farmers to take to planting bamboos in a large scale and add value to their finished products mother plants of various important species were supplied for homestead nurseries. Training was conducted with 60 peoples in Noagaon and 33 people in Kanchanpur for planting bamboo nurseries.

In 2014, 19 members took initiative in raising Bamboo Nurseries. In Kanchanpur, it was 9 members who have raised Bamboo Nursery. Again trainings were organised at both places. In Noagaon training was imparted to 64 members and in Kanchanpur, to 40 members. In 2015 out of 64 members, 31 members took initiative in raising Bamboo Nurseries at Noagaon and in Kanchanpur out of 40 members 17 members have raised Bamboo Nurseries. In 2015 no training session was organized at Noagaon but 59 peoples engaged themselves in Bamboo nursery but in Kanchapur training was organized with 45 peoples and out of this 39 members took to Bamboo Nurseries.

The potential of Bamboo Nurseries in the study areas is depicted in Fig. 1 & 2. From the study it is observed that rural communities of study area have gained their interest in the bamboo as potential activity in livelihood generation. By analyzing bamboo potential it can be easily pointed out that bamboo can be regarded as one of the most valuable natural resource available. Considering its vast application diversity, it can provide ample scope for the development of rural livelihood especially the tribal population and simultaneously contribute towards the sustainable growth keeping environment its ally. Phimmachanh et al 2015 examined the potential of bamboo as a source of income and better livelihood for rural communities. They looked at the importance of bamboo from a global perspective with special attention to its economic, social and ecological values. Using this approach, they observed that, bamboo is very ubiquitous, has a global presence and it is used for various purposes from toothpicks to dresses and construction of houses. They also found that, it is a lucrative business from which rural people with the proper and adequate skills and market value chains could adopt to come out of the poverty trap.

**Present status of bamboo nurseries:** In order to restore bamboo cover in the study area, community participation was being encouraged by establishing Community Livelihood Nurseries (CLNs) in demo villages which has been proved to be an effective approach in motivation, capacity building and sustainable income generation. So far small nurseries on homesteads have been initiated by different groups in study area by providing mother plants and training/technical support.

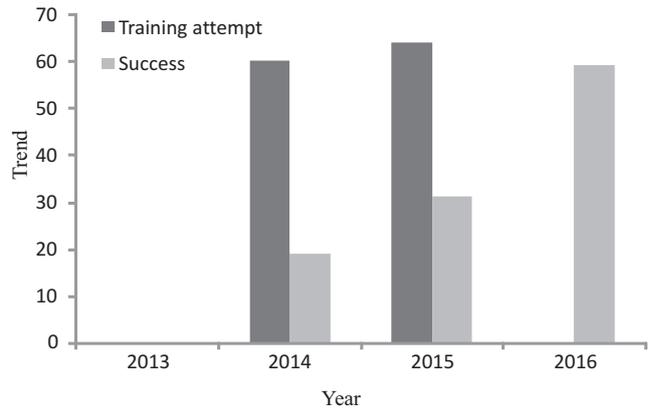


Fig. 1. Bamboo as livelihood potential in Noagaon village

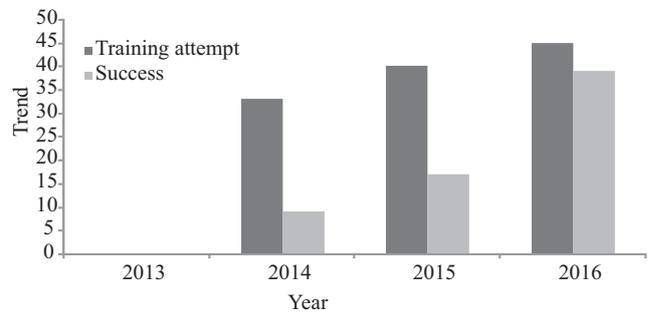


Fig. 2. Bamboo as livelihood potential in Kanchanpur village

These CLNs are expected to supply bamboo plants to various agencies. CLNs are managed by different societies viz. Noagaon Bamboo Growers Society (NBGS), Mars Socio Welfare Society (MSWS), Kanchanpur and Vaidyaraj Herbal Growers Society (VHGS), Kanchanpur.

**Purpose of bamboo plantation:** All the 75 respondents have planted bamboo in their land for different purpose like only self use; self use and selling; processing and use; processing and selling; and all (Table 1). Field survey showed that among the Bamboo grower respondents, 78.67% have planted bamboo for the purpose of self use and selling, 18.67% for processing and selling, 2.67% for self use and all other purposes.

**Bamboo nurseries of demo villages:** A visit was carried out in the Community Livelihood Nurseries of Noagaon and Kanchanpur village for observing the Bamboo species and collecting information about all nurseries (Table 2).

In the Community Livelihood Nurseries of Noagaon Bamboo Growers Society, seed of *Dendrocalamus longispathus* were sowed extensively followed by *Dendrocalamus hamiltonii* and *Bambusa tulda* and in the Mars Society Welfare Society, *Melocanna bacifera* are used extensively followed by *Bambusa tulda*, *Dendrocalamus hamiltonii* and *Schizostachyum dullooa* and in Vaidyaraj Herbal Growing Society it is *Schizostachyum dullooa* and then *Dendrocalamus longispathus*.

**Table 1.** Shows the purpose of growing bamboo

Purpose	Frequency	Per cent of bamboo growers
Self use	2	2.67
Self use and selling	59	78.67
Processing and Use	-	-
Processing and selling	14	18.67
Total	75	100.01

The common bamboo species found in both the study area were *Bambusa cacharensis*, *Dendrocalamus longispatus*, *Melocanna baccifera*, *Thyrsostachys oliveri*, *Bambusa vulgaris*, *Bambusa wamin*, *Guadua angustifolia* and *Schizostachyum dullooa*; and these were grown extensively in both the study area.

**Trend of each bamboo species at study area:** The efforts of different institutes and departments to increase the bamboo plantation has seen a rise in plantation area but despite the new plantations the demand of bamboo far exceeds the production and supply. Fig. 3 & 4 shows the details of bamboo plantation created in the study area during the past three years.

Research carried out in the study areas showed the use of *Dendrocalamus longispatus* followed by *Bambusa tulda*, *Dendrocalamus strictus* and *Dendrocalamus nutans* has increased year by year.

**Priority species for plantation in study area:** Some bamboos serve as a food source or as a construction material while others are strictly ornamental. The species of bamboo

which are put to various uses were ranked based on the priority of the people of the study area. An introduction to each of the priority taxa are given in the Table 5, to find out what type of bamboo is best suited to grow commercially or as a vegetable crop and are arranged as per their rank. This information has been collected from both study areas by interacting with the owners of Community Livelihood Nurseries and members of societies. *Bambusa tulda* was ranked no.1 followed by *Dendrocalamus longispatus* and *Bambusa polymorpha*. The species which ranked least were *Bambusa wamin* followed by *Bambusa bamboos* and *Bambusa pallida*.

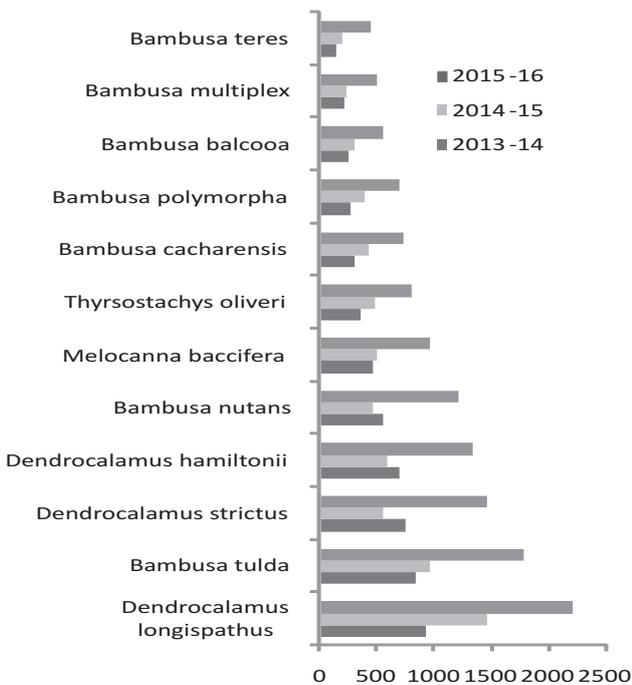
**Demand and supply pattern of bamboo nurseries in study area:** The demand for bamboo is increasing in the state and outside of the state for agarbatti raw sticks, furniture items, ornamental purpose, handicraft items and bamboo shoots. There is a huge demand of bamboo planting materials in both study areas. Supply of bamboo planting material is done under guidance of members of different societies. There are some organization like National Bamboo Mission, Tripura Bamboo Mission, Tripura JICA Project and Forest Departments etc which are interlinked with the societies for buying bamboo planting materials from them.

Priority bamboo plant materials from different CLNs were collected as per demand from different agencies and supplied (Table 6). In case of outside transportation advance payment has been made for the selected species by buyers to the society's member. Transportation cost of supply is met by the bamboo buyers. Value of each bamboo species is different from local market to the places where it is transported. Society's members buy bamboo species (which are meant to be transported outside) from bamboo growers in a local market price but sale price is higher than the local price. Demand of bamboo species in the study areas has been increasing day by day. So the socio economic status of bamboo growers has also increased.

Observation prevail that *Bambusa wamin* and *Bambusa polymorpha* is high in price and *Thyrsostachys oliveri*, *Bambusa tulda*, *Dendrocalamus longispatus*, *Bambusa pallida* and *Bambusa vulgaris* is the most priority Bamboo Species.

**Sale of bamboo species in different years:** Income generation from CLNs during 2014 and 2015 was collected from different society's member. Status of 2016 was observed by consulting the growers and consultation of reports available with them. An advance payment of demandable bamboo species has been done in this year and full payment is made during July, 2017 (Fig. 5).

This observation revealed that demand of bamboo species in study area are increasing day by day similar to what was observed by Jha (2011) who assessed the status of



**Fig. 3.** Species wise, year wise bamboo plantation created in Noagaon

**Table 2.** Bamboo nursery developed by CFLE during 2015-16 at Bamutia cluster

CLN growers code	Species Planted	Establishment	Planting technique	No. of plants/gms of seeds sown
NBGS 01	<i>Dendrocalamus longispathus</i>	05.02.2015	Seed & Seedling	100 & 50
	<i>Dendrocalamus hamiltonii</i>	09.04.2014	Seedling	200
	<i>Guadua angustifolia</i>	03.03.2015	Seedlings	50
NBGS 02	<i>Dendrocalamus longispathus</i>	09.04.2014	Seed	100 gram
	<i>Dendrocalamus hamiltonii</i>	30.05.2015	Seedling	200
NBGS 03	<i>Dendrocalamus longispathus</i>	09.04.2014	Seed	100 gram
	<i>Dendrocalamus hamiltonii</i>	19.08.2014	Seedling	200
NBGS 04	<i>Dendrocalamus longispathus</i>	09.04.2014	Seedling	100
	<i>Dendrocalamus hamiltonii</i>	30.05.2015	Seed	200 gram
NBGS 05	<i>Bambusa tulda</i>	16.04.2014	Seedling	100
	<i>Dendrocalamus hamiltonii</i>	16.04.2014	Seedlings	100
NBGS 06	<i>Bambusa nutans</i>	17.04.2014	Seedlings	70
NBGS 07	<i>Dendrocalamus longispathus</i>	17.04.2014	Seed	100 gram
NBGS 08	<i>Dendrocalamus longispathus</i>	17.04.2014	Seed	200 gram
NBGS 09	<i>Bambusa tulda</i>	17.04.2014	Seedlings	70
	<i>Dendrocalamus hamiltonii</i>	19.08.2014	Seedling	50
NBGS 10	<i>Bambusa tulda</i>	17.04.2014	Seedling	70
	<i>Dendrocalamus longispathus</i>	12.02.2015	Seedling	50
NBGS 11	<i>Dendrocalamus longispathus</i>	19.04.2014	Seed	150 gram
NBGS 12	<i>Dendrocalamus longispathus</i>	22.04.2014	Seedling	100
NBGS 13	<i>Bambusa tulda</i>	22.04.2014	Seedling	50
	<i>Dendrocalamus longispathus</i>		Seedling	50
NBGS 14	<i>Dendrocalamus longispathus</i>	25.04.2014	Seedling	50
NBGS 15	<i>Dendrocalamus longispathus</i>	30.04.2014	Seedling	100
NBGS 16	<i>Dendrocalamus longispathus</i>	03.05.2014	Seedling	100
NBGS 17	<i>Dendrocalamus longispathus</i>	03.05.2014	Seedling	100
NBGS 18	<i>Dendrocalamus hamiltonii</i>	03.05.2014	Seedling	100
NBGS 19	<i>Dendrocalamus hamiltonii</i>	03.05.2014	Seedling	100
NBGS 20	<i>Dendrocalamus hamiltonii</i>	03.05.2014	Seedling	100
NBGS 21	<i>Dendrocalamus hamiltonii</i>	05.05.2014	Seedling	100
NBGS 22	<i>Dendrocalamus longispathus</i>	06.05.2014	Seedling	100
NBGS 23	<i>Dendrocalamus hamiltonii</i>	09.05.2014	Seedling	100
NBGS 24	<i>Dendrocalamus hamiltonii</i>	09.05.2014	Seedling	100
NBGS 25	<i>Dendrocalamus hamiltonii</i>	13.05.2014	Seedling	100
NBGS 26	<i>Dendrocalamus hamiltonii</i>	13.05.2014	Seedling	100
	<i>Dendrocalamus longispathus</i>	09.02.2015	Seedling	100
NBGS 27	<i>Dendrocalamus longispathus</i>	13.05.2014.	Seedling	100
NBGS 27	<i>Guadua angustifolia</i>	13.05.2014	Seedling & Seed	40 & 100 gram
	<i>Dendrocalamus longispathus</i>	10.01.2015	Seedlings	100
	<i>Bambusa vulgaris</i>		cuttings	100
NBGS28	<i>Dendrocalamus hamiltonii</i>	27.05.2014	Seedling	300
NBGS 29	<i>Dendrocalamus hamiltonii</i>	27.05.2014	Seedling	300
NBGS 30	<i>Dendrocalamus hamiltonii</i>	27.05.2014	Seedling	300
NBGS 31	<i>Dendrocalamus hamiltonii</i>	27.05.2014	Seedling	300

Cont...

NBGS 32	<i>Dendrocalamus hamiltonii</i>	27.05.2014	Seedling	300
NBGS 33	<i>Dendrocalamus hamiltonii</i>	28.05.2014	Seedling	300
NBGS 34	<i>Dendrocalamus hamiltonii</i>	28.05.2014	Seedling	300
NBGS 35	<i>Dendrocalamus hamiltonii</i>	30.05.2014	Seedling	300
NBGS 36	<i>Dendrocalamus hamiltonii</i>	30.05.2014	Seedling	300
NBGS 37	<i>Dendrocalamus hamiltonii</i>	30.05.2014	Seedling	300
NBGS 38	<i>Dendrocalamus hamiltonii</i>	01.06.2014	Seedling	300
	<i>Dendrocalamus longispatus</i>	11.01.2015	Seedlings	100
	Golden Bamboo	24.02.2015	Seedling	17
	<i>Bambusa wamin</i>	09.02.2015	Seedlings	5
	<i>Bambusa tulda</i>	09.02.2015	Seedlings	50
NBGS 39	<i>Dendrocalamus hamiltonii</i>	01.06.2014.	Seedling	300
NBGS 40	<i>Dendrocalamus hamiltonii</i>	01.06.2014	Seedling	300
NBGS 41	<i>Dendrocalamus hamiltonii</i>	01.06.2014.	Seedling	300
NBGS 42	<i>Dendrocalamus hamiltonii</i>	10.07.2014.	Seedling	200
NBGS 43	<i>Dendrocalamus hamiltonii</i>	10.07.2014.	Seedling	200
NBGS 44	<i>Dendrocalamus hamiltonii</i>	11.07.2014.	Seedling	200
NBGS 45	<i>Dendrocalamus hamiltonii</i>	05.08.2014	Seedling	200
	<i>Dendrocalamus longispatus</i>	29.09.2014	Seedling	50
NBGS 46	<i>Dendrocalamus hamiltonii</i>	19.08.2014	Seedling	200
	<i>Guadua angustifolia</i>	05.02.2015	seedlings	50
NBGS 47	<i>Dendrocalamus hamiltonii</i>	19.08.2014	Seedling	200
	<i>Dendrocalamus longispatus</i>	09.02.2015	Poly bags	50
NBGS 48	<i>Dendrocalamus hamiltonii</i>	19.08.2014	Seedling	200
	<i>Dendrocalamus longispatus</i>	09.02.2015	seedlings	50
NBGS 49	<i>Bambusa vulgaris</i>	02.09.2014	Seedling	100
NBGS 50	<i>Bambusa vulgaris</i>	02.09.2014	Seedling	100
NBGS 51	<i>Guadua angustifolia</i>	28.01.2015	Seedlings and cuttings	25 and 75
NBGS 52	<i>Guadua angustifolia</i>	28.01.2015	Seedlings and cuttings	25 and 75
NBGS 53	<i>Guadua angustifolia</i>	28.01.2015	Seedlings and cuttings	25 and 75
NBGS 54	<i>Guadua angustifolia</i>	28.01.2015	Seedlings and cuttings	25 and 75
NBGS 55	<i>Guadua angustifolia</i>	12.02.2015	Seedling	25
	<i>Dendrocalamus longispatus</i>	12.02.2015	Seedling	50
NBGS 56	<i>Bambusa tulda</i>	20.02.2015	Seedling	100

Bamboo production in private land, its contribution to socio-economic condition and marketing trend of Bamboo and some of its product in Rautahat district.

**Income from CLNs:** During wellbeing ranking respondents were categorized into 3 categories namely rich, medium and poor by extensive meeting and request. Then the contribution of Bamboo in their economic condition was asked. The responses showed that Bamboo contributes about 57.79% annual income in poor, 26.27% in medium and about 14.28% in rich categories of HHs. The major sources of income in rich categories of HHs are agriculture, business, and Government/ private job and in medium categories HHs are agriculture, business, private job. Similarly the major family income source in poor HHs is wage laboring, bamboo enterprise and to some extent agriculture (Table 7). This shows that the poor are highly dependent on Bamboo than rich and medium categories.

Tanya (2015) analysed growing awareness in recent years about the importance of bamboo being an important means of economic growth and of improving the socio-economic conditions of the rural poor. Bamboo as an

industrial material can substitute wood to a great extent and that too at low cost. Bamboo has been traditionally harvested from forest lands in India. Smallholders at the forest fringe can, in particular, improve their livelihood by processing bamboo or growing it in their backyard. Bamboo as a resource needs to be seen as a form of development, with the primary value addition done closer to the resource in order to reap the livelihood benefits.

**Bamboo product in the study area:** In the study area, bamboo is utilized for: Rural Housing: posts, walls, roof structure, roofing material, scaffolding, fencing and gates (Bari, Barak, Muli, Makal); agricultural implements, baskets, food grain containers, rain shields, head gear and other functional products; edible shoots for food, particularly amongst tribal communities; handicraft items: toys, 'morra', winnowing trays, handfans, mats (Muli, Paora and Mritinga), wall panels, screens (Mritinga, makal), umbrella handles (Muli), fishing rods (Kanakkaich), agarbatti sticks (Paora, Dolu, Barak) and supply of raw material to paper mill. In addition Bamboo products of study area include Fan, Basket, Mat, Rack, Hukka handle, Fencing, Chalno and Nanglo.

**Table 3.** Bamboo nursery developed by MSWS during 2015-16 at Kanchanpur cluster

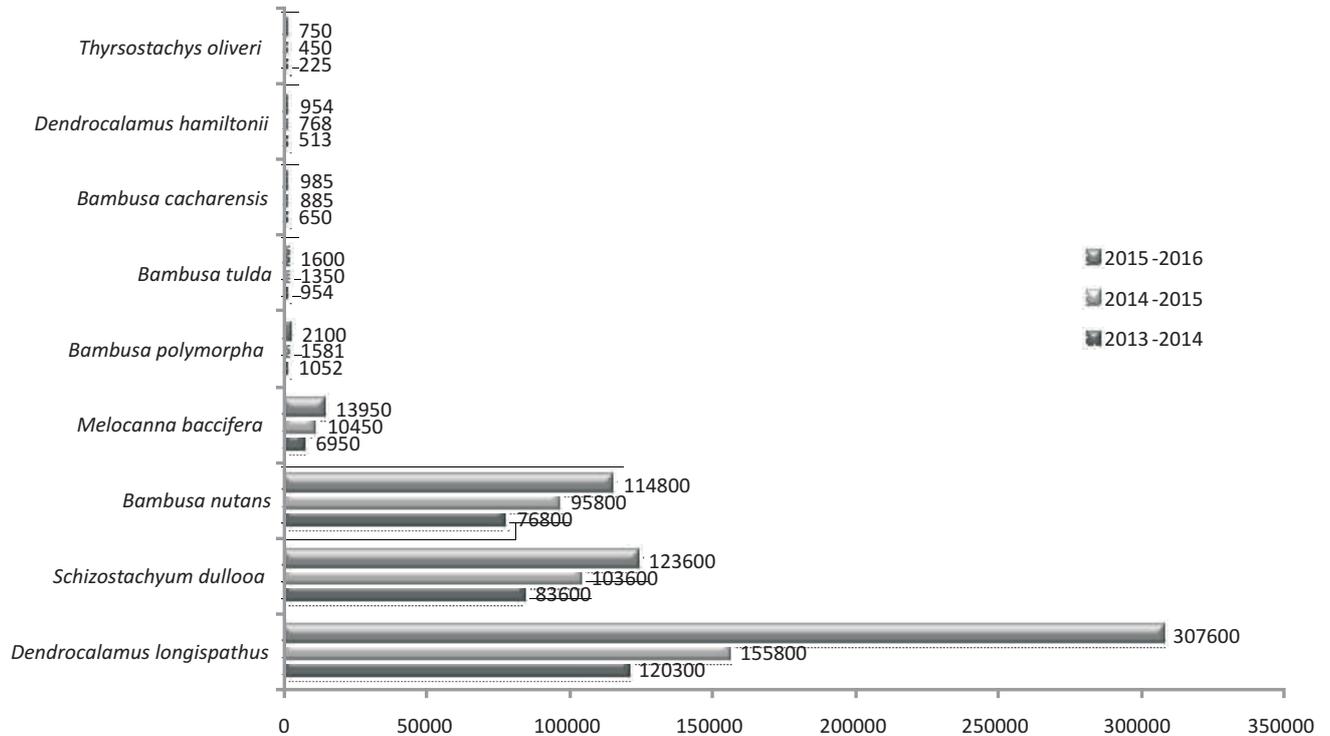
CLN growers code	Species	Date of establishment	Planting technique	No. of plants/gms of seeds sown
MSWS 01	<i>Melocanna baccifera</i>	23.08.2014	Seedling	400
	<i>Melocanna baccifera</i>	03.09.2014	Seedling	2000
	<i>Thyrsostachys oliveri</i>	10.10.2014	Rhizome	200
	<i>Dendrocalamus hamiltonii</i>	23.08.2014	Seedling	600
MSWS 02	<i>Melocanna baccifera</i>	19.08.2014	Seedling	3000
	<i>Bambusa tulda</i>		Seedling	2500
MSWS 03	<i>Melocanna baccifera</i>	02.09.2014	Seedling	1500
	Mritinga		Seedling	1000
	<i>Schizostachyum dullooa</i>		Seedling	1000
MSWS 04	<i>Bambusa tulda</i>		Seedling	2500
	<i>Bambusa tulda</i>	05.08.2014	Seedling	3000
	<i>Melocanna baccifera</i>			1000
	Pecha			15000
MSWS 05	<i>Bambusa tulda</i>	05.08.2014	Seedling	1000
	<i>Schizostachyum dullooa</i>			2000
	<i>Melocanna baccifera</i>			2000
MSWS 06	<i>Dendrocalamus hamiltonii</i>	05.08.2014	Seedling	600
	<i>Dendrocalamus longispathus</i>		Seedling	3000
	<i>Bambusa vulgaris</i>		Seedling	250
	<i>Thyrsostachys oliveri</i>		Seedling	100
MSWS 07	Kai			100
	<i>Dendrocalamus hamiltonii</i>	02.09.2014	Seedling	500
MSWS 08	<i>Dendrocalamus longispathus</i>			500
	<i>Dendrocalamus hamiltonii</i>	01.06.2014	Seedling	300
	<i>Dendrocalamus longispathus</i>	11.01.2015	Seedling	100
	Golden Bamboo	09.02.2015	Seedlings	17
	<i>Bambusa wamin</i>	09.02.2015	Seedling	5
	<i>Bambusa tulda</i>	24.02.2015	Seedling	50
MSWS 09	<i>Bambusa tulda</i>	17.04.2014	Seedling	70
	<i>Dendrocalamus hamiltonii</i>	19.08.2014	Seedling	200
MSWS 10	<i>Dendrocalamus hamiltonii</i>	03.05.2014	Seedling	100
MSWS 11	<i>Dendrocalamus hamiltonii</i>	05.05.2014	Seedling	100
MSWS 12	<i>Dendrocalamus longispathus</i>	06.05.2014	Seedling	100
MSWS 13	<i>Dendrocalamus hamiltonii</i>	09.05.2014	Seedling	100
MSWS 14	<i>Dendrocalamus hamiltonii</i>	09.05.2014	Seedling	100
MSWS 15	<i>Bambusa tulda</i>	05.08.2014	Seedling	1000
	Dolu		Seedling	2000
	<i>Melocanna baccifera</i>		Seedling	2000
MSWS 16	<i>Dendrocalamus hamiltonii</i>	27.05.2014	Seedling	300
MSWS 17	<i>Dendrocalamus hamiltonii</i>	27.05.2014	Seedling	300
MSWS 18	<i>Dendrocalamus hamiltonii</i>	27.05.2014	Seedling	300
MSWS 19	<i>Dendrocalamus hamiltonii</i>	27.05.2014	Seedling	300
MSWS 20	<i>Dendrocalamus hamiltonii</i>	27.05.2014	Seedling	300
MSWS 21	<i>Dendrocalamus hamiltonii</i>	28.05.2014	Seedling	300
MSWS 22	<i>Dendrocalamus hamiltonii</i>	28.05.2014	Seedling	300
MSWS 23	<i>Dendrocalamus hamiltonii</i>	30.05.2014	Seedling	300
MSWS 24	<i>Dendrocalamus hamiltonii</i>	30.05.2014	Seedling	300
MSWS 25	<i>Bambusa tulda</i>	05.08.2014	Seedling	3000;

**Contribution of bamboo in the socio economic status:** Peoples of Noagaon and Kanchanpur are not fully dependent on bamboo cultivation. They have other livelihood options. Survey was done for visualizing the contribution of bamboo nurseries in their livelihood option (Table 8).

In the study area, five major livelihoods including bamboo nurseries are analyzed. As their priorities and survey revealed that among the top five livelihood options CLNs activities score 2.33 and 1.84 ranks in Noagaon and Kanchanpur, respectively, which means Kanchanpur

**Table 4.** Bamboo nursery developed by VHGS during 2015-16 at Kanchanpur cluster

Sl. No.	Species	Planting technique	Source	Total number	Expected seedling after multiplication	Expected seedling after multiplication
VHGS 01	<i>Schizostachyum dullooa</i>	Seed	Lusaicherra	20000	60000	120000
	<i>Dendrocalamus</i>	Seed	Lusaicherra	12000	24000	48000
	<i>Bambusa vulgaris</i>	Branch cutting	Own Bamboo clump	300	600	1200`
	<i>Bambusa cacharensis</i>	Seedling / Branch cutting	Own Bamboo clump	100	200	400
VHGS 02	<i>Dendrocalamus</i>	Seed	Forest	12000	25000	50000
	<i>Melocanna baccifera</i>	Seed	Forest	120	200	300
	<i>Thyrsostachys oliveri</i>	Rhizome	CFLE	50	75	150
	<i>Bambusa vulgaris</i>	Seedling / Branch cutting	Forest	300	600	900
	<i>Schizostachyum dullooa</i>	Seedling	Lusaicherra	400	800	2400
	<i>Bambusa cacharensis</i>	Seedling / Branch cutting	Forest	50	100	150
VHGS 03	<i>Dendrocalamus</i>	Seed	Forest	30000	60000	100000
VHGS 04	<i>Dendrocalamus</i>	Seed	Forest	1000	2500	5000
	<i>Melocanna baccifera</i>	Seed	Forest	300	600	1000
VHGS 05	<i>Schizostachyum dullooa</i>	Seedling		400	800	1200
	<i>Dendrocalamus</i>	Seedling		300	500	1000



**Fig. 4.** Species wise, year wise bamboo plantation created in Kanchanpur

villagers have adopted bamboo nurseries more than Noagaon villagers. This way we can say that CLNs activities has got a place as an important livelihood option in their day to day activities.

**Ranks of livelihood option:** From Table 10, scenario of adoptability of livelihood is clear. Field observation reveal that Bamboo Plantation as livelihood option is accepted by every farmer of the study area.

**Major species as identified for viable income and higher production:** From field survey in both study area we analyzed which species is profitable for the rural people. On the basis of information taken from growers we came to know that which species is preferable for the growers (Table 11).

From Table 11, we can say that for the low multiplication and high cost of maintenance the overall performance of *Thyrsostachys oliveri* (Kanakaich) is medium. Among all the species *Bambusa balcooa* performed well followed by *Bambusa tulda*, *Dendrocalamus longispathus* and *Bambusa polymorpha*.

**Propagation techniques in study area:** In the study areas farmers have adopted five propagation techniques which are profitable for them. By interaction with growers we analyzed which propagation technique is more profitable. A graph has been made (Fig. 7) on the basis of comparison of mostly adopted propagation techniques between the study areas.

In the study area most common method of propagation

**Table 5.** Priority bamboo species declared as commercially important in study area

Rank	Species	Local Name	Uses
01	<i>Bambusa tulda</i>	Mritinga	Stick for <i>agarbatti</i>
02	<i>Dendrocalamus longispathus</i>	Rupai	Stick for <i>agarbatti</i> , Handicrafts, Mat
03	<i>Bambusa polymorpha</i>	Paura	Handicrafts, Mat
04	<i>Thyrsostachys oliveri</i>	Kanakaich	Furniture, Fishing rod, stick etc
05	<i>Schizostachyum dullooa</i>	Dolu	Mat, Handicrafts
06	<i>Bambusa cacharensis</i>	Bom/Betua	Handicrafts, Mat, Agarbatti stick
07	<i>Bambusa balcooa</i>	Barak/Barua	Construction, furniture, handicrafts
08	<i>Bambusa vulgaris</i>	Bari/Jai	Construction, furniture, handicrafts
09	<i>Dendrocalamus asper</i>	Asper bans	Bamboo shoot, stick for <i>agarbatti</i>
10	<i>Bambusa nutans</i>	Makal	Stick for <i>agarbatti</i> , construction
11	<i>Dendrocalamus hamiltonii</i>	Pecha	Industrial products
12	<i>Bambusa pallida</i>	Makal	Industrial products
13	<i>Bambusa bamboos</i>	Kanta baans	Industrial products
14	<i>Bambusa wamin</i>	'Buddhas Belly'	Ornamental

**Table 6.** Economical information of priority bamboo species under study area

Name of priority bamboo species	Value in local market (Rs. per plant)	Name of the place where transported	Sale price (Rs. per plant)
<i>Bambusa tulda</i>	10	Bangalore, Jabalpur, Kolkata, Maharashtra	25
<i>Dendrocalamus longispathus</i>	10	Bangalore, Jabalpur, Kolkata, Maharashtra	25
<i>Bambusa polymorpha</i>	15	Maharashtra	100
<i>Thyrsostachys oliveri</i>	10	Bangalore, Hyderabad, Jabalpur, Ranchi, Maharashtra	20
<i>Schizostachyum dullooa</i>	12	Bangalore, Ranchi	30
<i>Bambusa cacharensis</i>	12	Bangalore, Hyderabad, Jabalpur, Kolkata,	30
<i>Bambusa balcooa</i>	16	Hyderabad, Ranchi, Pune	40
<i>Bambusa vulgaris</i>	12	Bangalore, Hyderabad, Jabalpur, Kolkata,	25
<i>Guadua angustifolia</i>	25	Bangalore, Hyderabad, Maharashtra	45
<i>Bambusa nutans</i>	10	Maharashtra, Jabalpur	25
<i>Bambusa pallida</i>	10	Bangalore, Hyderabad, Jabalpur, Kolkata, Maharashtra	25
<i>Bambusa wamin</i>	25	Bangalore, Jabalpur, Pune	100
<i>Bambusa japonica</i>	15	Ranchi, Pune	30
<i>Oxytenanthera parvifolia</i>	10	Bangalore	25
<i>Bambusa straita</i>	11	Bangalore, Hyderabad	30

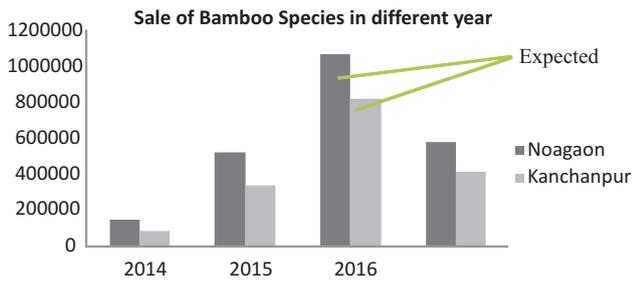


Fig. 5. Year wise income generation trend

Table 7. Income from bamboo

Wealth categories	No. of person	Income per year (Rs)	Income from bamboo (Rs)	Percentage of contribution of bamboo
Poor	21	1260000	690000	57.79
Medium	37	3996000	1050000	26.27
Rich	17	3276000	468000	14.28
Total	75	8532000	2208000	98.34

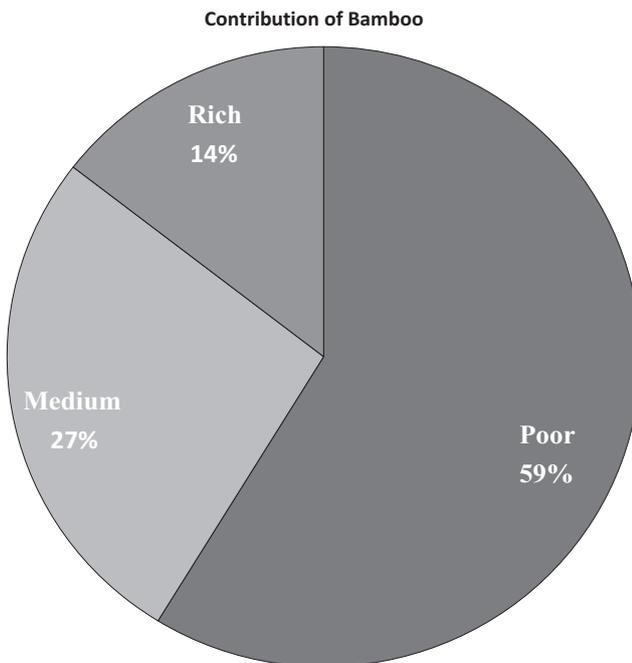


Fig. 6. Contribution of bamboo towards income in the study area

adopted was macro proliferation method. Farmers also know about the other methods of planting like culm and branch cuttings, rhizome and seed propagation. They have experienced that the success rate of propagation by macroproliferation is good because they get large bamboo from the beginning and it's a low cost method. The technique of raising culm cutting was the least preferred technique in all of the study area. Farmers have now introduced culm cuttings of bamboo plantation with the technical support from CFLE.

Table 8. Contribution of bamboo in the livelihood of bamboo growers in Noagaon

Sl. No.	Five major livelihood options of study area				
	Vegetables	Paddy culture	Business	Jobs	Bamboo nursery
N1	3	1	4	—	2
N2	4	—	1	3	2
N3	3	1	—	4	2
N4	2	1	—	—	3
N5	1	—	—	—	2
N6	3	2	1	5	4
N7	2	1	5	4	3
N8	2	1	—	—	3
N9	3	2	1	5	4
N10	2	3	5	4	1
N11	2	3	—	—	1
N12	2	3	—	4	1
N13	1	2	—	4	3
N14	2	1	—	—	3
N15	2	4	—	3	1
N16	3	4	1	—	1
N17	1	—	4	2	3
N18	1	—	2	—	3
Average	2.16	1.61	1.3	2.11	2.33

Table 9. Contribution of bamboo in the livelihood of bamboo growers in Kanchanpur

S. No.	Five major livelihood options of study area				
	Vegetables	Paddy culture	Business	Jobs	Bamboo nursery
K1	—	—	—	2	1
K2	1	—	2	—	3
K3	2	1	—	4	3
K4	4	—	1	3	2
K5	4	2	—	3	1
K6	1	—	3	—	2
K7	2	3	—	—	1
K8	2	4	—	—	1
K9	3	1	—	—	2
K10	2	—	—	—	1
K11	2	1	4	—	3
K12	3	1	—	—	2
K13	4	2	—	—	1
K14	2	—	3	—	1
K15	1	—	4	2	3
K16	1	—	2	—	3
K17	4	—	1	3	2
K18	4	2	—	3	1
K19	1	—	3	—	2
Average	2.26	0.89	1.21	1.05	1.84

Study area has rich bamboo culture. The different tribes inhabiting the region heavily depend on bamboos for various domestic and agricultural purposes. Their handicrafts using bamboo has gained popularity. These products are made of specific bamboos usually cultivated by the people. In recent times bamboos have been identified as a valuable industrial raw material substituting wood products and having potential for augmenting the economy.

Similarly a study aimed by Bwanali et al (2006) to determining the best and easy method of propagating *O. abyssinica* bamboo species from either seed or culm cuttings. The results showed that though all culm cuttings sprouted after two weeks of planting, the sprouting percentage varied highly between treatments. Nair et al (1997) found that one farmer in the primary sample had much interest in managing his bamboo clump and he found to have successfully adopted 'layering technique' for the propagation of bamboo. A low cost macro-proliferation technology for production of massive field planting stocks, was developed first time world-over at Forest Research Institute (FRI), Dehra Dun under Indian Council of Forestry Research and Education (ICFRE), Dehra Dun, India, in the beginning of the last decade of the 20th century, in 1991, for mass propagation of economically important sympodial bamboos for raising larger bamboo plantations. The development of macro-proliferation technology—a new universally applicable method for vegetative propagation of bamboo, has been stated to be a major breakthrough and a great achievement in the field of bamboo research. This technology is simple, easy, cost effective and involved the

**Table 10.** Ranks of livelihood option in study area

Livelihood option	Rank									
	1		2		3		4		5	
	N	K	N	K	N	K	N	K	N	K
Bamboo	16	12	11	9	9	7	5	4	3	2
Paddy culture	26	23	15	10	-	-	-	-	-	-
Vegetables	17	21	11	19	10	15	-	-	-	-
Business	12	14	9	7	8	5	-	-	-	-
Job	4	7	3	2	-	-	-	-	-	-

use of locally available materials. The planting stocks produced can be handled easily as these remain small in size. It is highly useful for sustained production of field plantable bamboo saplings in massive numbers rapidly, perpetually and plentifully for any desired number of years depending upon the targets and the facilities available. It solved, the ever existing major enigma regarding non availability of massive field planting stocks.

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**Table 11.** Bamboo species for protection in livelihood generation

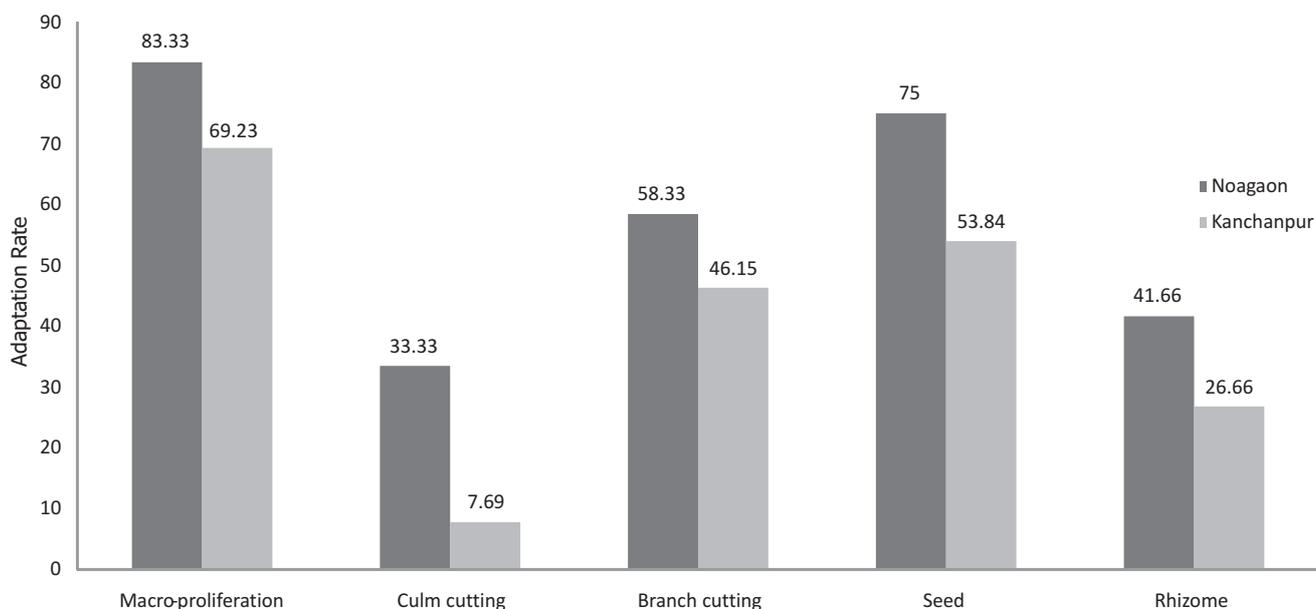
Name of species	Rate of multiplication	Cost of maintenance	Sale price	Overall performance
<i>Bambusa balcooa</i>	High (+)	Low (+)	High (++)	High (4+)
<i>Bambusa tulda</i>	High (+)	Low (+)	High (++)	High (4+)
<i>Dendrocalamus longispathus</i>	High (+)	Low (+)	High (++)	High (4+)
<i>Bambusa polymorpha</i>	High (+)	Low (+)	High (+++)	High (6+)
<i>Thyrsostachys oliveri</i>	Low (-)	High (+)	Medium (+)	Low
<i>Bambusa pallida</i>	High (+)	Low (+)	High (+++)	High (6+)
<i>Bambusa wamin</i>	High (+)	Low (+)	High (+++)	High (6+)
<i>Melocanna baccifera</i>	High (+)	Low (+)	High (++)	High (4+)
<i>Guadua angustifolia</i>	High (+)	Low (+)	High (++)	High (4+)

**Table 12.** Adaptability of propagation techniques in Noagaon village

Bamboo species	Propagation techniques					Percentage of adoptability
	Macro-proliferation	Culm cutting	Branch cutting	Seed	Rhizome	
<i>Dendrocalamus longispathus</i>						100
<i>Dendrocalamus hamiltonii</i>						80
<i>Bambusa tulda</i>						60
<i>Bambusa cacharensis</i>						40
<i>Thyrsostachys oliveri</i>						100
<i>Guadua angustifolia</i>						40
<i>Bambusa pallida</i>						40
<i>Bambusa vulgaris</i>						20
<i>Bambusa balcooa</i>						60
<i>Melocanna baccifera</i>						100
Lathi						40
Hill Jati						40
Total %	83.33	33.33	58.33	75	41.66	-

**Table 13.** Adaptability of propagation techniques in Kanchanpur village

Bamboo species	Propagation techniques					Percentage of adaptability
	Macro-proliferation	Culm cutting	Branch cutting	Seed	Rhizome	
<i>Dendrocalamus longispathus</i>		–				60
<i>Dendrocalamus hamiltonii</i>						60
<i>Bambusa tulda</i>						60
<i>Bambusa cacharensis</i>						20
<i>Thyrsostachys oliveri</i>						100
<i>Guadua angustifolia</i>						20
<i>Bambusa pallida</i>						20
<i>Bambusa vulgaris</i>						40
<i>Bambusa balcooa</i>						40
<i>Melocanna baccifera</i>						80
Lathi						20
Hill Jati						40
Dolu						40
Total (%)	69.23	7.69	46.15	53.84	26.66	

**Fig. 7.** Comparison of propagation techniques in study area

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# Seasonal Variation in Physicochemical Parameters and its Relationship with Zooplankton Abundance in River Asu, Nigeria

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**Abstract:** Seasonal variation in physicochemical parameters and its relationship with zooplankton abundance in River Asu, Nigeria was investigated monthly from October, 2013 to June, 2014 across wet and dry seasons. The study was aimed at investigating the seasonal variation in physicochemical parameters and its relationship with zooplankton abundance, diversity and biomass in the river. The relationship between the physicochemical parameters and zooplankton abundance in the two seasons was analyzed using Stepwise, Linear Regression. CCA showed that DO (3.0-8.5 mg/L), water temperature (23.85-32.85 °C), TDS (27.00-53.50 mg/L), phosphate (0.02-0.15 mg/L) and nitrate (0.02-0.05 mg/L) were the major environmental parameters that influenced zooplankton composition during the study. Temperature, DO, CO<sub>2</sub> and TDS correlated positively with the abundance of all the zooplankton groups in the dry season. Water pH had perfect correlation with copepod in the dry season. CO<sub>2</sub> significantly correlated positively with copepod and cladocera in both seasons but negatively correlation with copepod in the wet season. Only water temperature negatively correlated significantly with rotifer in the wet season ( $p < 0.05$ ). Rotifera were most dominant all through the study period. The result showed that water quality parameters exhibited great seasonal variation and controlled the structure of zooplankton community in the river.

**Keywords:** Akpoha, Physicochemical parameters, Relationship, River Asu, Seasonal variation, Zooplankton

Tropical rivers normally exhibit seasonal fluctuation in surface water level (Walker et al 1995) due to change in hydrological regime. Seasonal change in the metrological variables as commonly found in the tropics influences the physical and chemical composition of rivers (Aoyagui and Bonecker 2004). For instance, during the dry season, water volume usually decreases due to evaporation. This affects oxygen solubility in water and increases the concentration of solutes (MacIntyre and Melack 1984, Setaro and Melack 1984). Consequently, there will be rise in the concentration of dissolved solids and water conductivity. Freshwater ecosystems respond imminently to the variability of physical parameters such as temperature and water depth. Changes in physical and chemical variables of freshwater ecosystems impact the zooplankton and other resident aquatic biota (Combs 2003). Zooplankton community of freshwater ecosystem is characterized with the dominance of rotifers, copepods and cladocerans (Basu and Pick 1996). The tendency of zooplankton to respond to slight changes in the physical and chemical compositions of aquatic environment has made it a veritable tool in evaluating the water quality and the trophic state of an ecosystem. Zooplankton feed on algae, bacteria and other micro-organisms and are being preyed on by higher aquatic animals; thus they occupy central position in aquatic food chain and play part in

sanitizing the aquatic environment.

In contrast to its boom-bust reproductive success, zooplankton composition and density can be regulated by temperature, conductivity, pH, and water volume, nutrients, competition and predation (Hampton and Gilbert, 2001). There are still limited studies on tropical rivers (Bunn and Arthington 2002). Meanwhile, few studies on tropical rainforest rivers such as the study by Edema et al (2002) and Imoobe (2011) showed that there are seasonal variations in hydrobiology due to water level fluctuation. However, there is gap in having a clear knowledge of the relationship between these seasonal variations and the zooplankton community, its abundance, diversity and biomass in freshwater ecosystem (Nwonumara and Okogwu 2013). Therefore, this study is aimed at evaluating the seasonal variation in physicochemical parameters and its relationship with zooplankton abundance, diversity and biomass in River Asu.

## MATERIAL AND METHODS

River Asu is a feeder river (7.55°E and 5.56°N) located 7km away from Cross River. It is one of the major tributaries of Cross River. It flows through swampy rainforest with numerous creeks and forms an inland delta near its confluence with Cross River. The river experiences flooding during the peak of rainy season (August–October) and obviously reduces in

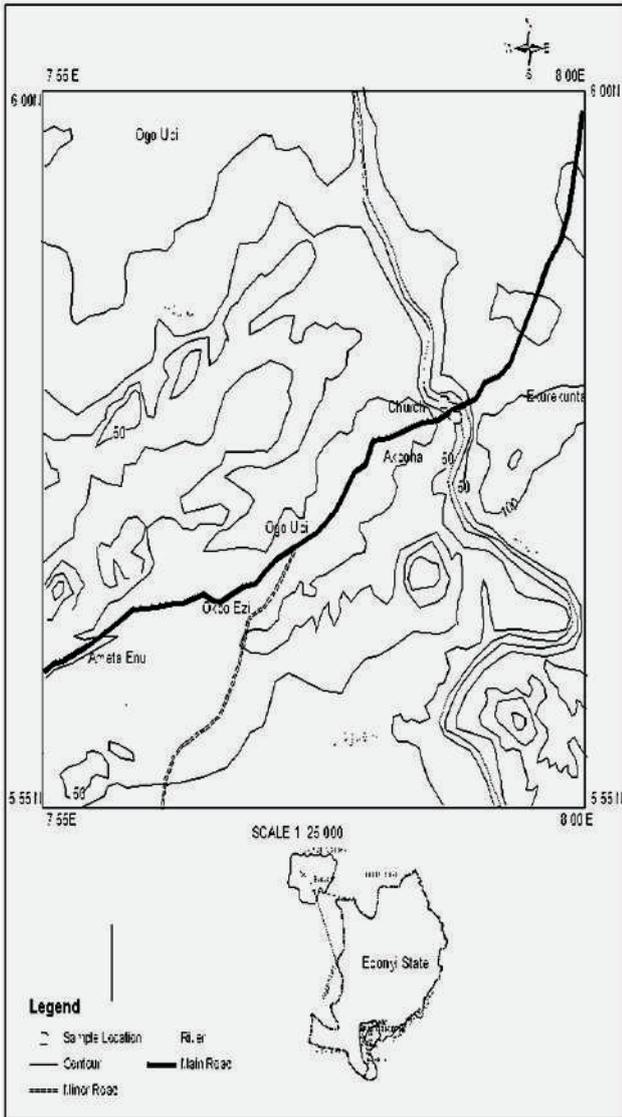


Fig. 1. Map of Akpoha showing the sampled stations

volume during the dry season. Farming takes place at the fringes of the river. Other anthropogenic activities that go on within the river are fishing, bathing, swimming and sand dredging. All of these activities can reasonably affect water quality. Samples for water quality and zooplankton analysis were collected monthly from two sampling sites (Station A and Station B) from October, 2013 to June 2014. Water temperature, dissolved oxygen and pH were determined *in situ* using portable Hanna field instruments. Phosphate ( $\text{PO}_4$ ) and nitrate ( $\text{NO}_3$ ) were measured according to AOAC (2003) Methods. Zooplankton samples were collected by towing plankton net of 50  $\mu\text{m}$  mesh size attached with 50 cm capacity bottle against water current for twenty 20 minutes, fixed in 4% buffered formalin solution and identified to species level using relevant keys of Semirnov (1974), Gebruder (1978), Jeje and Fernando (1986), Boxshall and Braide (1991) and Imoobe

(1997). Samples were identified using Olympus optical microscope (Model: B045781) at x400 magnification. Zooplankton biovolume was determined using length-width method (Johnson and Cunjak 1999) with automated worksheet calculator programmed by Sun and Liu (2003). Specific biomass of each species was estimated by multiplying its dry weight by the density and expressed in  $\mu\text{g L}^{-1}$ . Species diversity was estimated using Shannon-Weiner diversity index, and species richness with Margalef's index. One-way analysis of variance (ANOVA) was used to test the level of significance in seasonal variation of the physicochemical variables, zooplankton abundance and biomass. Values were considered significant at  $p < 0.05$  levels. The relationship between the physicochemical variable and zooplankton abundance was analyzed using Canonical Correspondence analysis (CCA). All the statistical analysis were carried out using Statistical Package for Social Science (SPSS).

## RESULTS AND DISCUSSION

**Physicochemical parameters:** The mean values of water temperature ( $30.28\text{ }^\circ\text{C}$ ), total dissolved solids ( $43.92\text{ mg L}^{-1}$ ) and carbon (iv) oxide ( $9.022\text{ mg L}^{-1}$ ) were highest during the dry season (Table 1). The pH value showed that the river was weakly acidic with mean values of 5.92 and 6.33 in the dry and wet seasons respectively. Dissolved oxygen ( $6.8\text{ mg L}^{-1}$ ), nitrate ( $0.02\text{ mg L}^{-1}$ ) and phosphate ( $0.09\text{ mg L}^{-1}$ ) all increased in the wet season. The depth of the river reduced greatly during the dry season and the lowest level ( $0.29\text{ m}$ ) was observed in March (peak dry season). Only nitrate and carbon (iv) oxide varied significantly between wet and dry seasons. The analysis of the canonical correspondence on the zooplankton abundance and environmental variables (Fig. 2) showed that CCA axis 1 explained 58.2% of the variation in zooplankton abundance. Zooplankton-environmental relationship was not significant for both axes 1 and 2. Variation in axis 1 is described by  $\text{NH}_3$  ( $r = 0.05$ ),  $\text{NO}_3$  ( $r = 0.05$ ),  $\text{PO}_4^{3-}$  ( $r = 0.05$ ) and pH ( $r = 0.25$ ), whereas most of the variance in axis 2 is explained by DO ( $r = -0.09$ ), TDS ( $r = -0.26$ ), water temperature ( $r = -0.12$ ) and transparency ( $r = -0.39$ ). Axis 1 is a reflection of nutrient enhancement in the River ecosystem while axis 2 is a reflection of true effect of the nutrient enhancement.

The physiochemical parameters showed no significant variation between the upstream and downstream and this can be attributed to the same human activities occurring in the two sections of the river and high turnover. Imoobe (2011) reported variation in water temperature in Okhuo River, Benin City across seasons. Variation in water temperature might be as a result of seasonal changes in meteorological variables in the tropics (Aoyagui and Bonecker 2004).

Decrease in dissolved oxygen in the dry season may probably be attributed to increase in water temperature which affects oxygen solubility (Abowei 2010). Sivakumar and Karuppasamy (2004) was of the opinion that increase in water turbulence as water volume increases can facilitate

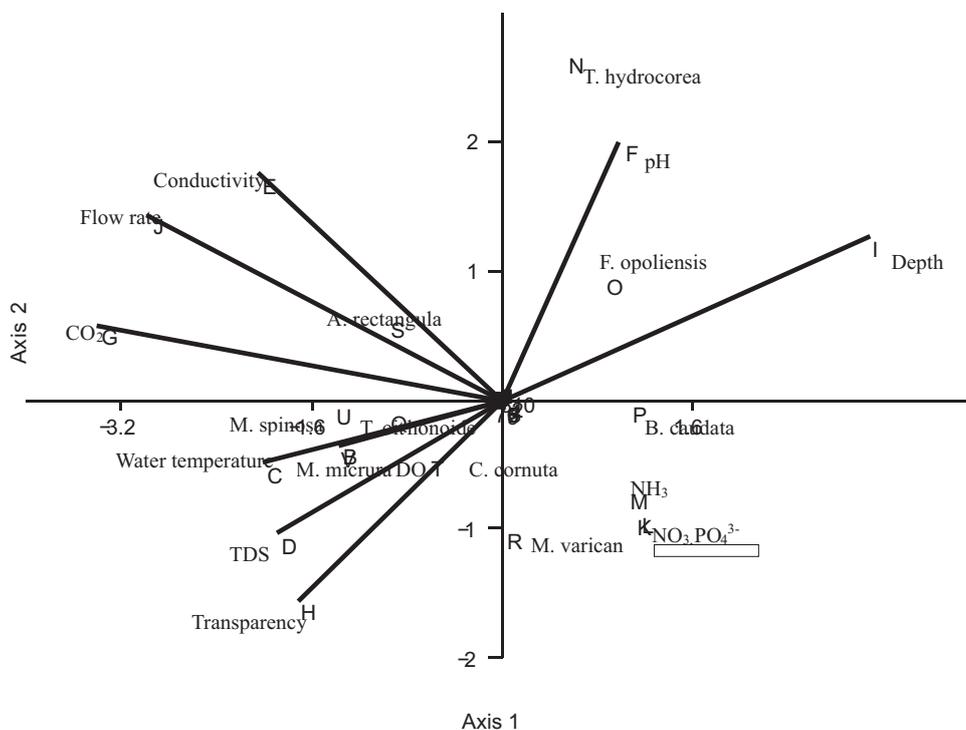
oxygen solubility in water consequent upon enhanced air-water interplay. This likely informs why oxygen concentration increased in the wet season.

The observed high TDS during the dry season can be associated with increase in evaporation (reduction in water

**Table 1.** Mean, standard deviation, minimum, maximum values and correlation between physicochemical variables and zooplankton of Asu River in the wet and dry seasons

Variable	Mean ± SD	Minimum	Maximum	R		
				Rotifer	Copepod	Cladocera
				Wet season (Dry season)	Wet season (Dry season)	Wet season (Dry season)
Temperature (°C)	30.07 ± 1.21 (30.28 ± 28)	28.70 (23.85)	31.00 (32.85)	-0.98 (0.37)	0.95 (0.35)	-0.01 (0.48)
DO (mg L <sup>-1</sup> )	6.87 ± 2.49 (4.28 ± 0.99)	4.00 (3.00)	8.50 (5.90)	0.69 (0.55)	-0.90 (0.27)	0.70 (0.14)
CO <sub>2</sub> (mg L <sup>-1</sup> )	7.06 ± 1.77* (9.02 ± 2.89*)	5.26 (5.78)	8.80 (13.97)	0.92 (0.79)	-0.98 (0.94)	0.35 (0.94)
Depth (cm)	106.30 ± 16.29 (59.10 ± 29.03)	88.40 (29.25)	120.25 (95.50)	0.63 (-0.42)	-0.31 (-0.82)	-0.80 (-0.83)
TDS (mg L <sup>-1</sup> )	34.50 ± 7.93 (43.92 ± 7.04)	27.00 (32.50)	31.50 (53.50)	-0.53 (0.04)	0.19 (0.37)	0.86 (0.17)
pH	6.33 ± 0.58 (5.92 ± 0.49)	6.00 (5.00)	7.00 (6.50)	0.99 (0.26)	-0.86 (0.00)	-0.19 (-0.13)
Phosphate (mg L <sup>-1</sup> )	0.09 ± 0.02 (0.09 ± 0.05)	0.07 (0.02)	0.10 (0.15)	0.03 (-0.14)	0.33 (-0.26)	0.00 (-0.36)
Nitrate (mg L <sup>-1</sup> )	0.02 ± 0.01* (0.04 ± 0.01*)	0.02 (0.02)	0.03 (0.05)	-0.36 (0.56)	0.00 (0.53)	0.94 (0.36)

**Note:** SD = Standard deviation, values with asterisks varied significantly between seasons (P < 0.05)



**Fig. 2.** Biplot of canonical correspondence analysis

volume) resulting from increase in atmospheric temperature and low humidity (Hamilton and Lewis 1987). Excessive loss of water through evaporation can increase salt concentration in water. Water pH decreased with increase in CO<sub>2</sub> in the dry season. CO<sub>2</sub> is an acidic gas and its presence can increase water acidity. Decrease in CO<sub>2</sub> concentration during the wet season may be attributed to its usage by phytoplankton,

decrease in decomposition and respiration (Wani and Subla 1990). Increase in the concentration of nitrate in wet season may be as a result of decay of riparian vegetations, aquatic weeds and plants submerged during inundation (Lauridson et al 1998). Meanwhile, runoff from farmlands, slaughter houses, residential and industrial effluents may be responsible for increase in phosphate concentration

**Table 2.** Zooplankton taxa, abundance and biomass in River Asu

Family	Abundance (ind L <sup>-1</sup> ) and percentage relative abundance (%)		Biomass (µg L <sup>-1</sup> ) and percentage biomass (%)	
	Wet season	Dry season	Wet season	Dry season
<b>Rotifera</b>				
	260 <sup>a</sup> (54.17)	300 <sup>a</sup> (48.39)	0.043 <sup>ab</sup> (4.32)	0.054 <sup>ab</sup> (3.89)
Brachionidae	40 <sup>a</sup> (8.33)	50 <sup>a</sup> (8.05)	0.0067 <sup>ab</sup> (0.66)	0.0081 <sup>ab</sup> (0.58)
Collothecidae	40 <sup>a</sup> (8.33)	40 <sup>a</sup> (6.44)	0.015 <sup>ab</sup> (1.48)	0.020 <sup>ab</sup> (1.46)
Euchlanidae	50 <sup>a</sup> (10.42)	50 <sup>a</sup> (8.06)	0.0037 <sup>ab</sup> (0.37)	0.0024 <sup>ab</sup> (0.18)
Floscularidae	20 (4.17)		0.00096 (0.096)	
Lecanidae	10 <sup>a</sup> (2.08)	30 <sup>a</sup> (4.83)	0.0018 <sup>ab</sup> (0.18)	0.0082 <sup>ab</sup> (0.59)
Synchaetidae	10 <sup>a</sup> (2.08)	20 <sup>a</sup> (3.22)	0.0077 <sup>ab</sup> (0.77)	0.0016 <sup>ab</sup> (0.12)
Trichocercidae	70 <sup>a</sup> (12.50)	110 <sup>a</sup> (17.73)	0.0077 <sup>ab</sup> (0.76)	0.014 <sup>ab</sup> (1.03)
<b>Copepoda</b>				
	90 <sup>a</sup> (18.75)	120 <sup>a</sup> (19.35)	0.47 <sup>ab</sup> (46.73)	0.65 <sup>ab</sup> (46.50)
Cyclopidae	60 <sup>a</sup> (12.51)	100 <sup>a</sup> (16.12)	0.36 <sup>ab</sup> (42.11)	0.57 <sup>ab</sup> (41.33)
Diaptomidae	30 <sup>a</sup> (6.24)	20 <sup>a</sup> (3.23)	0.11 <sup>ab</sup> (10.56)	0.072 <sup>ab</sup> (5.19)
<b>Zooplankton taxa</b>				
<b>Cladocera</b>				
	130 <sup>a</sup> (27.08)	200 <sup>a</sup> (32.26)	0.49 <sup>ab</sup> (48.94)	0.69 <sup>ab</sup> (49.60)
Bosminidae	10 (2.08)		0.05 (5.03)	
Chydoridae	40 <sup>a</sup> (8.33)	90 <sup>a</sup> (14.21)	0.15 <sup>ab</sup> (14.97)	0.17 <sup>ab</sup> (12.48)
Daphnidae	20 <sup>a</sup> (4.17)	30 <sup>a</sup> (6.45)	0.078 <sup>ab</sup> (7.84)	0.16 <sup>ab</sup> (11.50)
Macrothricidae	40 <sup>a</sup> (8.32)	30 <sup>a</sup> (6.45)	0.16 <sup>ab</sup> (16.18)	0.13 <sup>ab</sup> (9.37)
Moinidae	20 <sup>a</sup> (4.17)	30 <sup>a</sup> (6.45)	0.058 <sup>ab</sup> (5.83)	0.12 <sup>ab</sup> (8.65)
Sididae	10 <sup>a</sup> (2.08)	20 <sup>a</sup> (4.83)	0.041 <sup>ab</sup> (4.12)	0.11 <sup>ab</sup> (7.57)

Values with the same superscript on the same row are not significantly different ( $p > 0.05$ ). Figures enclosed in brackets are percentage relative abundance (%) and percentage biomass (%), respectively

observed in the wet season (Nigatu 2010).

**Zooplankton- Environment relationship :** Rotifer showed inverse relationship with water temperature ( $r = -0.93$ ) and total dissolved solids ( $r = -0.53$ ) in the wet season but positively correlated with dissolved oxygen ( $r = 0.69$ ), carbon (iv) oxide ( $r = 0.92$ ), depth ( $r = 0.63$ ), pH ( $r = 0.99$ ) and phosphate ( $r = 0.03$ ) in the same season (Table 1). Copepod had negative correlation with dissolved oxygen (carbon(iv)oxide, depth and pH but showed direct positive relationship with temperature, total dissolved oxygen and phosphate in the wet season .

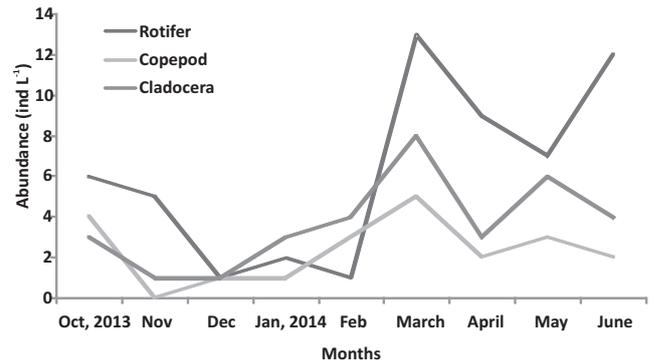
Cladoceran showed poor negative relationship with water temperature and pH during the wet season. Only rotifer correlated significantly with water temperature (during the wet season). Copepod showed perfect correlation with water pH in the dry season, Copepod and Cladocera both exhibited highly significant positive correlation ( $r = 0.94$ ,) respectively with carbon (iv) oxide during the dry season, and had significant negative correlation ( $r = -0.82$ ;  $-0.83$ ,  $p < 0.05$ ) respectively with depth in the same season.

**Variation in zooplankton abundance with season:** Zooplankton showed a remarkable variation in density during the study. Rotifer was at its peak in March ( $130 \text{ ind L}^{-1}$ ) (Table 2) and dropped to minimum ( $10 \text{ ind L}^{-1}$ ) in December and February. Copepod started rising in density between March and April with maximum number recorded in March ( $50 \text{ ind L}^{-1}$ ). Cladocera were mostly abundant from January to May having its maximum number in March. The respective mean zooplankton abundance in the wet and dry seasons were rotifera =  $88.33$  and  $50.17 \text{ ind L}^{-1}$ , copepod =  $30.00$  and  $20.00$

**Table 3.** Mean density, Shannon-Weiner diversity and Margalef's indices of Zooplankton groups in the wet and dry seasons

Zooplankton taxa	Wet season	Dry season
<b>Rotifer</b>		
Mean density ( $\text{ind L}^{-1}$ )	83.33 <sup>a</sup>	51.67 <sup>a</sup>
Shannon-Weiner index (H')	0.74	0.72
Biomass ( $\mu\text{g L}^{-1}$ )	0.043	0.054
<b>Copepod</b>		
Mean density ( $\text{ind L}^{-1}$ )	30.00 <sup>a</sup>	20.00 <sup>a</sup>
Shannon-Weiner index (H')	0.27	0.20
Biomass ( $\mu\text{g L}^{-1}$ )	0.47	0.65
<b>Cladocera</b>		
Mean density $\pm$ SD ( $\text{ind L}^{-1}$ )	43.33 <sup>a</sup>	33.33 <sup>a</sup>
Shannon-Weiner index (H')	0.72	0.70
Biomass ( $\mu\text{g L}^{-1}$ )	0.49	0.69

Mean values with the same superscript on the same row are not significantly different ( $p > 0.05$ )



**Fig. 3.** Monthly variation in zooplankton abundance

$\text{ind L}^{-1}$ , cladocera =  $40.33$  and  $30.33 \pm 2.58 \text{ ind L}^{-1}$  (Table 3). There was no significant variation in zooplankton abundance between the seasons.

**Zooplankton composition:** During the study period rotifera contributed 54.17, copepoda 18.75 and cladoceran 27.08 percent to be total zooplankton abundance in the wet season (Table 2). In contrast, rotifer, copepoda and cladoceran accounted for 48.39, 19.35 and 32.26 percent of the total zooplankton abundance respectively, in the dry season. Zooplankton abundance did not vary significantly between the wet and dry season. Rotifera contributed only 4.32 and 3.89 percent to the total zooplankton biomass in the wet and dry seasons. Copepod and Cladocera contributed 46.73 and 19.09 percent, respectively in the wet season, and 46.50% and 26.68% in dry season (Table 2). There was no significant variation in zooplankton biomass between the two seasons.

Rotifera were dominant during the present study in Asu River. Dominance of rotifera in rivers was reports by Imoobe and Akoma (2009) and Edema et al (2002). The dominance of rotifera may be attributed to pressure from planktivorous fishes that preferentially prey on micro-crustaceans. The increase in abundance of cladoceran between January and May must have been prompted by increase in pH. Sharma et al (2010) also recorded high biomass of cladoceran during the dry season. This may be attributed to stable water flow, nutrient enhancement and the consequent higher phytoplankton productivity (Okogwu et al 2009). These factors promote growth and increase of zooplankton biomass in rivers. Low abundance of copepod during the study may be associated with increase in predation by juvenile fishes and the fluvial nature of the river, which makes it difficult for a stable population to be established. Copepods made very low contribution to the total zooplankton biomass in the wet season. Adverse environmental condition, inter-specific competitions and predation by juvenile fishes may have been responsible for low biomass recorded by copepod in the dry The Canonical Correspondence analysis (CCA) revealed that

TDS, water temperature, DO, phosphate and nitrate are the major drivers of zooplankton dynamics in River Asu. The study further reveals that rotifera responded significantly to change in water temperature and copepod to carbon oxide in the wet season. Copepoda and cladoceran both positively responded significantly to carbon oxide fluctuations and significantly showed negative response to change in water level during the dry season. Therefore, there is need for more regular studies on River Asu and other similar rivers to have better knowledge of the possible impact of human and climate related factors on zooplankton composition in the river.

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## Hierarchical Clustering of Wild Edible Mushrooms used by Tribes based on Ecological Characteristics

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**Abstract:** The study on classification of wild edible mushrooms consumed by six tribal communities of Kerala, India was done through hierarchical agglomerative cluster analysis. The study incorporated extensive field visits, documentation of ethnic knowledge, collection and identification of wild edible mushrooms from Attappady and Wayanad areas of Kerala. Hierarchical cluster analysis of thirty seven wild edible mushrooms species gave a realistic grouping based on ecological characteristics. The most distinguishing character that separate mushrooms in to two divergent groups was substance on which it grows; ie soil or wood. Mushrooms growing in soil were successively classified further in to individual groups based on soil type, association with trees or termites and according to growing pattern. The distinction of lignicolous mushrooms were based on the place where it sprout i.e. whether on dead wood or on roots/stumps of trees.

**Keywords:** Cluster analysis, Diversity, Ecology, Ethnic knowledge, Wild edible mushrooms

Clustering has a wide range of applications in the field of life sciences such as taxonomy, ecology, and molecular biology. Cluster analysis involves a group of multivariate techniques whose primary purpose is to group individuals or objects based on characteristics they possess. So that within cluster has homogeneity and between groups heterogeneity (Odilia and Kylee 2015). Hierarchical clustering works in two processes, agglomerative and divisive. Agglomerative starts with considering each data as individual groups, successively it groups data based on similarity in characteristics. Divisive method starts with whole data as a single group, iteratively separates data sets base on dissimilarity in characteristics. Similarity / dissimilarity are done based on distance matrix. Different linkage measures define the distance between pairs of clusters. Hierarchical cluster analysis is best illustrated using dendrogram, which indicates the distance between two joining clusters (Landau and Chis 2010). Fungi are diverse group of organisms which make up a large part of the biodiversity of forest ecosystems. They do critical ecological roles as mycorrhizal symbionts that promote plant health, decomposers, recyclers and pathogens (Deacon 2006). Western Ghats of Kerala is blessed with rich macro fungal diversity. Moist-deciduous and semi-evergreen forests support a maximum number of macrofungi followed by evergreen and Shola forests in this state (Farook et al 2013, Mohanan 2014). Wild edible mushrooms are important to rural and tribal livelihoods. The knowledge on edibility of mushroom is mainly through

traditional knowledge; it includes knowledge such as the fruiting patterns, habitats, substrates and habits of mushrooms (Pradeep et al 2007). Indigenous knowledge will differ in each community since it is based on culture, availability of mushroom, vernacular naming, edibility are an area yet to be documented. Knowledge on mushrooms with tribal and local populations is an important criterion in identifying the habitats and to develop strategies for habitat conservation. Keeping this in mind the present study envisage to study the diversity of wild edible mushrooms used by tribes of Kerala based on vernacular naming, ecology and habitat. Information collected with the support of indigenous knowledge of different tribal communities from Attappady (Irula, Muduga & Kurumba) and Wayanad (Paniya, Kuruma Wayanad (Paniya, Kuruma & Kattunaikka).

### MATERIAL AND METHODS

**Geographic locations and tribal groups:** The study focuses on two tribal areas of Kerala; Attappady and Wayanad. Wayanad district is located in the North east part of Kerala State lies between North latitudes 11° 26' to 12° 00' and east longitudes 75° 75' to 76° 56'. The altitude varies from 700 to 2100 meters above Mean Sea Level (MSL). The moist deciduous forest is the dominant vegetation type. Southern moist-mixed deciduous forests consists the evergreen families. The district abode socioeconomically and culturally different six tribal communities. The present study is among the three mycophilic communities Paniya,

Kattunaikka and Kuruma. Attappady is an extension mountain valley of 731 Sq. Km in area lying at Western Ghats ranges located in the mid-eastern part of Kerala on the north east of Palakkad district adjoining Coimbatore and Nilgiri district of Tamil Nadu. The Attappady valley altitude ranges from 750 meters to 11° 6' 32" to 11.10889° North and 76° 33' 8" to 76.55222° East. The region is drained by the two rivers, namely Bhavani and Siruvani. The forest area includes evergreen/semi evergreen dense forest, evergreen /semi evergreen open forest and deciduous forest. Attappady tribal area constituted of Agali, Pudur and Sholayar tribal villages. The three major tribal groups in Attappady are Muduga, Irula and Kurumba. Irula is the largest group in Attappady tribal area. Mudugas are the second largest group and Kurumbas are a small group in Attappady tribal area. The Mudugas have the highest literacy. Kurumbas are the most primitive tribal group and they are still residing in the interior forest area.

**Data collection and identification of mushroom:** Local traditional mushroom knowledge was collected by extensive field trips and semi structured interviews during 2014-2016, among 192 individuals. Initially most of the mushrooms were identified with traditional methods by the help of key knowledge's in each community, deputed the local names. Identified each mushrooms based on macro morphology and micro morphology. Scientific names were given according to Index Fungorum database.

**Data recording and analysis:** This study is based on 18 characters of wild edible mushrooms related to ecology, habitat and habit (Table 1). The Similarity / dissimilarity are done based on distance matrix generated by Squared Euclidian Distance.

In the equation  $a$  and  $b = \sum_{j=1}^k (a_j - b_j)^2$  are two sets of data that is compared by each character running from 1 to  $k$ , whereas  $k$  is the total number ( $k=18$ ) of characteristics in the analysis. The grouping of mushrooms was done by hierarchical agglomerative cluster analysis using SPSS statistical software version 24.

The characteristics of wild edible mushrooms used for hierarchical clustering include soil type (humus and leaf littered soil/ termite associated soil/ soil mixed with dung/ loose soil), habitat (grass lands/ paddy fields,/under or associated with herbs roots/ paddy straws/ near *Hopea/Dipterocarpus* trees/ road sides and forest edges/on dead woods/ stumps and roots of trees), and based on habit (Individual/scattered,fairy rings on grass/small cluster/ large groups).

## RESULTS AND DISCUSSION

Thirty seven species of mushrooms were collected during the study. Tribes collect mushrooms cautiously and

did not use which are new to them. The local names have stayed in use in all region and they have been passed down through generations and allow for easy identification. This makes it easy to recall key characteristics of the mushroom. The respondents reported that the ecological growth requirements such as trees, soil, moisture, and morphological features of mushrooms such as colour, shape and size give rise to the designation of their respective names. The taxonomic name, habitat, soil type and habit of mushroom studied were represented in table 1. Hierarchical clustering analysis results are represented as dendrogram (Fig. 1). Vertical lines indicate distance between clusters whereas horizontal lines represent difference of these distances. The longest horizontal line represents largest differences. Dendrogram shows two groups of species (Squared euclidian distance 25), I and II. Group 1 were wild edible mushrooms seen on soil. Group I is divided in to two sub groups A and B based on their difference in niche, the group A represents symbiotic mushrooms. This sub group again grouped in to two (a, b). Group a consist of mushrooms seen associated with termites (Karun and Sridhar 2013). The outlier of this group *Xylaria acuminati longissima* (XY) is fused to this group at much higher distances (Partially /fully submerged on soil in termite comb/old buildings). The distance with the other groups d, e and f is due to their habitat (Small cluster < 10, Individual/scattered, Seen as large > 15 groups). The sub group includes mushrooms having ectomycorrhizal association (Sathe and Daniel 1980). Due to their difference in host species and appearance again grouped in to g, h and i. Kattunaikka tribes generally use the term 'Jal anave' (Jal= Hopea tree, Anave= Mushroom) for the mushroom group g and h which shows their high perception on mushroom ecology. Within group B heterogenous grouping can be seen based on difference in soil types, habitat and formation of fruit body. The group II belongs to the mushrooms seen on wood. Here also grouping can be seen based on their appearance on tree. *Lentinus bambusinus* (LB) and *Lentinus cladopus* (LC) usually sprout on the stump/roots of trees (Kumar and Manimohan 2005). *Ganoderma species* (GS) and *Lentinus squarrosulus* (LS) usually seen both in dead trees and on stump/roots whereas all the other lignicolous species share wide range of host and seen as large groups on decayed woods (Leelavathy 2000, Senthilarasu 2015).

## CONCLUSION

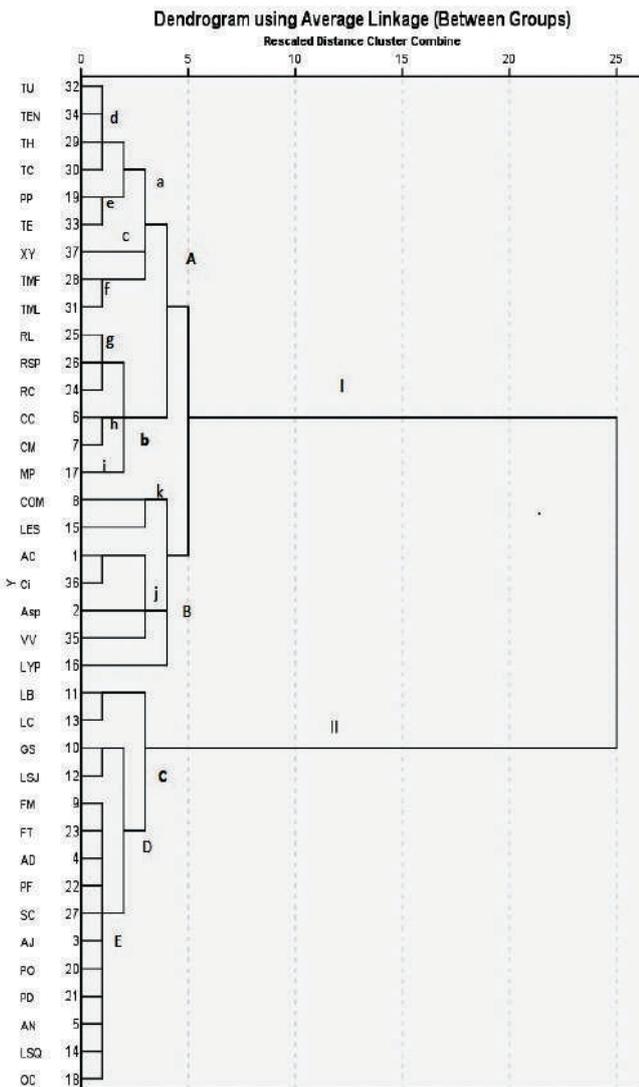
Hierarchical clustering provided a realistic grouping of wild edible mushrooms used by tribes of Attappady and Wayanad regions of Kerala. Wild edible mushrooms basically classified based on growing media, soil and wood.

**Table 1.** Taxonomy and ecology of wild edible mushrooms

Taxonomy	Habitat and soil type	Habit
<i>Termitomyces microcarpus f. elongatus</i>	On ejected termitorium and on heavily littered soil associated with faecal pellets of termite.	Large groups (>15 numbers).
<i>Termitomyces microcarpus-large</i>	In open areas with termite.	Small groups (<10 numbers).
<i>Termitomyces heimi</i>	Associated with termite mounds.	Solitary, in small groups.
<i>Termitomyces clypiatus</i>	In littered ground and termite associated soil	Solitary, in small group.
<i>Termitomyces eurrhizus</i>	Termite associated soil	Individual and scattered.
<i>Termitomyces unkowaan</i>	Termite associated soil	Solitary or in small clusters.
<i>Termitomyces entelomoides</i>	Termite associated soil and on termitorium	Individual, in small clusters.
<i>Russula Leelavathyi</i>	Distributed on river side under <i>Hopea</i> and <i>Meristica trees</i>	Individual and scattered.
<i>Russula congoana</i>	Distributed on river side under <i>Hopea</i> and <i>Meristica trees</i>	Individual and scattered.
<i>Russula sps</i>	Distributed on river side under <i>Hopea</i> and <i>Meristica trees</i>	Individual and scattered.
<i>Cantharellus cibarius</i>	Highly littered Dipterocarpaceae forest, In and around <i>Hopea</i> tree roots near road sides.	Individual and scattered/paired
<i>Cantharellus minor</i>	Highly littered Dipterocarpaceae forest, In and around <i>Hopea</i> tree roots near road sides.	Individual and scattered.
<i>Macrolepiota procera</i>	Found at forest edges, grasslands, under <i>Eucalyptus trees</i> and <i>Solanum indicum</i> .	Individual and scattered
<i>Agaricus campestris</i>	On soil, grass lands/along paddy field.	Solitary and as fairy rings.
<i>Agaricus species</i>	Grass lands/along paddy field on soil with dung remains.	Small groups/ as fairy rings.
<i>Phlebopus portentosus</i>	On soil under Jack fruit tree.	Solitary and scattered
<i>Lepista sordida</i>	On black loose soil.	As fairy rings
<i>Calocybe indica</i>	On soil, grass lands/along paddy field.	As fairy rings/small groups
<i>Lycoperdon sp</i>	On loose soil/grass lands/ along paddy field/ road sides/forest edges.	Scattered/ small clusters
<i>Coprinellus micaceus</i>	Under/associated with herbs roots on loose soil	Small clusters
<i>Volvariella volvacea</i>	On soil, grass lands/along paddy field.	Small clusters
<i>Xylaria acuminatilongissima</i>	Partially /fully submerged on soil in termite comb/old buildings	Small clusters
<i>Lentinus bambusinus</i>	Seen on stumps and roots of bamboo tree	Small clusters
<i>Lentinus cladopus</i>	Seen on stumps and roots of trees	Small clusters
<i>Ganoderma lucidum</i>	On fallen trees, stumps and roots of trees	Individual/ in small clusters.
<i>Lentinus sajor-caju,</i>	On fallen trees/dead woods, stumps and roots of trees	Small / large clusters
<i>Favolaschia manipularis</i>	On fallen forest trees/dead woods,	Small / large clusters
<i>Favolus tenuiculus/Polyporus tenuiculus</i>	On fallen trees/dead woods	Small / large clusters
<i>Auricularia delicata,</i>	On fallen forest trees/dead woods,	Small / large clusters
<i>Auricularia auricula-judae</i>	On fallen trees, logs of trees	Small as well as large clusters
<i>Auricularia nigricans</i>	On fallen trees/dead woods	Small / large clusters
<i>Pleurotus flabellatus</i>	On fallen trees/dead woods	Small / large clusters
<i>Pleurotus ostreatus</i>	On fallen trees/dead woods	Small / large clusters
<i>Oudemansiella canarii</i>	On fallen trees/dead woods	Small / large clusters
<i>Schizophyllum commune</i>	On fallen trees/dead woods	Small / large clusters
<i>Pleurotus djamor,</i>	On fallen trees/dead woods	Small / large clusters
<i>Lentinus squarrosulus</i>	On fallen trees/dead woods	Small / large clusters

Those which grow on soil again classified in to symbiotic and saprophytic mushrooms. Symbiotic mushrooms further clustered in to ectomycorrhizal and termite associated mushrooms. Lignicolous mushrooms are less divergent they differ based on habit and on the part of the tree where they

sprout. Hierarchical cluster analysis is an accurate representation of ecological characteristics and gives confidence in applying to similar topics in more detailed approach. The Knowledge of the distribution and ecology of wild mushrooms signifies monitoring and retention of diversity and selection of species for forest nurseries.



(TU= *Termitomyces umkowaan*, TEN=*Termitomyces entolomoides*, TH=*Termitomyces heimii*, TC=*Termitomyces clypeatus*, TE=*Termitomyces eurrhizus*, PP= *Phlebopus portentosus*, TML=*Termitomyces microcarpus* - large form, XY= *Xylaria acuminatilongissima*, COM=*Coprinellus micaceus*, VV= *Volvariella volvacea*, TMF=*Termitomyces microcarpus*, RL= *Russula leelavathyi*, RSP=*Russula sp.*, RC= *Russula congoana*, CC= *Cantharellus cibarius*, CM=*Cantharellus minor*, MP= *Macrolepiota procera*, AC=*Agaricus campestris*, Ci= *Calocybe indica*, LES= *Lepista sordida*, Asp= *Agaricus sp.*, LYP=*Lycoperdon sp.*, LB=*Lentinus bambusinus*, LC=*Lentinus cladopus*, GS=*Ganoderma lucidum*, LSJ=*Lentinus sajor-caju*, FM=*Favolaschia manipularis*, POT=*Favolus tenuiculus/Polyporus tenuiculus*, AD=*Auricularia delicata*, PF= *Pleurotus flabellatus*, SC= *Schizophyllum commune*, AJ= *Auricularia auricula-judae*, PO= *Pleurotus ostreatus*, PD= *Pleurotus djamor*, AP=*Auricularia nigricans*, LSQ= *Lentinus squarrosulus*, OC= *Oudemansiella canarii*)

Fig. 1. Dendrogram from hierarchical cluster analysis of wild edible mushroom with linkage

ACKNOWLEDGEMENT

We are grateful to Kerala State Council for Science, Technology & Environment, Back to Lab Project of Women Scientist Division for financial support. Thanks to Forest & Tribal Development Department of Kerala for giving permission to this study.

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# Native, Endemic and Utilization Pattern of Woody Species of Dandachali forest of Tehri Forest Division, North-West Himalaya

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**Abstract:** The present investigation was conducted in Dandachali forest of Tehri Forest Division, North-Western part of Himalaya. Forty seven woody species (26 trees; 21 shrubs) belonging to 25 families and 33 genera, and 6 forest communities viz., *Pinus roxburghii*-*Quercus leucotrichophora* mixed, *Pinus roxburghii*, *Pinus roxburghii*-*Rhododendron arboretum* mixed, *Cedrus deodara*-*Pinus wallichiana* mixed, *Cedrus deodara*-*Rhododendron arboretum* mixed and *Rhododendron arboretum*-*Quercus leucotrichophora* mixed, have been recorded in 16 sites between 1482-2200 mean above sea level. Besides, utilization pattern of the species was assessed through interviews and interactions with local people of nearby villages. Utilization pattern showed that all the recorded species have high economic importance for the local inhabitants. 23 species were used commonly for medicine, 22 as wild edible, 17 for fuel, 23 for fodder, etc. Among all the species, leaves were most usable parts of the 33 species. Maximum medicinal plant and fodder species were found in *C. deodara*-*Rhododendron arboretum* mixed and edible species in *Pinus roxburghii* community. Thirty two species of Himalayan native and endemic (endemic: 01 & near endemic: 09) species were recorded from the area showing its conservation value. Maximum 23 native and near seven endemic species were in *C. deodara*-*R. arboretum* mixed community.

**Keyword:** Utilization, Native, Endemic, Medicine, Economics, Ecology

India is among the important mega-biodiversity centers of the world, with a lot of contribution from the Himalayan ecosystem. The Indian Himalayan Region (IHR) is very well known throughout the globe due to its representative, unique, natural, and socio-economically important flora and fauna and after China, India is second largest country export to medicinal of millions raw material worth US\$ 46 million annually (Kala 2005). Due to this peculiar feature, the eastern Himalaya has been identified one of the biodiversity hot spots (Myers 1990). This rich biodiversity is being utilized by the inhabitants of the region for medicine, as wild edible (food), fodder, fuel, timber, in making agriculture tools, religious and various other purposes Forest diversity is the main source of livelihood of the people living in Uttarakhand, Central Himalaya. With the increasing human population, the demand of the economically important biodiversity is increasing fast. Collection of fodder and fuel species from the forests has been identified one of the chronic problems in the IHR for the degradation of forest (Singh 1998). The anthropogenic pressures including heavy grazing coupled with the natural calamities have led the degradation of natural habitats of many species to a great extent. Such practices are discouraging the moisture loving species and promoting the hardy and spiny species having least value for the society. This loss of biodiversity and changing pattern of vegetation

has necessitated for assessment of biodiversity of the region and prioritize habitats, communities and species for conservation.

## MATERIAL AND METHODS

The study was carried out in Dandachali forest of Tehri Forest Division, Tehri Garhwal (district), Uttarakhand part of North West Himalaya.

**Selection of sites and habitats for vegetation sampling:** Sites were selected on each and every accessible aspect along an altitudinal gradient. The habitats were identified based on the physical characters and dominance of the vegetation. Sites having closed canopy with high percentage of humus and moisture were considered as moist habitats, whereas, low percentage of the same as dry habitats.

**Assessment of the forest vegetation:** In each site, a plot of 50x50m (0.25 ha) was laid. Trees, saplings and seedlings were sampled by randomly placed 10, 10x10m quadrats and shrubs by 20, 5x5m quadrats. For the collection of data from these quadrates standard ecological methods were followed. The circumference at breast height (cbh at 1.37m from ground) for each tree individual was recorded. Based on cbh, the tree individuals were considered as tree (cbh 31.5 cm), sapling (cbh 10.5-31.4 cm) and seedling (cbh < 10.5 cm). Shrubs were considered as the woody species having

several branches arising from their base (Saxena and Singh, 1982).

**Selection of villages and assessment of species utilization pattern:** In the study area, nearest and dependent habitation were surveyed. During the surveys, knowledgeable persons from the villages viz., Veetgaon, Dargi, Saalamkhet and Dandachali nearby forest area were interviewed and information was generated on the utilization pattern (fuel, fodder, timber, edible, medicinal, religious, etc.) of the species present in the study area. A questionnaire was used to collect basic information (local name and uses) on the species. Also, an extensive survey of literature was carried out for the compilation of indigenous uses of the plant species.

**Identification and distribution pattern of the native and endemic species:** Nativity of the species was identified following Anonymous (1883-1970) and Samant et al 1998) and endemism on the basis of the phyto-geographical distribution of the species (Samant and Dhar 1997, Samant et al 1998a).

## RESULTS AND DISCUSSIONS

**Site and habitat characteristics:** The 16 study sites fall between 30°18.808'N and 30° 17.995'N latitudes; 078° 25.154'E and 078° 25.009'E longitudes and cover an altitudinal range of 1482 to 2200 m amsl (Table 1). The main habitats were identified as dry degraded, shade moist, dry and moist and slope varied from 30 to 70°. Maximum sites were represented by dry degraded habitats and shady moist

(7 each). Seven sites were represented by North-West, six sites by North east and three sites by North aspect. A total of 47 species belonging to 25 families and 33 genera were recorded in the study area (Table 3). Out of which, 26 species were trees and 21 shrubs. Family Rosaceae dominated with maximum six species followed by five species of Fabaceae, Pinaceae and three species each of Moraceae and Cornaceae, two species each of Ericaceae, Ulmaceae, Symplocaceae, Berberidaceae and Anacardiaceae. All other families had only one species. Dominant genera were *Ficus*, *Rubus*, and *Desmodium* with three species each, followed by *Pinus*, *Celtis*, *Simplocus*, *Prunus*, *Quercus*, *Berberis* and *Rush* with two species each. *Pinus roxburghii*, *Quercus leucotrichophora* and *Myrica esculenta* were represented in all sixteen sites followed by *Berberis aristata* and at fifteen sites each, *Myrsine Africana*, *Rhododendron arboreum* and *Rubus ellipticus* at twelve sites each and *Pyrus pashia* and *Rubus niveus* at ten sites. Shady moist habitat was the richest with 34 species followed by dry degraded (33 spp.) and dry habitats (28 spp).

**Community diversity:** A total of six forest communities were delineated in the study area (Table 3). *Pinus roxburghii* community represented in maximum six sites, followed by *Cedrus deodara Rhododendron arboreum* mixed (3, each), *C. deodara Pinus wallichiana* mixed (2) and *P. roxburghii Q. leucotrichophora* mixed and *R. arboreum, Q. leucotrichophora* mixed (1 each). These communities fall between 30°18.808'N and 30° 17.995'N latitudes; 078° 25.154'E and 078° 25.009'E longitudes and cover an

**Table 1.** Physical characteristics of study sites

Altitude (m)	Habitat	Aspect	Slope (°)	Latitude	Longitude	Dominated species
1482	D, Deg	NE	45	30° 18.808'N	078° 25.154'E	<i>P. roxburghii</i> – <i>Q. leucotrichophora</i>
1525	D, Deg	NW	35	30° 18.080'N	078° 25.137'E	<i>P. roxburghii</i>
1586	D, Deg	N	50	30° 18.727'N	078° 25.135'E	<i>P. roxburghii</i>
1684	D, Deg	NE	45	30° 18.570'N	078° 25.090'E	<i>P. roxburghii</i>
1784	D, Deg	NW	60	30° 18.368'N	078° 24.957'E	<i>P. roxburghii</i>
1787	D, Deg	NW	55	30° 18.472'N	078° 25.066'E	<i>P. roxburghii</i>
1791	D, Deg	NE	50	30° 18.470'N	078° 25.073'E	<i>P. roxburghii</i>
1863	D	N	30	30° 18.242'N	078° 25.995'E	<i>P. roxburghii</i> – <i>R. arboreum</i>
1873	SM	N	70	30° 18.189'N	078° 25.936'E	<i>C. deodara</i> – <i>P. wallichiana</i>
1928	SM	NW	60	30° 18.101'N	078° 25.145'E	<i>R. arboreum</i> – <i>C. deodara</i>
1968	D	NE	55	30° 18.213'N	078° 25.104'E	<i>P. roxburghii</i> – <i>R. arboreum</i>
1987	SM	NE	30	30° 18.197'N	078° 25.061'E	<i>R. arboreum</i> – <i>C. deodara</i>
2015	SM	NE	50	30° 18.204'N	078° 25.059'E	<i>R. arboreum</i> – <i>P. roxburghii</i>
2015	SM	NW	55	30° 18.204'N	078° 25.059'E	<i>C. deodara</i> – <i>P. wallichiana</i>
2116	SM	NW	50	30° 17.893'N	078° 25.004'E	<i>C. deodar</i> – <i>R. arboreum</i>
2200	SM	NE	55	30° 17.995'N	078° 25.009'E	<i>Q. leucotrichophora</i> – <i>R. arboreum</i>

**Abbreviation:** SM=Shady Moist; D=Dry; Deg=Degraded; N=North; NW=North West and NE=North East P=*Pinus*; QL= *Quercus*; R=*Rhododendron*; C=*Cedrus*

altitudinal range of 1482 to 2200 m amsl and 30-70° slopes. These communities were represented in the North, North West and North East. Similar to present study Joshi and Samant (2004) observed the various numbers of communities of the different angiosperms and gymnosperms species in different habitats in the Nanda Devi Biosphere Reserve, Western Himalaya. However, Samant and Joshi (2005) studied plant diversity and conservation status of high land Nanda Devi National parks where as reported 90 species belonging to 281 genera and 89 families of Angiosperms and Gymnosperms have been recorded. Maximum species were represented in the family Rosaceae, genus *Saxifraga* and 73% of species were native, 2% were endemic and 34% species were near endemic.

**Species utilization by local people:** Of the total 47 species recorded, 23 species are used commonly for medicine, 22 for food (wild edible), 17 for fuel, 23 for fodder, 6 for agricultural tools, 5 for dye and tannin, 4 for timber and 14 species for miscellaneous uses (Table 3). Most of the species are used for more than one purpose and thus, overlapped in the number of species under different category of uses and parts used. The most usable parts were leaves (33 species), fruits (22 species), wood (18 species), bark and flowers (14 species each), roots (4 species), seeds (5 species) and stem and fibre (5 and 3 species each), twigs (2 species) and resin and galls (1 species each,). Maximum medicinal plant and fodder species were found in *Cedrusdeodara-Rhododendron arboreum* mixed and edible species in *Pinus roxburghii* (Fig. 1). Similar results were reported by Butola and Samant (2010) on medicinal plant in Indian Himalayan Region.

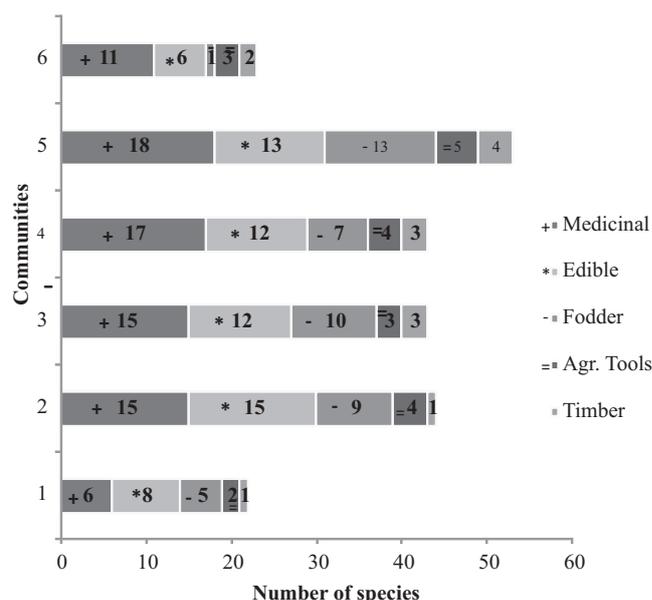


Fig. 1. Community wise utilization pattern of woody species

**Abbreviations used:** 1= *Pinus roxburghii*- *Quercus leucotrichophora* mixed; 2= *Pinus roxburghii*; 3= *Pinus roxburghii*- *Rhododendron arboreum* mixed; 4= *Cedrusdeodara*- *Pinus wallichiana* mixed; 5= *Cedrusdeodara*-*Rhododendron arboreum* mixed; 6= *Rhododendron arboreum*-*Quercus leucotrichophora* mixed

**Diversity and distribution of native and endemic species:**

Of the total 47 species (26 trees and 21 shrubs), 32 species were native; 15 species non-natives; 9 species near endemic and 1 species was endemic to Himalayan region (Table3). *C. deodar-R. arboreum* mixed community supported maximum native species (50 %) followed by *P. roxburghii* (43.48 %), *C.*

Table 2. Community types, their distribution, habitats and major associated species in study sites

Community types	SR	AR (m)	Habitat	Slope (°)	Aspect	Latitude	Longitude	Major associated spp.
<i>Pinus roxburghii</i> - <i>Quercus leucotrichophora</i> mixed	1	1482-1495	D, Deg	45	NE	30° 18.808'N 30° 18.900'N	078° 25.154'E 078° 25.204'E	<i>P.roxburghii</i> , <i>Q. leucotrichophora</i> , <i>B. aristata</i> , <i>R. parviflora</i> , <i>R. cotinus</i>
<i>Pinus roxburghii</i>	6	1525-1791	D, Deg	35-50	NW, NE	30° 18.080'N 30° 18.470'N	078° 25.137'E 078° 25.073'E	<i>L. valifolia</i> , <i>M. esculenta</i> , <i>R.arboreum</i> , <i>B. aristata</i> , <i>M. Africana</i> , <i>A.adscendens</i>
<i>Pinus roxburghii</i> - <i>Rhododendron arboreum</i> mixed	3	1863-2015	D, SM	30-50	N, NE	30° 18.204'N 30° 18.242'N	078° 25.059'E 078° 25.995'E	<i>L.ovalifolia</i> , <i>C. capitata</i> , <i>C. deodara</i> , <i>M. africana</i> , <i>R. ellipticus</i> , <i>I. atropurpurea</i> , <i>P. plectranthoides</i>
<i>Cedrus deodara</i> - <i>Pinus wallichiana</i> mixed	2	1873-2015	M, SM	50-70	N, NW	30° 18.204'N 30° 18.189'N	078° 25.059'E 078° 25.936'E	<i>R. arboreum</i> , <i>P. roxburghii</i> , <i>P. ciliate</i> , <i>R. ellipticus</i> , <i>P. plectranthoides</i> , <i>R. paniculatus</i>
<i>Cedrus deodara</i> - <i>Rhododendron arboreum</i> mixed	3	1928-2116	SM	60-50	NW, NW	30° 18.101'N 30° 17.893'N	078° 25.145'E 078° 25.004'E	<i>L. ovalifolia</i> , <i>P. roxburghii</i> , <i>P. ciliate</i> , <i>M. africana</i> , <i>R. ellipticus</i>
<i>Rhododendron arboreum</i> - <i>Quercus leucotrichophora</i> mixed	1	2116-2200	SM	55	NE	30° 17.893'N 30° 17.995'N	078° 25.004'E 078° 25.009'E	<i>C. deodara</i> , <i>L. ovalifolia</i> , <i>P. wallichiana</i> , <i>M. africana</i> , <i>B. aristata</i>

**Abbreviation:** SR=Site representation; AR= Altitudinal range; SM=Shady Moist; D=Dry and Dgr=Degraded; N=North; NW=North West and NE=North East P=*Pinus*; QL= *Quercus*; B=*Berberis*; R=*Rhus*; L=*Lyonia*; M=*Myrica* or *Myrsine*; C=*Cornus* or *Cedrus*; R=*Rhododendron* or *Rubus*; I= *Indigofera*; P= *Pogostemon* *Populus*

**Table 3.** Diversity, distribution, indigenous uses, nativity and endemism of floristic diversity in study area

Species	Altituderange (m)	Habitat (s)	Life form	Part used	Indigenous uses (originating uses naturally in a particular place) by Butola and Samant (2010)	Nativity (that occurs or thrive naturally within a region)	
<b>Adoxceae</b> <i>Viburnum cylindricum</i> Buch-Ham ex D. Don.	1863-1968	D, Deg	3	T	Fl, L	Fuel as well as fodder; flower useful source of bee-forage. <i>Viburnum</i> species are used in treatment of different diseases, such as diarrhea, rheumatoid arthritis and tumefaction. Anti-diabetic, anti-oxidant and anti-bacterial.	Himalayan Region
* <i>Viburnum cotinifolium</i> D. Don.	1784-1784	D, Deg	1	S	Fr, B, Fl.	Fruit edible; the decoction of bark used in hepatic and digestive troubles; flowers useful source of bee-forage	Himalayan Region
<b>Anacardiaceae</b> <i>Rhus parviflora</i> Roxb.	1482-1482	D, Deg.	1	S	Fr, L, Wd, Fl	Fruit edible; leaves mixed tobacco; fruit grinded and mixed with flour; wood as fuel; flowers useful source of bee-forage.	America and Australia Tropical
<i>Rhus cotinus</i> L.	1482-2015	D, Deg, SM	10	S	Fr, Fl, L, B	Medicinal; edible; fuel; fodder; miscellaneous (bark and leaves are used for tanning and yellow dye; leaves for cattle padding)	Region Mediterranean Oriental Region.
<b>Aspargaceae</b> <i>Asparagus adscendens</i> Roxb.	1482-2015	D, Deg, SM	11	S	Rt	Medicinal (anthelmintic, aphrodisiac, rheumatism, bleeding from nose, blood from urine, cough, diarrhea, dysentery, febrifuge, gastric complaints, gonorrhoea, headache, impotence, leucorrhoea, menstrual complaints, snake bite, stomachache, tonic, ulcer on tongue, urine complaints, wounds, antiseptic, abortifacient, refrigerant); edible	Indian Oriental Africa Tropical Australia
<b>Auilifoliaceae</b> <i>Ilex dipyrena</i> Wall.	2116-2116	SM	1	T	Wd, L	Fuel; fodder; agricultural tools	Himalayan Region
<b>Betulaceae</b> <i>Betula alnoides</i> Don.	1863-1863	D	1	T	Wd, L, B	Wood used for furniture; leaves lopped for fodder; bark with hot butter used as snake antidote	Himalayan Region Europe Oriental Assia Minor
<b>Berberidaceae</b> * <i>Berberis aristata</i> DC.	1482-2200	D, Deg, SM	14	S	Rt, B, Fr	Medicinal (bite of rat, snakes, boils, eye complaints); edible; fuel; agricultural tools	Indian Oriental
* <i>Berberis lyceum</i> Royle.	1536-1787	D, Deg, SM	3	S	Fr, B, Rt	Ripe fruits edible bark and roots orally taken relive jaundice and menorrhagia. Bark of stem or root yield <i>Rasaut</i> used for eye ailments	Himalayan Region
<b>Coriariaceae</b> <i>Coriaria neplensis</i> Wall.	1536-1928	D, Deg	7	S	Fr, L, B	Fruit edible, also given as an emetic; leaves and bark used to intoxicate fishes, basket are made from stem.	Himalayan Region, China
<b>Cornaceae</b> <i>Cornus capitata</i> Wall.	1863-2116	D, Deg, SM	5	T	Fr, Wd	Medicinal (antiviral and semen coagulating properties); edible (wild animals); fuel; timber; agricultural tools	Himalayan Region
<i>Swida macrophylla</i> (Wallich)	2015-2015	D, Deg	1	T	Wd, L, Fl, Fr.	Wood for agricultural implements; leaves lopped for fodder; flowers useful in apiculture as bee-forage; fruits edible; an important plant of social forestry	Himalayan Region, China Japan

Cont...

<b>Ericaceae</b> <i>Lyonia ovalifolia</i> (Wall.) Drude.	1784-2116	D, Deg, SM	11	T	Wd, L, Sd	Medicinal (skin eruption, worms, wounds; seed paste applied on wounds, boils and pimples); fuel	Himalayan Region, Japan
<i>Rhododendron arboreum</i> Sm.	1784-1784	D, Deg, SM	11	T	Wd, Fl	Medicinal (flower and bark used for digestive and respiratory disorders; dysentery, fever, headache, rheumatism, wounds); edible; fuel; religious; miscellaneous	Himalayan Region, Indian Oriental
<b>Fabaceae</b> <i>Indigofera heterantha</i> Wall. exBrandis.	1863-1968	D, Deg	4	S	Fl, L, Twg	Medicinal (leaf juice taken in diarrhea, dysentery and cough); edible; fodder; miscellaneous (twigs made into baskets or containers)	Himalayan Region
<i>Indigofera atropurpurea</i> DC.	1684-2015	D, Deg, SM	6	S	L, St, Fl	Leaves lopped for fodder; stem as fuel; edible flowers made into vegetables and snacks	Himalayan Region, China
<i>Desmodium renifolium</i> (L.)	1784-1928	D, Deg	2	S	L	Leaves use for fodder purpose	Himalayan Region
<i>Desmodium gangaticum</i> (L.) DC.	1784-1928	D, Deg	2	S	Rt	Medicinal roots astringent and tonic, used in fever and dysentery	Assia Tropical Australia
<i>Desmodium podocarpum</i> (Thunb.) DC.	1987-1987	SM	1	S	L	Leaves use in the fodder	Himalayan Region, China Japan
<b>Fagaceae</b> <i>Quercus serrata</i> Murray	1868-1968	D	1	T	L, Fr, Sd	Seed edible; leaves use mulch of the leaves repels slugs, grubs	Himalayan Region
<i>Quercus leucotrichophora</i> A. Camus	1482-2200	D, Deg, SM	7	T	Wd, L, Fr	Medicinal (scabies, skin diseases, urinary complaints, gum used for gonorrhoeal and digestive disorders); edible by wild animals; fuel; fodder	Himalayan Region
<b>Lamiaceae</b> <i>Pogostemon plectranthoides</i>	1863-2116	D, Deg, SM	8	S	Fl	Flower as a source of bee-forage	Himalayan Region, Indian Oriental
<b>Mimosaceae</b> <i>Acacia dealbata</i> Link.	1968-1968	SM	1	T		Fuel; miscellaneous	Australia
<b>Moraceae</b> <i>Ficus palmate</i> Forsk.	1482-1525	D, Deg	2	T	L, Fr, Fl	Medicinal (dysentery, indigestion, laxative); edible; fuel; fodder	Africa Tropical Arab Indian Oriental
<i>Ficus cunia</i> Buc – Ham. Ex Roxb.	1525-1525	D, Deg	1	T	Fr, L	Fruit edible; leaves fodder purpose	Himalayan Region
<i>Ficus roxburghii</i> Wallich ex Miq.	1482-1482	D, Deg	1	T	Fr, L	Fruit edible; leaves fodder purpose	Himalayan Region, Burma
<b>Myricaceae</b> <i>Myrica esculenta</i> Hem. Ex Don.	1784-2200	D, Deg	16	T	Fr, B, Wd	Medicinal (asthma, cholera, cough, diarrhoea, dysentery, fever, indigestion, malaria, menorrhoea and rheumatism); edible; fuel; fodder; miscellaneous (bark yields yellow dye)	Assia Tropical Sub tropical
<b>Oleaceae</b> <i>Fraxinus micrantha</i> Lingelsh	2116-2200	SM	1	T	St, L, B	Medicinal (fever, dysentery); fuel; religious; timber; miscellaneous (agricultural tools)	N. Mexico
<b>Pinaceae</b> * <i>Pinus roxburghii</i> Sarg.	1482-2915	D, Deg, SM	14	T	Wd, Sd, L, Resin	Medicinal (saw-dust with honey used in asthma and bronchitis); fuel; timber; miscellaneous (resin for varnishes, paints and turpentine)	Himalayan Region

Cont...

<i>*Pinus wallichiana</i> Jacks	1871-2116	D, Deg, SM	5	T	Wd, St, Sd, L	Medicinal (abscess, dislocation of joints, rheumatic pain, ulcer, unconsciousness); fuel; timber boxes etc.);	Himalayan Region
<i>Cedrus deodara</i> Roxb. ex D. Don*	1863-2200	D, Deg, SM	9	T	Wd, St	Medicinal (aqueous paste of bark used in bowel complaints and piles; wood-oil massaged in lumbago, rheumatic arthritis and urticaria); fuel; timber	Himalayan Region
<b>Primulaceae</b> <i>Myrsine africana</i> L.	1684-2200	D, Deg, SM	12	S	Fr, Fl	Medicinal (cathartic, colic pain, fruits used as laxative in colic, sometimes anti-helminthic, traditionally with the name of "Bayabirang");	Himalayan Region, Africa Australia and Tropical Insular
<b>Rosaceae</b> <i>Rubus ellipticus</i> Sm.	1525-2200	D, Deg, SM	12	S	Fr, L	Medicinal (root extract used in local beverages as intoxicating ingredient; other uses for dysentery, malaria, stomachache and worms); edible;	Indian Oriental
<i>Rubus niveus</i> Thunb	1791-2200	D, Deg, SM	10	S	Fr,	Fruit edible; extract or boiled fruits taken in dysmenorrhoea; root juice used as an antidote of snake bite	Himalayan Region
<i>*Rubus paniculatus</i> Sm.	1863-2116	D, Deg, SM	8	S	Fr, L	Medicinal (diarrhoea, stomach disorder, skin ailments); edible	Himalayan Region
<i>Pyrus pashia</i> Buch. – <i>Ham.</i> ex D. Don.	1428-2200	D, Deg, SM	6	T	L, Fr, Fl	Medicinal (fruits in digestive disorder; eye complaints); edible (fruits are eaten); fuel; religious; miscellaneous (to check soil erosion; wood made into sticks; flowers used in apiculture)	Himalayan Region
<i>Prunus cerasoides</i> Don.	1784-2015	D, SM	3	T	Wd, B, Fl, Tgs	Medicinal (bark as psychomedicines and applied for body swellings and contusions; other uses for bone dislocation, fracture, burns, cuts, wounds, diarrhoea, fever, hemicrania and venereal disease); edible; fodder; religious	Himalayan Region
<i>Rosa brunanii</i> Lindley.	1791-2200	D, SM	7	S	L, Fl	Leaf and flower juice used in wounds and ophthalmia; dried flower powder given in diarrhea; flowers useful in apiculture as bee-forage; plant acts as soil binder.	Himalayan Region
<b>Symplocaceae</b> <i>Symplocos</i> <i>crataegoides</i> Buch – <i>Ham.</i> Ex	1525-2200	D, Deg, SM	3	T	B, L	Bark and leaves yield yellow dye; leaves as fodder; bark is also used in indigenous medicines; good source of bee-forage	Himalayan Region
<i>Symplocos</i> <i>paniculata</i> (thumb.) Miq.	1525-1525	D, Deg	1	T	Fl, B, L	Flower sucked for nectar by bees; yellow dye obtained from the bark; leaves lopped for fodder	Japan
<b>Salicaceae</b> <i>Populus ciliata</i> Wall	1873-2015	D, Deg, SM	2	T	Wd, B, L	Wood used for various purposes, mainly in paper industry, match boxes and sports goods. bark used as tonic, and blood purifier.	Himalayan Region
<b>Thymelaeaceae</b> <i>*Daphne papyracea</i> Wall.	2116-2200	SM	1	T	Fb, St, L	Medicinal (intestinal complaints; leaf paste applied on eczema); fodder; miscellaneous (ropes and sacs by stem fibre; papers by stem and leaves used in religious purposes)	Himalayan Region

<b>Ulmaceae</b> <i>Celtis australis</i> Var. <i>iocarpa</i> (Decne.) Hook. F.	1863-1863	D	1	T	Fr, L, B, Wd.	Fruit edible; leaves provide good fodder. Bark gives yellow dye; wood used from making small articles. Bark paste applied on bones, pimples, contusions, sprains and joint pains; an important tree of agroforestry	Europe Asia Tropical
<i>Celtis eriocarpa</i> Decne.	1928-1928	D, Deg	1	T	L, Wd.	Leaves provide good fodder; wood used for making small articles	Indian Oriental
<i>Trema orientalis</i> (L.)Bl.	1863-1863	D	1	T	B, Fb, L, Fr, Wd.	Bark yields strong fibre; leaves fodder; fruits edible; wood used for fuel and charcoal.	Gerontia Tropical
<b>Urticaceae</b> <i>Debregeasia</i> <i>longifolia</i> (Burm. f.) Wedd.	1784-1784	D	1	S	B, L, Fb, Fr	Medicinal (bark yields strong fibre and plaster made from pulverized bark for bone fracture); edible; fodder	Indian Oriental
<b>Verbenaceae</b> ** <i>Premna interrupta</i> Wall. exSchauer.	1987-1987	SM	1	S	Wd, L	Wood used as fuel; leaves with black pepper given in cold and fever	Himalayan Region

*deodara*-*P. wallichiana* (41.30 %), however, only *C. deodara*-*R. arboretum* supported one endemic species, i.e., *Premna interrupta*. Maximum near endemic (13.04 % ) species were in *C. deodara*-*P. wallichiana* mixed, *R. arboretum*-*Q. leucotrichophora* mixed and *C. deodara*-*P. wallichiana* mixed (13.04 % n=6, each) communities. Similar study was conducted by Samant *et al* (2007) in the Catchment Area of Parbati Hydroelectric Project Stage – III in Northwestern Himalaya and Butola and Samant (2010) in Saussurea species in Indian Himalayan Region. Endemic and habitat-specific species are generally considered more prone to extinction than widespread habitat generalists.

### CONCLUSION

The area has potential in terms of high number of native, endemic and economically important plants. Results of the present study can be used for development of conservation management and micro planning of this areas and thus, socio-economic development of the inhabitants, in particular and biodiversity of the Himalaya, in general.

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## Organic Carbon Stocks in Various Land-use Types of Karst Landscape in Northeastern India

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**Abstract:** Although karst landscapes cover about 20 per cent of the Earth's ice-free land surface, their potential for climate change mitigation is still widely unexplored. The present study investigated the variation in organic carbon stocks under different land uses of karst landscape in Meghalaya, India. The sampled land uses of Mawsmi village karst landscape were forest land (Mawlong sacred forest and Ramjadong forest), grassland and homegarden. There was a decline in total organic carbon stocks along Mawlong sacred forest ( $236 \text{ Mg C ha}^{-1}$ ), Ramjadong forest ( $158 \text{ Mg C ha}^{-1}$ ), homegarden ( $116 \text{ Mg C ha}^{-1}$ ), and grassland ( $50 \text{ Mg C ha}^{-1}$ ). Land use history of Mawlong sacred forest represented by lower disturbance intensity as compared to that of the non-sacred Ramjadong forest had a positive impression on its total organic carbon stocks. Yet even Mawlong sacred forest had relatively low organic carbon stocks as compared to that reported for other comparable forests in literature indicating a potential negative impact of karst topography on forest carbon stock. Homegarden land use of the karst landscape was found to have the potential to store substantial amount organic carbon stock per unit area.

**Keywords:** Carbon stock, Karst, Meghalaya, Land use, Sacred forest, Grassland, Homegarden

Biological storage of carbon is an ecosystem service with several potential benefits; its role in climate change mitigation policies is progressively growing (Davies et al 2011). Malhi et al (2003) highlighted the important role that forests play in climate change mitigation, reasoning that this can be seen from the evident impact of forest loss on atmospheric carbon concentration. Carbon emissions from forest degradation can be investigated by comparing carbon storage under different forest conditions (Gibbs et al 2007). Not only in forest land, there is a growing interest to inspect the opportunities of storing carbon in different land use types (Murthy et al 2013). Karst is a terrain, usually underlain by limestone, in which the topography is mainly formed by the dissolving of rock, and is normally characterized by closed depressions, underground drainage, and caves (Indiana Natural Resources Commission 1999). Karst makes up about 20 percent of the ice-free continental surface (Ford and Williams 2007). From the ecological point of view, the chemical processes in karst landscape form an important  $\text{CO}_2$  sink which may contribute in buffering climatic change phenomenon (White et al 1995). Apart from the study of Liu et al (2013) that estimated organic carbon stocks in the karst region in southwestern China for four land cover types and different pools, the focus of most other studies was on soil pool (Ahmed et al 2012, Chen et al 2014, Qi et al 2014). Within the Indian subcontinent, the Meghalaya Plateau of northeastern India is the richest location of karst features (Prokop 2014). This study aims to investigate organic carbon

stocks' potential and variability in inhabited karst landscape. Hence, the objective of the present study is to estimate total organic carbon (carbon in above-ground biomass, below-ground biomass (for trees), dead wood, litter, and soil organic matter) in different land use types of inhabited karst landscape.

### MATERIALS AND METHODS

**Study area:** The present study was conducted in Mawsmi village, East Khasi Hills district, Meghalaya, India (Fig. 1). Mawsmi is located between  $25^{\circ}14'21.86''$  and  $25^{\circ}15'08.61''$  North latitudes and  $91^{\circ}43'05.45''$  and  $91^{\circ}43'57.02''$  East longitudes. The altitude is between 1150 and 1240 m above sea level and village is part of Cherrapunji Plateau. The climate of the area is humid subtropical, divided into three seasons: dry winter season from November to February, short spring season during March and April and rainy season from May to October. For the decade spanning from 2004 to 2013, the annual rainfall at Sohra was in the range of 7560 to 14791 mm with an average of 10953 mm. The mean monthly temperature in the year 2013 varied between a maximum of  $21.8^{\circ}\text{C}$  in June and a minimum of  $11.9^{\circ}\text{C}$  in January. The meteorological data were collected from Indian Meteorological Department office at Lower Sohra/Cherrapunjee, approximately 3 km to the north of Mawsmi village. Mawsmi forest is a relict rain forest ecosystem which contains climax vegetation found at higher elevations in Meghalaya. There is an abrupt boundary between this

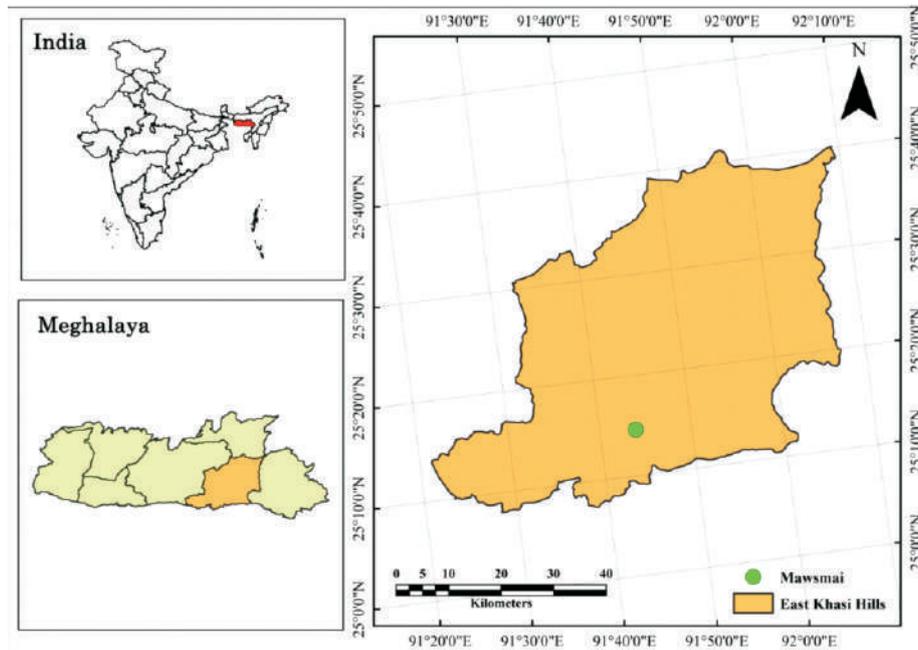


Fig. 1. Location map of the study area

subtropical forest and the surrounding landscape, which is primarily grassland. Limestone formation underlies the fragile, highly leached soil of Mawsmai forest (Ramakrishnan 1997). The soil of Sohra sacred groves is sandy loam of color gradient ranging from dark brown at the top to a yellowish colour in deeper horizons (Khiewtam and Ramakrishnan 1993). The soil is generally shallow and rock outcrops are common in the forest.

**Field inventory:** The sampled land uses are: 1–forest land, 2–homegarden, and 3–grassland. Mawsmai forest land was further stratified based on its historical status into 1–Mawlong Syiem sacred forest (Mawlong sacred forest) representing forest land of about 70 ha within Mawsmai village and having Mawsmai show cave. The forest is the historically sacred portion of larger forest land that extends out of Mawsmai village boundaries. 2–Ramjadong forest, representing non-sacred forest fragment with an area of about 5 ha. There are small irregular forest patches at the western part of Mawsmai village. Disturbance magnitude for Mawlong and Ramjadong forests was calculated as a ratio of the basal area of cut trees to the total basal area of all trees (intact and felled) following Kanzaki and Yoda (1986) as cited in Rao et al (1990). The disturbance was calculated for tree diameter class 10 cm. Typical homegardens were identified following the definition of Hoogerbrugge and Fresco (1993) in which a homegarden represents a small, multi-layered ecosystem with well-defined boundaries. Out of the twenty-five homestead gardens present in the village, only fourteen could be considered as typical homegardens. The houses that do not

have gardens, are surrounded by either grassland, or civil structures. Five organic carbon pools as per IPCC (2006) guidelines were estimated for each land use type during the rainy season. The pools are: above-ground biomass, below-ground biomass, dead wood, litter, and soil organic matter.

**Biomass estimation:** Square nested plots of 1000 m<sup>2</sup> described in the field inventory manual of Forest Survey of India, FSI (2002) were used for biomass estimation for forest and grassland. Each nested plot is composed of: one main plot of area 1000 m<sup>2</sup> for sampling trees and palms 5 cm Diameter at Breast Height (DBH) and standing dead trees pools; four sub-plots of area 9 m<sup>2</sup> for trees and palms < 5 cm, shrubs, climbers and woody litter pools; and four sub-plots with area 1 m<sup>2</sup> for herbs, leaf litter and duff. Eight 1000 m<sup>2</sup> nested plots were established for the stratified random sampling of the forest land of the village. The number of the plots met the precision level of 15% of the mean total above-ground carbon at a 95% confidence level for each forest. Seven random 1000 m<sup>2</sup> nested plots were used for sampling grassland. The study adapted the Y-shaped sampling frame of Henry et al (2009) for sampling village homegarden land use. Eventually, 6 homegardens out of the 14 typical homegardens of the village were analyzed. The sampling intensity is therefore 43%. The average area of a homegarden (excluding the house) was about 278 m<sup>2</sup>. Being land use type smaller than 0.1 ha, the sampled homegardens were analyzed in totality. At each main 1000 m<sup>2</sup> sampling plot, the DBH and the height of all trees and palms having DBH 5

cm were measured. The above-ground biomass of each tree/palm tree was estimated using biomass regression equation cited in FAO (1997)-

$$\text{Biomass (tree)} = 21.297 - 6.953 \times (\text{DBH}) + 0.740 \times (\text{DBH})^2$$

Where, biomass is in kg and DBH is in cm

$$\text{Biomass (palm)} = 10.0 + 6.4 \times (\text{total height})$$

Where, biomass is in kg and total height is in m.

For sampling trees having < 5 cm DBH, shrubs, climbers and herbs, destructive harvesting techniques were used, employing the four 9 m<sup>2</sup> sub-plots of each nested plot, except for herbs where the 1 m<sup>2</sup> sub-plots were used. Oven dry weight was recorded. It should be noted that particularly in sampling homegarden land use, reference unit method described in Andrew et al (1997) was used when destructive techniques could not be used. For down dead wood, line intersect method described by Harmon and Sexton (1996) was used for determining the volume of each dead wood class (rotten, intermediate and sound). The minimum diameter considered for down dead wood was 5.0 cm diameter (FSI default). The dry mass of dead wood was measured as a product of volume and the wood density for each corresponding class. The biomass of standing dead tree having branches and twigs was estimated as for live tree by subtracting the biomass of leaves (2-3 % of above-ground biomass) as per Pearson et al (2007). For a dead tree when a tree has no branches and is only a bole, tree volume was estimated as per Walker et al (2012). Then biomass was estimated using the appropriate wood density class. Below-ground biomass was calculated based on the relation to above-ground biomass. For this calculation, above-ground biomass for standing dead trees was added to above-ground biomass for live trees for calculations of tree above-ground biomass at the plot level as per Kirby and Potvin (2007). Below-ground biomass was estimated using regression equation developed by Cairns et al (1997):

$$\text{BGBD} = \exp \{-1.059 + 0.884 \times \ln(\text{AGBD}) + 0.284\}$$

Where, BGBD = below-ground biomass density; AGBD = Above-ground biomass density.

In the four 9 m<sup>2</sup> sub-plots in each nested plot, all woody litter, i.e. all fallen branches below 5 cm diameter were collected, weighed and subsamples were collected. In the four 1 m<sup>2</sup> sub-plots of each 1000 m<sup>2</sup> nested plot, all leaf litter and duff within the sample frame were collected and all samples from the plots were pooled and weighed. Well-mixed subsamples were collected and placed in marked bags. The subsamples were used to determine oven-dry-to-wet mass ratios to convert the total wet mass to oven-dry mass. The herbaceous litter found in the grassland was included under leaf litter category. Biomass results were

expressed in Mg ha<sup>-1</sup> after plot area was corrected for slope.

**Organic carbon estimation:** The carbon stock (Mg C ha<sup>-1</sup>) of each vegetation pool was calculated by multiplying biomass density by carbon fraction value. The IPCC (2006) default carbon fraction value of 0.37 was used for leaf litter and duff while the value of 0.5 was used for the woody litter pool. The IPCC (2006) default carbon fraction value of 0.47 was used for all other vegetation pools. Soil samples were collected to the complete profile depth available from within the four 1 m<sup>2</sup> sub-plots at the corners of each 0.1 ha nested plot using a corer. For homegardens, three soil samples from each homegarden were collected. The numbers of soil samples collected for estimating soil organic carbon were 20, 12, 18 and 28 in Mawlong sacred forest, Ramjadong forest, homegarden and grassland respectively. Similar numbers of samples were collected for soil bulk density analysis. The concentration of soil organic carbon was estimated by Walkley and Black wet digestion method as described by Okalebo et al (1993). The results were then corrected by multiplying with the commonly applied correction factor 1.32 (Skjemstad et al 2000). Soil organic carbon density was calculated by using the equation suggested in IPCC (2003). One way analysis of variance and Tukey Kramer post hoc test were used to analyse the data.

## RESULTS AND DISCUSSION

The disturbance index was 8.51 and 39.45 per cent for Mawlong sacred and Ramjadong forest respectively. Hence, Mawlong sacred forest can be described as mildly disturbed while Ramjadong forest as a moderately to highly disturbed forest. Carbon density in total above-ground biomass was highest in Mawlong sacred forest (104.4 Mg C ha<sup>-1</sup>). Ramjadong forest (50.9 Mg C ha<sup>-1</sup>) had comparable total above-ground carbon stock values with that of homegarden (Table 1). Live trees and palms 10 cm DBH accounted for 95, 91 and 94 per cent of total above-ground biomass for Mawlong sacred forest, Ramjadong forest and homegarden respectively. In Mawlong sacred forest, trees above 60 cm DBH accounted for 25 per cent of the total above-ground carbon stocks in trees and palms 10 cm, which is the highest share among other tree classes. The same tree class accounted for 21 per cent of the total above-ground carbon stocks in trees and palms 10 cm in Ramjadong forest while the class 30-40 DBH had the highest share 24 per cent. The least disturbed Mawlong sacred forest had lower shrub contribution to total biomass as compared to the more disturbed Ramjadong forest. Herb pool in both Mawlong and Ramjadong forests represented a minor component of carbon stocks (<1 % of total organic carbon stocks). The soil bulk density in the sampled land uses of the landscape

ranged from 0.84 g cm<sup>-3</sup> at the upper soil layer of homegarden to 1.61 g cm<sup>-3</sup> at the deepest soil layer of the grassland. The values of soil coarse fragments (volume %) in the soil layers 0–10 cm and 10–20 cm were significantly higher in grassland than Mawlong sacred forest and Ramjadong forest (Table 2). Statistically significant differences in soil organic carbon concentrations between corresponding soil layers of the land uses were not observed. Soil organic carbon concentration (upper to deepest soil layer) ranged from 3.72 to 0.83; 3.23 to 1.12; and 2.97 to 0.92 per cent at Mawsmal forest land, homegarden and grassland respectively. Total organic carbon stocks was highest in Mawlong sacred forest followed by Ramjadong forest and homegarden; while the lowest value was reported for grassland (Table 1). With regards to the contribution of each major pool to organic carbon stocks

of the land uses, above-ground biomass stored the largest amount of organic carbon in Mawlong sacred forest (44.2%) followed by soil pool (37.1%). Soil pool was the pool of greatest share of organic carbon in Ramjadong forest (38.7%) and homegarden (59.5%). Soil pool stored most of the organic carbon (96.3%) in grassland.

**Forest land:** Since Mawlong and Ramjadong forests were situated in proximity to each other and have similar physiographic, climatic and edaphic features, the differences in average carbon stocks of above-ground biomass between the two forests could be attributed largely to the more disturbance imposed on the non-sacred Ramjadong forest (39.45%) as compared to Mawlong sacred forest (8.51%). The disturbance reported in Mawlong sacred forest reflects change in the social attitude toward the sacredness of the

**Table 1.** Organic carbon stocks (Mg C ha<sup>-1</sup>) of vegetation and soil pools

Vegetation	Mawlong sacred forest	Ramjadong forest	Homegarden	Grassland
<b>Carbon in above-ground pools</b>				
Trees 10 cm DBH	97.47a	45.18ab	34.00b	–
Trees 5 cm to < 10 cm DBH	3.10a	2.68a	0.53b	–
Trees < 5 cm DBH	0.09a	0.63b	0.13a	0.01c
Palm trees 10 cm DBH	1.82a	0.90a	–	–
Palm trees < 10 cm DBH	0.09a	0.08a	0.27a	–
Shrubs	0.31a	0.81b	0.06c	–
Climbers and creepers	0.07a	0.09a	0.001b	0.003b
Large herbs (banana)	–	–	0.43	–
Bamboo	1.03a	–	0.03b	–
Herbs	0.38a	0.52a	0.68a	1.55b
Total above-ground carbon	104.36a	50.90b	36.12b	1.56c
<b>Carbon in below-ground pools (for trees, palms and standing dead wood)</b>				
Total below-ground carbon	29.03a	20.17b	9.69b	0.005c
<b>Carbon in dead wood pools</b>				
Downed dead wood	2.24a	1.42a	–	–
Standing dead wood	9.60a	21.49b	0.42c	–
Total Dead wood	11.84a	22.91b	0.42c	–
<b>Carbon in litter pools</b>				
Woody litter	0.45a	0.57b	0.01c	–
Leaf litter	0.50a	0.48ab	0.16bc	0.25c
Duff	2.20a	2.08a	0.71b	–
Total litter	3.14a	3.13a	0.88b	0.25b
<b>Soil organic carbon (Soil layer depth)</b>				
0–10 cm	28.17ab	35.60a	24.06b	24.33b
10–20 cm	27.94a	25.69a	19.47ab	12.59b
20–30 cm	21.17a	–	14.58ab	10.78b
30–40 cm	10.25a	–	11.02a	–
Total soil organic carbon	87.53	61.29	69.13	47.70
Total carbon stocks	235.90	158.40	116.24	49.52

Means in a row followed by different letters are significantly different ( $P < 0.05$ ), “–” refers to the absence of a vegetation pool or soil layer

**Table 2.** Volumetric fraction of coarse fragments ( $\text{cm}^3 \text{cm}^{-3}$ ) at intervals of 10 cm along soil profiles of different land use types of Mawsmmai village

Land use	0–10 cm	10–20 cm	20–30 cm	30–40 cm
Mawlong sacred forest	0.05 <sup>a</sup>	0.07 <sup>a</sup>	0.11 <sup>a</sup>	0.20 <sup>a</sup>
Ramjadong forest	0.05 <sup>a</sup>	0.07 <sup>a</sup>	–	–
Homegarden	0.11 <sup>ab</sup>	0.17 <sup>b</sup>	0.22 <sup>a</sup>	0.24 <sup>a</sup>
Grassland	0.17 <sup>b</sup>	0.22 <sup>b</sup>	0.27 <sup>a</sup>	–

Means in a column followed by different letters are significantly different ( $P < 0.05$ ). “–” refers to the absence of soil layer

forest. The sacredness of Mawlong forest is derived from the indigenous Khasi religion that gradually vanished from Mawsmmai village with the arrival of British missionaries in the mid of the nineteenth century (Anonymous Mawsmmai village inhabitants, personal communication 2013). Tree class > 60 cm DBH was a major contributor to above-ground carbon in both Mawlong and Ramjadong forests. Similar finding was reported in Baishya et al (2009) for other Meghalayan forest. Above-ground carbon in live trees of Mawlong sacred forest is within the above-ground carbon range of 81.2–118.2 Mg C ha<sup>-1</sup> reported by *Thokchom and Yadava* (2013) for subtropical forests of Manipur, North-East India, and the range of 96.77–129.32 Mg C ha<sup>-1</sup> reported by Upadhaya et al (2015) for reserved forests in Garo hills, Meghalaya, North-East India. However, above-ground carbon densities in live trees 10 cm DBH for both forests are markedly lower than that reported in literature for subtropical and tropical forests around the world (Lewis et al 2009, Kho et al 2013, Brown et al 2014). Hence, it could be inferred that Mawlong sacred forest and, to a greater degree, Ramjadong forest have relatively low above-ground biomass. Soil organic carbon density values (full soil profile) for Mawlong sacred forest of 87.5 Mg C ha<sup>-1</sup> and Ramjadong forest of 61.3 Mg C ha<sup>-1</sup> are markedly lower than that of 19.1 kg m<sup>-2</sup> (190 Mg C ha<sup>-1</sup>) reported in Post et al (1982) for average soil organic carbon density (1 m depth) in tropical forest wet life-zone. Soil organic carbon densities of both Mawlong and Ramjadong forests are also lower than that reported for tropical forests in Asia (Houghton 1999, Ziegler et al 2012). Soil organic carbon concentrations of Mawlong and Ramjadong forests are comparable to that reported in Sanchez (2012) for tropical soils and to that reported for other forests in India (Mishra et al 2005, Gautam et al 2011). The limited soil depth could then be a main reason behind the relatively low soil organic carbon densities reported for the forests of the Mawsmmai karst landscape. In fact, soil organic carbon density is even lower than the reported one. The equation used frequently in calculating soil organic carbon density assumes that soil layer is continuous. Not accounting for rock outcrop coverage ratio would lead to overestimating soil

organic carbon density.

Average carbon stocks in above-ground live, downed dead and standing dead vegetation reported for Mawlong sacred forest (116.2 Mg C ha<sup>-1</sup>) and Ramjadong forest (73.81 Mg C ha<sup>-1</sup>) are lower than that of 147.5 Mg C ha<sup>-1</sup> reported by Brakas and Aune (2011) for natural rainforest in the Philippines where illegal logging is practiced. Total organic carbon stocks in Mawlong and Ramjadong forests are markedly lower than the 305 Mg C ha<sup>-1</sup> reported by Woome et al (2000) for slightly disturbed forests in the humid tropics. Ramakrishnan (1998) considered Mawsmmai forest as stunted and attributed this state to the forest development over unbalanced soil derived from limestone. Liu et al (2013) estimated organic carbon stocks in subtropical karst landscape in southwestern China for four land cover types (i.e. secondary forest, forest shrub transition, thorn shrubbery, and shrub grassland). Their study found that karst ecosystems in southwestern China have lower organic carbon stocks (biomass carbon as well as soil organic carbon) in comparison to other non-karstic ecosystems. The present study reports similar finding for a forest land of a karst landscape in northeastern India. The similarities in the findings indicate that karst topography may have negative impacts on organic carbon stocks.

**Grassland:** Above-ground biomass of Mawsmmai grassland (3.3 Mg ha<sup>-1</sup>) is less than the IPCC (2006) default value of 6.2 Mg ha<sup>-1</sup> for peak above-ground biomass in tropical grassland after conversion from other land use. Above-ground carbon stocks of Mawsmmai grassland (1.56 Mg C ha<sup>-1</sup>) is below the range of 3–35 Mg C ha<sup>-1</sup> reported in Ziegler et al (2012) for total above-ground carbon biomass in grasslands of South-east Asia. Above-ground carbon stocks of Mawsmmai grassland is also less than that of 2.9 Mg C ha<sup>-1</sup> reported by Brakas and Aune (2011) for Claveria, the Philippines. The absence of trees and palms 5 cm DBH contributed to the relatively low above-ground biomass in the grassland of Mawsmmai village karst landscape. The relatively high volumetric fraction of coarse fragment in grassland has played a role in the 54% decline in soil organic carbon density in full soil profile in grassland as compared to Mawlong sacred forest. It should be noted that using soil corer might not be the best method for sampling for soil bulk density in this karstic landscape. This is particularly relevant for sampling grassland where high volumetric fraction of coarse fragment is present. The soil organic carbon density value of Mawsmmai village grassland of 47.7 Mg C ha<sup>-1</sup> (0–30 cm) falls below the range of 66–198 Mg C ha<sup>-1</sup> estimated by Ziegler et al (2012) for total soil organic carbon reported in grasslands of South-east Asia. For the soil layer 0–20 cm, the grassland

of Mawsmal karst landscape had soil organic carbon density value of 36.9 Mg C ha<sup>-1</sup> that is lower than that of 60.4 Mg C ha<sup>-1</sup> reported for grassland on karstic landscape in southwest China (Zheng et al 2012). However, soil organic carbon density of Mawsmal village grassland was comparable to the 50 Mg C ha<sup>-1</sup> (1 m depth) reported by Houghton (1999) for grassland in tropical Asia. The total organic carbon stocks in Mawsmal village grassland was very close to the value 48 Mg C ha<sup>-1</sup> reported in Woomer et al (2000) for grassland in the humid tropics in which soil pool (50 cm) also stored most of the organic carbon.

**Homegarden:** The average above-ground carbon stock value reported for Mawsmal homegarden land use (36.1 Mg C ha<sup>-1</sup>) is lower than that of 75.47 Mg C ha<sup>-1</sup> reported by Kirby and Potvin (2007) for homegardens and outfield gardens in Eastern Panama. Average carbon stocks in above-ground live, downed dead and standing dead vegetation reported for Mawsmal homegarden land use (36.5 Mg C ha<sup>-1</sup>) is markedly lower than that of 159.7 Mg C ha<sup>-1</sup> reported in Brakas and Aune (2011) for Philippine homegardens. However, average above-ground carbon stocks reported for Mawsmal homegarden is higher than the two averages of 13.8 and 17.3 Mg C ha<sup>-1</sup> documented by Henry et al (2009) for homegarden systems of two districts in western Kenya. Average above-ground carbon stock for Mawsmal homegarden is at the higher end of the range of 16 to 36 Mg C ha<sup>-1</sup> reported by Kumar (2011) for above-ground carbon stocks in homegardens of central Kerala, India. Homegarden land use in Mawsmal village karst landscape stored carbon in its above-ground biomass pool comparable to that of the disturbed forest, Ramjadong. A particular homegarden was able to store substantial amount of carbon (81.86 Mg C ha<sup>-1</sup>) in total above-ground biomass making the land use promising with regards to organic carbon storage per unit area.

### CONCLUSION

With regards to above-ground carbon, forest land and homegardens of Mawsmal karst landscape are like oases of carbon in a desert of grassland that extends over vast areas in Sohra plateau. There is a decline in total organic carbon stocks along the historically sacred forest, non-sacred forest, homegarden and grassland of Mawsmal village karst landscape. Land use history represented by higher disturbance intensity in the non-sacred Ramjadong forest as compared to Mawlong sacred forest had negatively impacted its total organic carbon stocks. Nevertheless, even the less disturbed forest (Mawlong sacred forest) showed relatively low organic carbon stocks as compared to that reported in literature for other comparable forests. The karst topography may have a negative impact on forest organic carbon stocks.

Total collapse of the forest sacredness concept without having an alternative custom that can meet the needs of the people and the integrity of the sacred forests would negatively impact their biological carbon storage service. Homegarden stored substantial amount of organic carbon making it a valid option for storing organic carbon in this karst landscape.

### ACKNOWLEDGEMENTS

Financial assistance from the Indian Council for Cultural Relations (ICCR), Government of India, is greatly acknowledged.

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# Rural Households' Perception on Forest Resource Utilization during Climatic Adversities in Garhwal Himalaya

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**Abstract:** The present study was carried out to assess the utilization of forest resources by rural households during climatic adversities by evaluating perception of villagers of Garhwal Himalaya. Primary data was collected from 123 randomly selected households using semi-structured questionnaire on basic household's attributes and prevailing climatic adversities. The climatic adversities reported by households in the study region were erratic rainfall, crop loss by climatic factor, landslide, flood, drought and cloudburst. The result of the study revealed that use of forest resources was the most common activity carried out by the households to overcome the adversities due to climate. Thus the study suggests necessity for more empirical assessment to acquire better understanding regarding climatic adversities and their possible mitigation. The study findings will be helpful in development of mechanisms to overcome adversities and thereby will assist in minimizing rural households as well as community vulnerability against climatic adversities.

**Keywords:** Ecosystem, Forest resources, Garhwal Himalaya, Livelihood

Forest resources facilitate in mitigating climate change and improving rural livelihood particularly in developing countries (Kalaba et al 2013). It is estimated that about 1.6 billion people globally depend on forest resources for food, fuelwood, shelter, income generation (Moon 2015), and livelihood sustenance through strengthening numerous rural livelihood strategies (Shackleton and Shackleton 2004). In recent years, policy planners and the international community has focused on forest role in securing household economy as well as rural development in developing countries (Angelsen et al 2014). A wide range of adversities affect livelihood sustenance of rural households (Debela et al 2012). Households suffer due to different types of adversities either it is household based such as death, illness, loss of property etc, or community based such as cloud burst, landslide, drought, flooding, epidemic of human and cattle diseases, etc. (McSweeney 2004, Paumgarten and Shackleton 2011). To overcome such adversities, households use numerous approaches such as selling of forest products, assistance from friends and relatives, engage themselves in other income generating activities, or sometimes by reducing consumption level too (Dercon 2002, Debela et al 2012). In many studies, researchers has reported increased use of forest resources for consumption purpose as well as for income generation to sustain livelihood during adverse times (Debela et al 2012). Increasing levels of human vulnerability to various adversities has increased rural household's reliance on forest resources progressively

(Shackleton and Shackleton 2012). Thus, the present situation demands the necessity to understand human-environment relations against the climatic adversities along with contribution to human well-being (MEA 2005). This can be achieved by providing clear understanding of forest resources role in securing rural livelihood during adversities and by the help of more empirical case study researches. In this context, the present study was carried out with the development of hypothesis that rural households depend on forest resources during climatic adversities. To confirm the hypothesis, the present study was taken into account focusing on local people's use of forest resources in response to various climatic adversities. The results of the study will be helpful in understanding the vital role of forest resources as a basis for effective mechanism in mitigating or minimizing the adverse effects of climate.

## MATERIAL AND METHODS

Garhwal Himalayan region is a part of Uttarakhand state which lies between 29°30' N -31°30' N latitudes and 79°43' E -80°10' E longitudes covering a total area of 32, 169 km<sup>2</sup>. The mountainous region of Garhwal Himalaya ranges in altitude from 300 m to more than 7000 m. The climate of the study area can be well-defined into three different seasons, namely summer, rainy and winter. Major part of rainfall pattern in the area is governed by the monsoon rains (July-September), which account for about 60-80% of the total annual rainfall (Sharma et al 2009). The inhabitants

have agro-pastoral life and depend heavily on traditional agricultural practices with 70% of the farmers having less than 1 ha land holdings (Gairola et al 2009). Forest resource utilization also is a key activity carried out by the inhabitants of the study area to fulfill diverse requirements which critically supports their livelihoods and wellbeing.

**Sampling methodology:** The present study was carried out in Rudraprayag and Pauri Garhwal district of Garhwal Himalayan region. All surveyed villages lie in between 700 m and 1800 msl and are surrounded by temperate pine forests and agricultural fields. Multistage random sampling technique was used for selecting villages and then informants. Primary data was collected using semi-structured questionnaire from 123 randomly selected households in between May 2015 and February 2016. Household were interviewed using semi-structured questionnaires at the respondent's house, in Hindi or local dialect (Garhwali), depending on the respondent's language. The respondents, generally the heads of households, were approached for interviews. Data collection on basic household's attributes such as gender of household head and income, various climatic adversities and forest resource use was gathered. All the respondent participated for this study were read about the purpose of the interview verbally and prior oral consent was obtained. Descriptive statistics and Chi-square test for independence was determined using SPSS 21 software.

## RESULTS AND DISCUSSION

The study results reported that households of the study area encountered with various climatic adversities with most of households experiencing more than one type of adversity leading to income shortage and increased expenditure. Poor and intermediate households highly depend on forests to

overcome income shortage. The focus group meetings were also conducted and the results reported various climatic adversities affecting rural household's production system over the last 5 year period. Since the present study is based on the rural households' perception therefore field data on adversities due to climate was collected based on the information provided by rural households between May 2015 and February 2016. Most disastrous climatic adversity during last five year in Garhwal Himalaya was Kedarnath flood in the year 2013 which caused immense loss to humans as well as Himalayan ecosystem.

The largest proportion of households reported damage due to erratic rainfall (97.6%), followed by crop loss by climatic factor (94.3%) and landslide (43.1%). Other reported climatic adversities were flood (21.9%), drought (14.6%) and cloud burst (10.6%). All the identified adversities were common in the study region and affected all the household differentiated in different income levels (Table 1). In the present study, the households have been classified in three different income level based on income level. The households having monthly income less than Rs 3000, 3000–12000 and more than 12000 were classified as poor, middle and rich, respectively. The results of the study showed significant difference between income level of household and experienced adversities due to cloud burst ( $\chi^2 = 15.77$ ;  $p < 0.05$ ), landslide ( $\chi^2 = 15.7$ ;  $p < 0.05$ ), flood ( $\chi^2 = 15.5$ ;  $p < 0.05$ ) with middle households being affected more than that of rich and poor households. In similar studies by Paumgarten and Shackleton (2011), reported that poor households of African countries with less alternatives and low agricultural capacity suffered more frequently due to various household adversities, which is inconsistent with the present study.

The results of the present study also indicate that households used diverse strategies in response to various

**Table 1.** Climatic adversities reported by rural household under different income level

Climatic adversities	Household head		Income level			$\chi^2$ ( $p$ -value)
	Male (n=98)	Female (n=25)	Poor (n=30)	Middle (n=59)	Rich (n=34)	
Crop loss by climatic factor	91	25	27 (21.9 %)	56 (45.5 %)	33 (26.9 %)	2.86 (> 0.05)
Erratic rainfall	95	25	30 (24.4 %)	56 (45.5 %)	34 (27.6 %)	3.34 (> 0.05)
Cloud burst	7	6	0 (0.0 %)	13 (10.6 %)	0 (0.0 %)	15.77 (< 0.05)
Landslide	43	10	6 (4.9 %)	32 (26.0 %)	15 (12.2 %)	15.7 (< 0.05)
Flood	21	6	1 (0.8 %)	21 (17.1 %)	5 (4.1 %)	15.5 (< 0.05)
Drought	14	4	1 (0.8 %)	9 (7.3 %)	8 (6.5 %)	3.73 (> 0.05)

Values in the parenthesis are the overall proportion of affected households

**Table 2.** Different strategies used by affected rural household

Climatic adversities	Affected households	Strategies		
		Labor work	*Forest resource use	**Other resource use
Crop loss by climatic factor	116 (94.3 %)	47 (38.2 %)	60 (48.8 %)	97 (78.9 %)
Erratic rainfall	120 (97.6 %)	35 (28.5 %)	90 (73.2 %)	50 (40.7 %)
Cloud burst	13 (10.6 %)	6 (4.9 %)	6 (4.9 %)	0 (0.0 %)
Landslide	53 (43.1 %)	5 (4.1 %)	10 (8.1 %)	8 (6.5 %)
Flood	27 (21.9 %)	12 (9.8 %)	20 (16.3 %)	20 (16.3 %)
Drought	18 (14.6 %)	0 (0.0 %)	6 (4.9 %)	12 (9.8 %)

Values in the parenthesis are the overall proportion of affected households.

\* Forest resource use includes collection of fuelwood, fodder, NTFPS for income generation, wild edibles for supporting household consumption, use of timber and stones for construction of damaged houses and animal huts due to climatic adversities.

\*\* Other resource use includes assistance from friends or relatives and buying items from market.

climatic adversities (Table 2). The strategies employed by the greatest proportion of households were use of forest resources during erratic rainfall (83.9%) followed by crop loss due to climatic factor (73.1%), flood (21.5%), landslide (8.1%) while forest resource use for cloud burst and drought was reported by 6.5% households. Labor work as coping strategy to overcome loss was used mostly by rural households during crop loss by climatic factor (38.2%) followed by erratic rainfall (28.5%), flood (9.8%), cloud burst (4.9%) and landslide (4.1%), while use of labor work as coping strategy was not reported during drought. Other resource use by households such as assistance from others or relatives and buying items from market was used maximum during crop loss due to climatic factor (78.9%) followed by erratic rainfall (40.7%), flood (16.3%), drought (9.8%) and landslide (6.5%) while during cloudburst other resource use was not reported by any of the household. Use of diverse strategies such as forest resource use and help from relatives has also been reported by Heemskerk et al (2004); McSweeney (2004); Paumgarten and Shackleton (2011); Kalaba et al (2013).

The prevailing crop loss by climatic factor and drought condition in the study region is attributed to non-availability of water for irrigation and erratic rainfall while flood problem was due to location of households on the bank of river Alaknanda. The findings of the study also clearly elucidate that forest resources can be an important factor in minimizing the effects resulting due to climatic adversities and play an essential role in securing rural livelihoods. Apart from the forest resource use other strategies were also adopted by the affected rural

households to minimize the effect of the various adversities.

The present study has provided insights on the relative importance of forest resources to rural livelihoods during adversities due to climate and the differentiation in use of forest resources in relation to household income level. The findings of this study revealed that forest resources contribute substantially to rural livelihood. The results however suggest that most of the households depend on the forest as a source of construction materials as they could not afford other construction materials particularly during loss to property due to climatic adversity. Further, forest provides food during adversities and thereby helps in increasing livelihood security. Similar findings has also been reported by Shackleton and Shackleton (2006) in a study clarifying that households depend on forests as they helps in saving the income through direct use of forest products. Since over use of forests can degrade the quality and quantity of resources available to the rural households therefore flexible forest management policies focusing on well being of people might be helpful in achieving sustainable livelihood development (Varughese and Ostrom 2001).

## CONCLUSION

The present study outlines the influence of household income level; type of climatic adversity that affect entire household's sustainability. The study shows that use of forest resources was most widely used by rural households during climatic adversities. Due to limited available option comparatively a higher proportion of households depend on forest resources to overcome hardships faced due to adversities. The study results clearly demonstrates that resources from forest make an important contribution to livelihoods of rural people's and acts as protective mechanism against climatic adversities. The results of the study also suggests that the well-being of rural households and rural communities can be enhanced through sustainable human interaction with environment and its products with the support of appropriate management practices and improved technology adoption. Thus, the study suggests necessity for more data-base assessment to attain enhanced understanding regarding climatic adversities and their potential mitigation.

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Received 16 November, 2017; Accepted 10 January, 2018



# Insect Community in Agroforestry: Role of Weather Parameters on Population Dynamics

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**Abstract:** The abundance, diversity and richness of the insects associated with crops and effect of weather parameters on the population dynamics of the insects were studied in an agroforestry area in Bangladesh during July 2015 to June 2016. In total 2936 collected insects, Hemiptera were most abundant (50.2%). The abundance of pest, predator, pollinator and other category were 63.2%, 12.4%, 13.8% and 10.6%, respectively. The pest population associated with mango were significantly higher (74.8%) followed by citrus (22.6%) and pineapple (2.6%). The pests showed highest abundance and diversity on mango but highest richness on citrus. The insects were highest abundant in the month of May and lowest in November. The abundance of insects revealed significant positive correlation with temperature, and insignificant positive correlation with relative humidity and rainfall, while insignificant negative correlation with light intensity. Multiple linear regression equation showed 53.8% role of weather parameters on population build up. Temperature exerted the most important effect, which individually contributed 25% on population abundance. The result of this study is a scenario of insects in an agroforestry and the finding indicates the importance of conservation of predator and pollinator insects.

**Keywords:** Agroforestry, Citrus, Mango, Pineapple, Pest, Predator, Pollinator, Seasonal dynamics

Agroforestry is an agricultural system, which constitutes with the diversity of plants, and provides habitat for pests, predators and pollinators, which are linked to crop productivity (Donald 2004). The intensive agricultural system creates disturbance of the natural habitats, and affects species abundance, richness and diversity (Debinski and Holt 2000). The forest areas in the tropical regions are reducing and agricultural lands are converted to non-agricultural purposes. That is why the cultivated areas in these regions are gaining interest for conserving tropical biodiversity.

In Bangladesh, agro-based multistorey cropping is an ancient farming system, and in this way many fruit plants and vegetables are grown (Rahman et al 2012). The agroforestry system is not only a composition of crop plants of different species but also a habitat for varying species of weeds, and pest, predator and pollinator insects. In any agroforestry systems, weeds compete with crops for nutrient and abiotic factors of the environment and provide shelter for insects, and play significant role on the population dynamics of pests, predators and pollinators (Desaeger et al 2004). The diversity of crop species in the agroforestry provides a variety of resources like shelter and food for predators and

pollinators. Thus the heterogeneity of the habitat in the agroforestry area alters the quality and quantity of bio-resources and regulates ecological niches of various species in the community (Bugg and Waddington 1994).

The composition of an agroforestry system interrupts its microclimatic factors such as temperature, relative humidity, light intensity, precipitation, wind, carbon dioxide and water vapor and effects on the diversity and abundance of insect species (Dwivedi et al 2003, Anitha et al 2009). Seasonal variations of the weather factors also play a vital role in multiplication, growth, development and distribution of insects, and influence on their population dynamics (Dhaliwal and Arora 2001). But insect diversity, abundance and richness are poorly understood and little quantified in the agroforestry in Bangladesh. Therefore, this study was conducted to know the community composition of insects in an agroforestry in Bangladesh, and the role of temperature, humidity, rainfall and light intensity on their population dynamics.

## MATERIAL AND METHODS

The study was conducted in the agroforestry field laboratory of Bangabandhu Sheikh Mujibur Rahman

Agricultural University (BSMRAU), Gazipur (25° 25' North latitude and 89° 5' East longitude), Bangladesh during July 2015 to June 2016. The area is surrounded by sal, *Shorea robusta* Gaertn forest and characterized by a well-defined dry season (February to May), rainy season (June to September) and short winter (December and January). Annual mean maximum and minimum temperatures, relative humidity and rainfall are 36.0 and 12.7 °C, 65.8% and 237.6 cm, respectively. The agroforestry system was interrupted by different management intensity, grasslands, rice, fruit and vegetable crops. The study area was 2205 m<sup>2</sup> and had citrus, mango (variety Amrapali, each 11 years old, 3-4 m height and 7 m apart) and pineapple plants. During the study, there was no middle and lower storied crops, and 22 weed species emerged.

**Insect collection and identification:** Free-living insects were collected using a 30 cm diameter sweep net having 1.5 mm mesh, and attached with a 2 m long rod. Every two weeks interval, sweeping was done in between 10.00 and 11.30 am, and each sample was consisted of 40 sweeps encompassing an area from ground level to the top of the trees. The collected insects were brought from the experiment field to the Entomology Laboratory of BSMRAU for identification and counting of their abundance. The insects were killed by storage in a freezer for a few hours, then mounted on points, dried and morphotyped. The insects were classified into different taxonomic orders and also grouped as pest, predator, pollinator and other category. Voucher specimens were deposited in the insect museum of BSMRAU.

**Collection of weather data:** Light intensity was measured with a digital light meter (Model 401025, Extech Instruments Corporation, USA). Data were collected fortnightly and in between 10.00 and 11.00 am from the canopy area of the trees. Mean daily temperature, relative humidity and rainfall data were collected from the weather station of BSMRAU.

**Statistical analysis:** Chi statistic was applied to find out significant difference among the abundance of insects in different taxonomic orders, associated crop plants, and among the pest, predator, pollinator and other categories. One way analysis of variance (ANOVA) was employed for analyzing abundance (total number of individuals), diversity (Simpson Index of Diversity) and richness (total number of species). Diversity was calculated following the formula of Simpson (1949). Correlation coefficients were calculated for total species abundance with meteorological parameters. All the analyses were performed using IBM SPSS 21.0. (IBM SPSS statistics 21, Georgia, USA).

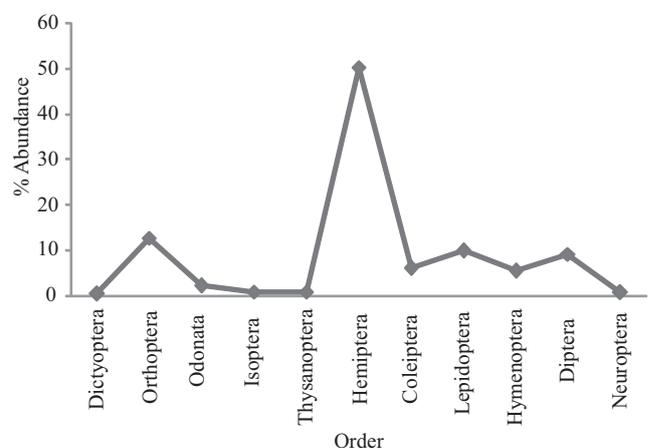
## RESULTS AND DISCUSSION

Information on insect abundance and the effect of

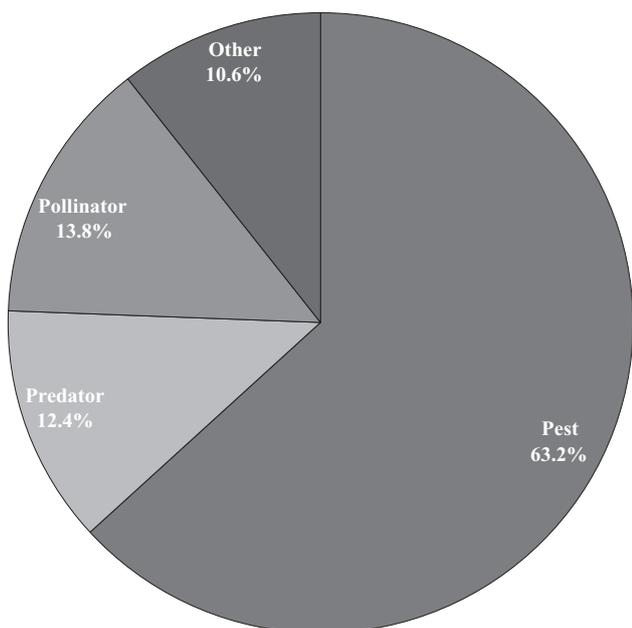
meteorological parameters on their population dynamics is to be noted for effective management of the pests and proper utilization of predators and pollinators. In the present study, a total of 2936 insects were collected from a citrus, mango and pineapple based agroforestry area throughout a year and the insects were classified into 11 taxonomic orders (Fig. 1). The abundance of insects belonged to different taxonomic orders differed significantly ( $\chi^2 = 234.1$ ,  $df = 11$ ,  $p < 0.001$ ). Insects of the order Hemiptera were most abundant (50.2%) and it was least in Dictyoptera (0.6%). Hymenoptera, Coleoptera, Diptera, Lepidoptera and Orthoptera showed 5.7 to 12.9% abundance, whereas, Neuroptera, Thysanoptera, Isoptera and Odonata revealed 0.9 to 2.4% abundance. Amin et al (2015) collected 1751 insects from a mango-based agroforestry area in Bangladesh during January to June 2013 and classified them into 11 taxonomic orders, of which Hemiptera were most abundant (59.8%), followed by Diptera (20.9%), Hymenoptera (10.3%), Lepidoptera (5.0%) and Coleoptera (3.7%).

There were found significant differences among the abundance of pest, predator, pollinator and other category insects (Fig. 2;  $\chi^2 = 85.4$ ,  $df = 3$ ,  $p < 0.001$ ). Their abundance varied from 10.6 to 63.2%. Our findings showed agreement with Amin et al (2015) who observed significantly higher abundance of pest insects compared to predator, pollinator and other group in a mango based agroforestry area in Bangladesh.

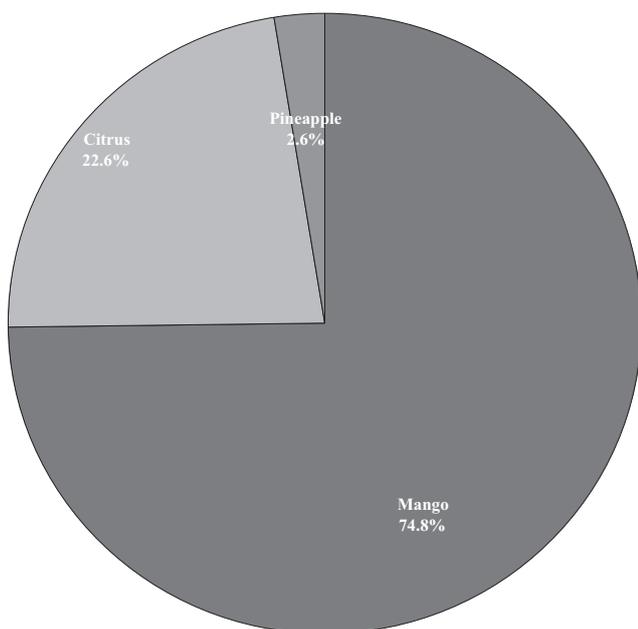
Different host plant species vary in their biochemical contents, and morphological and physiological characteristics, thus affect the abundance of insect pests. In the present study, insect pest population associated with mango, citrus and pineapple differed significantly (Fig. 3;  $\chi^2 = 82.0$ ,  $df = 2$ ,  $p < 0.001$ ). The pest population associated with mango were statistically higher (74.8%), followed by citrus



**Fig. 1.** Abundance of insects belonged to different orders in the agroforestry area during July 2015 to June 2016



**Fig. 2.** Abundance of pest, predator, pollinator and other category insects found in the agroforestry area during July 2015 to June 2016



**Fig. 3.** Insect pest population associated with different crops in the agroforestry area during July 2015 to June 2016

(22.6%) and pineapple (2.6%). There were found significant differences among the abundance ( $F_{2,69} = 38.9, p < 0.001$ ), richness ( $F_{2,69} = 28.9, p < 0.001$ ) and diversity ( $F_{2,69} = 23.4, p < 0.001$ ) of the pests of citrus, mango and pineapple (Table 1). The abundance, richness and diversity of the pests among the fruit crops varied from 2.0 to 57.8, 1.3 to 10.4 and 0.02 to 0.59, respectively.

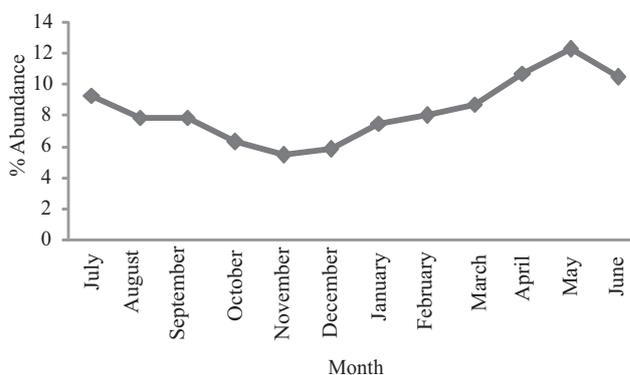
**Table 1.** Average abundance, richness and diversity of pest insects associated with different crops in the agroforestry area during July 2015 to June 2016

Crop plant	Abundance	Richness	Diversity
Citrus	17.2	10.4	0.02
Mango	57.8	5.3	0.59
Pineapple	2.0	1.3	0.11

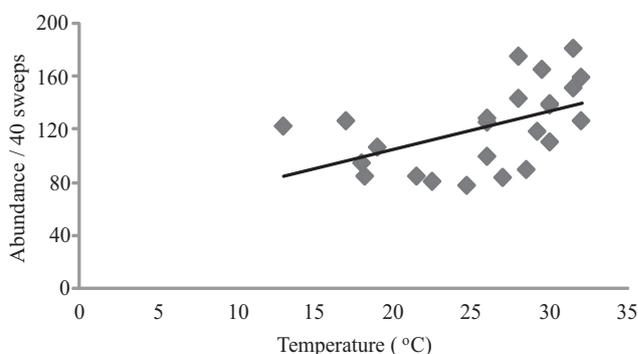
Means per insect group are taken from 40 sweeps per total collection

Kannan and Rao (2007) observed negative correlations between the incidence of hopper and minimum temperature, relative humidity, rainfall, and positive relationship with maximum temperature, and morning relative humidity. In the present study, the monthly abundances of the insects in the agroforestry area showed significant difference ( $F_{11,12} = 8.4, p < 0.001$ ) and the results varied from 5.43 to 12.24% (Fig. 4). Insect abundance was highest in the month of May and it was lowest in November.

Relationship between insect abundance and weather parameters revealed that insect abundance had significant positive correlation with temperature (Fig. 5;  $y = 47.586 + 2.882x, r = 0.50, F_{1,22} = 7.3, p < 0.05$ ), insignificant negative correlation with light intensity (Fig. 6;  $y = 132.068 - 0.002x, r =$

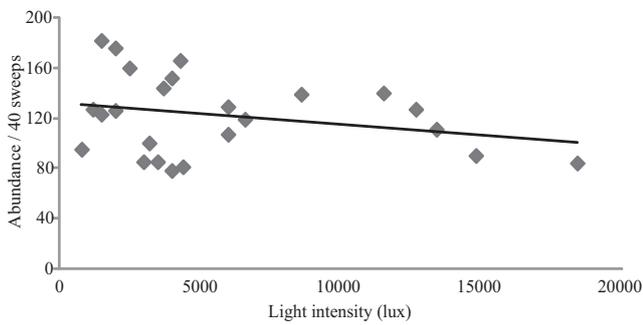


**Fig. 4.** Monthly abundance of insects found in the agroforestry area during July 2015 to June 2016

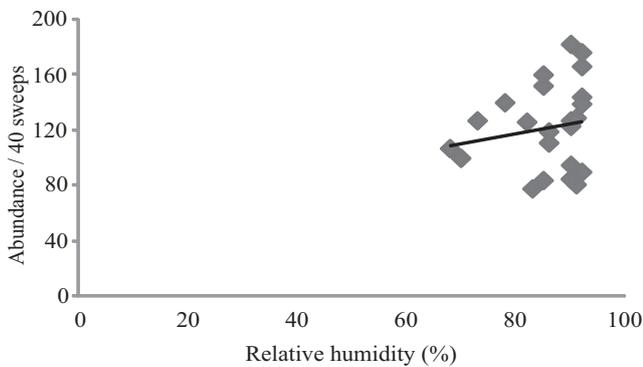


**Fig. 5.** Relationship between temperature and total insect abundance found in the agroforestry area during July 2015 to June 2016

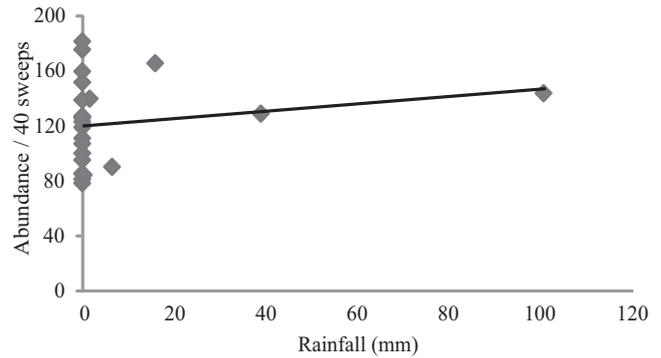
0.264,  $F_{1,22} = 1.6$ ,  $p = 0.21$ ), insignificant positive correlation with relative humidity (Fig. 7;  $y = 61.595 + 0.702x$ ,  $r = 0.160$ ,  $F_{1,22} = 0.57$ ,  $p = 0.46$ ), and insignificant positive correlation (Fig. 8;  $y = 120.018 + 0.278x$ ,  $r = 0.193$ ,  $F_{1,22} = 0.8$ ,  $p = 0.37$ ) with rainfall. The increased abundance of the insect population during April to May was associated with increased temperature, relative humidity, rainfall and may be due to the flushing of inflorescence. The insect population was lowest in November to January due to higher light intensity. High light intensity occurred in these months because of clear sunshine and deciduous plant characteristics of the agroforestry. Paul



**Fig. 6.** Relationship between light intensity and total insect abundance found in the agroforestry area during July 2015 to June 2016



**Fig. 7.** Relationship between relative humidity and total insect abundance found in the agroforestry area during July 2015 to June 2016



**Fig. 8.** Relationship between rainfall and total insect abundance found in the agroforestry area during July 2015 to June 2016

and Lalnunsalgi (2011) studied insect population abundance at some agroforestry systems in Mizoram, India during 2000 to 2002 and found significantly higher and lower abundances in summer and winter seasons, respectively.

The multiple linear regression analysis presented in Table 2 showed that temperature individually contributed 25.0% abundance and its effect was significant. The combination effect of temperature and light intensity was significant and exerted 52.4% abundance. The individual contribution of light intensity was 27.4%. The relative humidity along with temperature and light intensity contributed 53.6% abundance of insect which was statistically significant. The individual effects of humidity and rainfall on insect abundances were 1.2% and 0.2%, respectively. The multiple linear regression analysis showed that all the weather parameters together contributed 53.8% population abundance of insects in the agroforestry area and the equations were significant.

Gan et al (2000) reported that the high temperatures (18–28°C) and relative humidity (> 90%) favored the incidence of mango hopper. Shekh et al (1993) carried out field studies in Gujarat, India and reported that temperature < 20°C kept population of *A. atkinsoni* under control and pest outbreak occurred when the temperature ranged between 20 and 25°C. They also found that fruit fly, *Ceratitidis cosyra*

**Table 2.** Multiple linear regression models along with coefficients of determination ( $R^2$ ) regarding the impact of weather parameters on the abundance of insects found in the agroforestry area during July 2015 to June 2016

Regression equation	$R^2$	100 $R^2$	% Role of individual factor	F statistic	
$Y = 47.586 + 2.882 X_1$	0.250	25.0	25.0	$F_{1,22} = 7.3$	$p < 0.05$
$Y = 34.077 + 4.235 X_1 - 0.004X_2$	0.524	52.4	27.4	$F_{2,21} = 11.5$	$p < 0.001$
$Y = -9.20 + 4.236X_1 - 0.004X_2 + 0.493X_3$	0.536	53.6	1.2	$F_{3,20} = 7.7$	$p < 0.01$
$Y = -4.037 + 4.190X_1 - 0.004X_2 + 0.44X_3 + 0.068X_4$	0.538	53.8	0.2	$F_{4,19} = 5.5$	$p < 0.05$

Y, insect population /40 sweeps;  $X_1$ , temperature (°C);  $X_2$ , light intensity (lux);  $X_3$ , relative humidity (%);  $X_4$ , rainfall (mm).

population was positively and negatively correlated with temperature and humidity, respectively while the population of *Bactrocera invadens* showed vice versa.

Plant species of an agroforestry system acts as a secured habitat for predator and pollinator insects. Combining trees with crops in an agroforestry system provide ambient conditions for proper reproduction and development of pest, predator and pollinator species. This study clearly focused the seasonal abundance of insects in an agroforestry in Bangladesh, which could be helpful to growers for development of pest management programs emphasizing on the restoration of predator and pollinator species.

#### ACKNOWLEDGMENTS

This study was funded by the Ministry of Science and Technology, Government of the Peoples' Republic of Bangladesh to whom the authors are grateful.

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# Structure and Diversity of Associated Plant Communities along the Age Series in Sal Plantations of North-Eastern UP

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**Abstract:** The associated communities of plantation forest of sal (*Shorea robusta* Gaertn.) which dominate the tropical deciduous vegetation of north-eastern U.P., India, were observed in an age series of 10, 20, 40, ~70 and >100 year stands at low and high disturbances to study the changes in their diversity and community attributes. Irrespective of the disturbance level, the species richness increased with increasing maturity of sal stands indicating the relative importance of successional status and degree of disturbance in determining the community composition. The leguminous trees and climbers were rare in younger stands and more so in stands facing high disturbance. The sum of IVI for leguminous and non-leguminous shrubs as well as for trees other than sal was significantly higher in less disturbed stands. However, the sum of relative density for leguminous shrubs was greater in older stands facing high disturbances. The sal stands along the age series showed significant differences among their  $\alpha$ -diversity as well as  $\beta$ -diversity values. The 70-years stands, facing moderate disturbances, had optimum plant diversity. We now solely depend on managed forest for plant diversity because the anthropogenic disturbance and extraction of forest resources are inevitable. Since the moderate disturbance shows little adverse impact on plant diversity, a guided extraction of plant resources may be feasible to keep the local economy going without significant loss to diversity and ecosystem attributes of the associated communities of sal plantations.

**Keywords:** Associated communities, Disturbance level, Maturity status, Sal plantations, Structure and diversity

The forested landscape of eastern Uttar Pradesh (terai plains) of India is geographically a part of great belt of sal forests and presents a mini-centre of biodiversity especially of woody and non-woody perennial plants. Trees contribute to the major structural and functional basis of the tropical forest ecosystem and also as an indicator of the change in the landscape. The natural growth forests of terai plains have largely been replaced by sal plantations. The organization of associated communities of the least disturbed plantation forests of sal, however, largely matches the complexity of the natural growth forests of the region. These communities constitute a number of leguminous and non-leguminous species population exhibiting different growth habits (Pandey and Shukla 2005) but different sorts of recurrent anthropogenic disturbances have drastically changed the structure and diversity pattern of these communities. The importance of disturbance to the maintenance of species diversity of different forest ecosystem has been increasingly recognized (Carreno-Rocabado et al 2012, Gautam et al 2014) and a number of studies on the impact of disturbance on species richness and abundance in forest communities have been made (Saha and Howe 2003, Majumdar et al 2012). Due to continued alteration of habitat through anthropogenic disturbances, the resulting landscapes are acting as 'death-traps' for several wild species of socio-

economic importance. Tree diversity differs from place to place in tropical forests due to dissimilarities in biogeography, habitat suitability, responses to climate change and anthropogenic pressures (Sundarapandian and Karoor 2013). The vegetation structure and species composition of these forests differ with the duration of the wet season, the amount of rainfall, latitude, altitude and anthropogenic activities (Reddy et al 2008). Human uses of tropical forest resources in developing countries are in direct conflict with the conservation of biodiversity and habitat destruction and degradation of tropical forest and can be hailed as the major factor contributing to the decline of global biodiversity (Mishra et al 2003). No significant attempt has, so far, been made to analyse the pattern of change in the composition and diversity of associated communities of sal representing early to late successional stages especially in relation to disturbance. The present study aims to investigate the overall pattern of change in structure and diversity of communities associated with plantation forests of sal in an age series including the relative importance of successional status and disturbance level in shaping the structure of overall community.

## MATERIAL AND METHODS

The study was conducted in Sohagibarwa Wildlife

Sanctuary under Gorakhpur Forest Division, UP. The sanctuary is located between 27°05' and 27°25'N latitude and 83°20' and 84°10'E longitude and at 95 m altitude. The climate is seasonal and sub-tropical. The total average annual rainfall is about 1814 mm, 87% of which occurs during the wet summer or monsoon season. During the relatively dry period of about 8 months, i.e. January– June and November–December the monthly rainfall is less than 100 mm. The soil is old Gangetic alluvium. The texture is sandy loam and the soil reaction is circum-neutral. The regional forest of north-eastern UP is of subtropical semi-evergreen type with a number of deciduous elements.

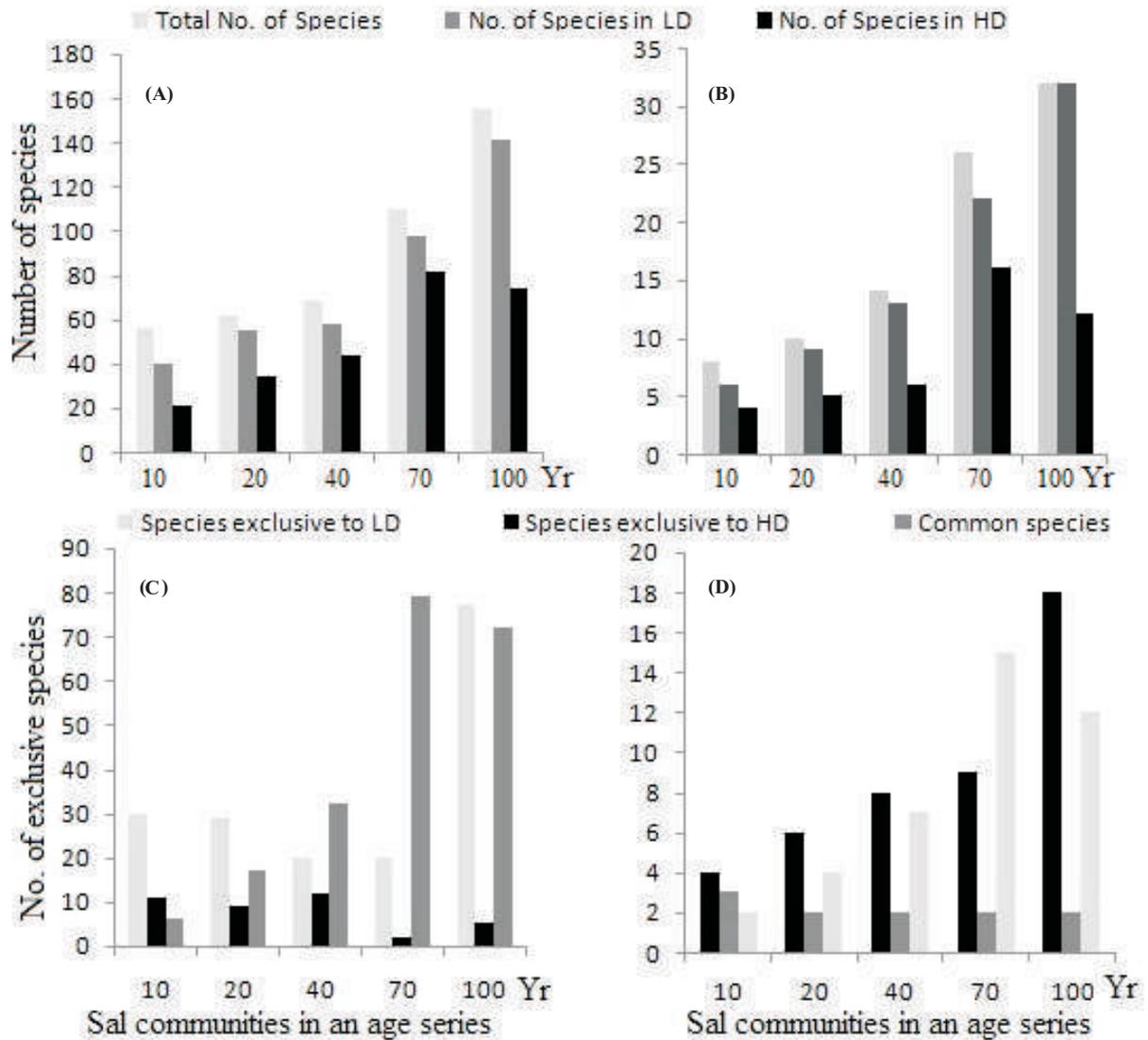
The sal communities of different age were identified on the basis of forest records and growth features of sal trees, especially of young plantations. The sal stands of five age groups were selected. The younger age groups had the maturity stages of 10-, 20-, and 40- years and the older groups were represented only by two maturity stages—~70 and > 100 year with a deviation of 2–5 years. Individuals with >30 cm girth at 1.37m above ground level were treated as tree. In order to show the pattern of change of different phytosociological attributes in relation to stand maturity and to avoid the confusion in comprehending the community data, the species of common habits were grouped into different habit components. The sal trees formed the first and foremost component (STR) and the non-leguminous trees, taken as 'other trees' (OTR) as separate component. The group of non-leguminous individuals of woody species having a gbh of <30 cm were termed as 'other shrubs and climbers' (OSC). The woody legumes treated separately and were segregated initially into two different habit groups—the leguminous trees (LTR) and all other woody legumes. The latter group was divided into leguminous shrubs (LSH) and leguminous climbers (LCL). Herbs and herbaceous climbers (HBC) were treated separately.

The disturbance index (DI) was determined as the number of cut, severed or mutilated woody individuals, expressed as the percentage of total number of such woody individuals per 100m<sup>2</sup> area (Pandey and Shukla 1999). A plant having separate identity at the soil surface was treated as an individual. Stands, facing high disturbance, had DI>65% and those within a DI range of 15 to 28% were taken as less disturbed stands. A sample plot or quadrat of 10m x 10m area was used for observation on community organization. The 20 random quadrats per stands were observed, irrespective of stand area. The occurrence of different species and the number and diameter of their individuals were recorded. The stands were analysed through conventional phytosociological methods (Mueller-Dombois and Ellenberg 1974).

Frequency of a species was taken as the number of its occurrence expressed as a per cent of the total number of randomly placed quadrats observed. Density was calculated as the total number of individuals of a species present within all the sample plots divided by the number of sample plots. The abundance: frequency (A/F) ratio was used to interpret the distribution patterns of species (Whitford 1949). The values of other importance indices were also calculated including Importance Value Index (IVI) =relative frequency (RF) + relative density (RD) + relative dominance (R Dom). The values of each indices for a group of species, identified as having common habit, were summed to compare different species' groups within the same stand and the same group among different stands. The Dominance (C) for each community was calculated by Simpson's index ( $C = \frac{1}{\sum p_i^2}$ ), Diversity by Shannon's index ( $H = - \sum p_i \ln p_i$ ) and Evenness by Pielou's index ( $e = H / \ln S$ ). The  $p_i$  represents the proportional abundance of  $i$ th species in any given stand and  $S$  is the number of species.  $\beta$ -diversity or species turnover was calculated by using the formula,  $\beta = \gamma / \alpha$ , where  $\alpha$  is the diversity of discrete stands and  $\gamma$  is the diversity of forested landscape of the region (Ricklef 1993).

## RESULTS AND DISCUSSION

**Species richness:** The total number of species constituting a community increased with the increasing maturity status of sal stands along the age series (Fig. 1). The change, however, was more drastic for less disturbed communities (1A). The number of species, exclusively occurring in less disturbed stands was much higher as compared to those occurring in highly disturbed stands. The difference in the number of exclusive species among less disturbed stands of the age series was significant ( $P < 0.001$ ) while that among highly disturbed stands was not so. The number of species, common to both the less disturbed as well as highly disturbed stands also increased with increase in the stand maturity (1B). The total number of leguminous species showed a steady increase along the age series. A 70-year old less disturbed sal stand, however, had maximum number of legume species (1C). The legume species, exclusively only to less disturbed stands, showed a steady increase along the age series but those, exclusive only to high disturbance, showed no such trend and were much rare also. The number of leguminous species, common to communities facing low and high disturbance, increased only up to 70-year stand age with a significant decline in >100-year old communities (1D). The correlation coefficient between total species and exclusive species of less disturbed stands of different age along the age series was not significant but a correlation between the number of total species of less disturbed and of



**Fig. 1.** The number of total species (A) and that of exclusive species (B) facing low or high disturbances in stands of different maturity status. The number of total leguminous species (C) and that of exclusive legume species (D) in stands of different maturity status under low or high disturbances

highly disturbed stands of similar age was significant. It indicates the relative importance of successional status and disturbance level in determining the community composition.

**Analytic characters of species under different habit groups:** The importance value index of different species grouped under six habit components in an age series of sal communities facing high (2A) and low (2B) disturbances and leguminous trees increased considerably only after 40-year age and were maximum in 70 years at both the disturbance level (Fig. 2). The LSH showed a slow but steady increase with stand maturity. The pattern of change in IVI of LSH first increased up to 70-year at high disturbance but at less disturbance, it increased significantly only from 70-year to

100-year age. The IVI of OSC was much higher in less disturbed than in highly disturbed sal stands. Under high disturbance, however, the OSC decreased significantly and steadily from 20-year onward. The species groups like *Shorea* trees and other trees (OTR) showed drastic increase in the pattern of their IVI as their basal cover contributed significantly to the sum of IVI values in older stands. This increase was much more spectacular for OTR from 40-year onward in less disturbed stands and 70-year onward in highly disturbed stands. For LTR the pattern of change of IVI was quite similar to change of their relative density along the age series.

**Dominance, diversity and evenness:** The  $\alpha$ -diversity

increased consistently with stand maturity up to 70-year stage with some aberration for highly disturbed stands. Under low disturbance, however, the diversity increased from 40-year to 70-year stage was most spectacular. It increased up to > 100-year stage with considerable change from 70-year old stand. The correlation between maturity stage and  $\alpha$ -diversity was positive and significant at 2% P-level at low disturbance and at 5% P-level at high disturbance. In both cases, the 70-year old stand showed maximum on near maximum diversity.  $\beta$ -diversity exhibited an inverse relation with stand diversity but its correlation with maturity status was significantly only at low disturbance (<0.02). In general, evenness decreased from young to old sal stands at high disturbance showing negative correlation with stand maturity but showed a slow and consistent increase at low disturbance having positive correlation. The correlation of maturity stage with dominance, however, was negative and significant ( $P < 0.02$ ) irrespective of disturbance level (Table 1). Under high disturbance, the differences in the values of sum of RD among the stands of different maturity was significant at 5% level and that among the different species

groups was significant at 1% level. In case of less disturbed stands, the difference in the sum of IVI was significant at 1% level but among the species groups it was significant at 5% level (Table 2).

**Analytic characters of legume components:** The associated communities in an age series of sal plantation constituted a number of leguminous species, divisible among three different habit groups, leguminous trees (LTR), leguminous shrubs (LSH) and leguminous climbers (LCL). LTR and LCL were absent from highly disturbed stands up to 40 year age but at low disturbance, it was so only up to 20 years stand age. In general, the sum of frequency, sum of abundance: frequency ratio and the sum of relative density of LSH consistently increased with stand maturity at low disturbance, but at high disturbance, these sums increased only up to 70 years stand age. The differences in the values of those indices were more prominent between stands of 40 years and 70 years age irrespective of the level of disturbance. The sum of IVI of LSH was much greater for younger stands facing low disturbances. This trend was, however, reversed for older age groups i.e. the sum of IVI of

**Table 1.** Different diversity indices for sal communities in an age series

Diversity indices	Disturbance level	Sal communities at different maturity status (Years)					Correlation coefficient ( r )
		10	20	40	~70	>100	
$\alpha$ -diversity	HD	2.87	3.09	3.03	3.37	3.35	0.897
	LD	2.52	2.51	2.95	3.78	3.89	0.968*
$\beta$ -diversity	HD	1.14	1.31	1.33	1.20	1.21	0.876
	LD	1.60	1.1	1.37	1.07	1.04	0.962*
Evenness	HD	0.958	0.900	0.796	0.765	0.769	-0.869
	LD	0.688	0.648	0.740	0.817	0.778	0.819
Dominance	HD	0.084	0.065	0.065	0.056	0.042	-0.934*
	LD	0.125	0.130	0.073	0.039	0.035	-0.935*

**Table 2.** Analysis of variance for sum of relative density (RD) and of importance value index (IVI) of species grouped under different habit groups in an age series of sal stands facing low/ high disturbance

Source of variance	Degree of freedom	For sum of RD		For sum of IVI	
		Mean sum of	F-ratio	Mean sum of	F-ratio
<b>High disturbance</b>					
Along the age series (between the columns)	4	7140	3.52**	6429	10.75*
Among the species groups (between rows)	6	1282	6.32*	2653	4.44*
Residual	24	203		598	
Total	34				
<b>Low disturbance</b>					
Along the age series (between the columns)	4	714	6.10*	6429	13.04*
Among the species groups (between rows)	6	1081	9.24	1563	3.17*
Residual	24	117		493	
Total	34				

LSH was greater in 40, 70 and 100 years' stands facing high disturbances (Table 3). The sum of the above indices for LTR and LCL increased from 40 years onwards to be maximum for 100 years stand facing low disturbance, but at high disturbance the sum of the values of these indices were maximum for 70 years stand. LTR, too had maximum sum of relative density and of IVI in 70 years stand facing low disturbance. At high disturbance, however, the sum of IVI was maximum for 100 years stands (Table 4). The successional forest types in the Gorakhpur Forest Division

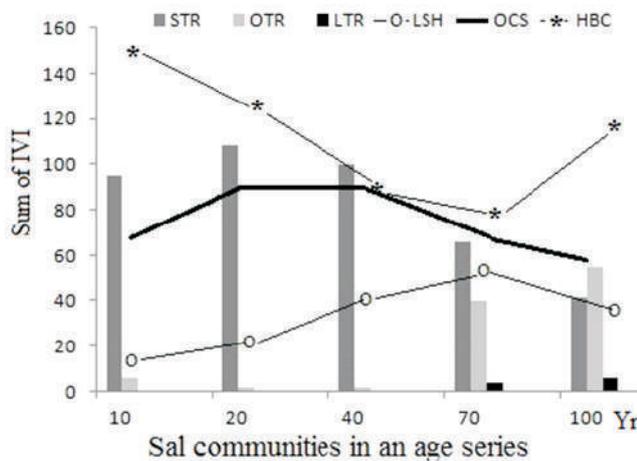
showed a remarkable variation in their vegetation structure and species composition. The importance of natural and anthropogenic disturbances in maintaining the species diversity has often been pointed out by many workers (Sapkota et al 2010, Sagar et al 2003). The highest species richness in more than 100 years old stands, facing low disturbance and in 70 years stand, facing high disturbance, suggests that the maturity stage or successional status is of overriding importance as compared to the degree of disturbance in regulating diversity pattern of the community.

**Table 3.** Values of different analytic quantitative characters of leguminous shrubs (LSH) in sal communities at different maturity status, facing high or low disturbance (HD/LD)

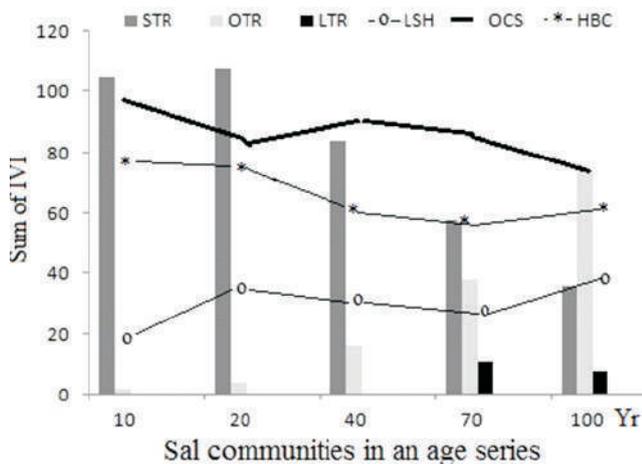
Analytic characters	Disturbance level	Maturity status Sal communities (Years)				
		10	20	40	~70	>100
Frequency	HD	95	205	255	470	265
	LD	10	240	325	365	570
Abundance/ frequency ratio	HD	0.71	1.31	1.91	5.84	6.24
	LD	2.46	3.00	3.19	6.52	7.36
Relative density	HD	1.61	11.8	20.2	24.8	19.0
	LD	10.7	10.8	11.2	12.1	16.5
Importance value index	HD	9.6	19.0	33.2	42.2	31.8
	LD	19.2	34.8	29.8	24.7	31.2

**Table 4.** Values of different analytic quantitative characters of leguminous trees and leguminous climbers in sal communities in an age series, facing high or low disturbance (HD/LD)

Habit groups of species	Analytic characters	Disturbance level	Maturity status sal communities (years)			
			40	70	100	
<b>Trees (LTR)</b>	Frequency	HD	-	45	20	
		LD	10	95	75	
	Abundance/ Frequency ratio	HD	-	0.25	0.20	
		LD	0.1	0.48	0.70	
	Relative Density	HD	-	0.09	0.04	
		LD	0.04	0.27	0.16	
	Importance Value Index	HD	-	3.7	4.6	
		LD	1.3	11.2	7.4	
	<b>Climbers (LCL)</b>	Frequency	HD	-	30	10
			LD	10	105	125
Abundance/ Frequency ratio		HD	-	1.23	0.10	
		LD	0.20	0.78	1.14	
Relative Density		HD	-	0.36	0.02	
		LD	0.07	0.89	1.13	
Importance Value Index		HD	-	1.40	0.50	
		LD	1.31	4.43	6.5	



**Fig. 2A.** Sum of importance value index (IVI) of leguminous and non-leguminous species grouped under six habit group in an age series of sal communities facing high disturbance



**Fig. 2B.** Sum of importance value index (IVI) of leguminous and non-leguminous species grouped under six habit group in an age series of sal communities facing low disturbance

Nevertheless, the sum total of species content under high disturbance was lower. A greater diversity of plant species in old growth forests than in younger stands may be expected as the spatial variation in resource availability is liable to increase habitat diversity (Timilsina et al 2007).

A greater increase in the sum of IVI of non-legume trees and woody shrubs along the maturity stages of stands facing lesser disturbances as compared to those facing much greater disturbances suggests that a high degree of disturbance degrades the structure and reduces the species richness as has also been observed for some residual forest (Pandey and Shukla 2001). The ubiquity of few species like *Clerodendron infortunatum*, even in highly disturbed

environment, has been attributed to its efficient sprouting and ramet proliferation at any growth stage (Pandey and Shukla 2003). The  $\alpha$ -diversity and dominance varied generally in relation to stand age, irrespective of the disturbance level. This pattern agrees with the observation made in other studies that the non-environmental factors such as stand structure influence the diversity of understorey vegetation (Chauhan et al 2010). Evenness showed slight variation between the high and low disturbance along the age series.

As evident from the data, a 70-year old stand, facing mild disturbance, is conducive to the maintenance of considerable high plant diversity. On the other hand, the stands where high disturbance is inevitable, a few vigorously sprouting and ramet-producing species may easily be spared from complete destruction so that their vegetal cover may provide niches to a group of disturbance-tolerant species including several legumes, which can support the ecosystem attributes of the recurrently disturbed forest stands. The judicious exploitation of forest resources, by local inhabitants, is unique feasible as well as essential to keep their economy viable, which may be achieved through guided extraction without disrupting the process of regeneration and replenishment of plant diversity in the region.

#### ACKNOWLEDGMENTS

Thanks are due to Ranger and Divisional Forest officers of the Gorakhpur Forest Division for their active cooperation in the field work. I express my gratitude to anonymous referee(s) for their critical comments and guidelines to improve the manuscript.

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# Estimation of Biomass and Carbon Stock Variations in Vegetation of Differently Managed *Quercus leucotrichophora* Forests along an Elevation Gradient in Western Himalaya, India

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**Abstract:** The findings of the study conducted to estimate biomass and carbon stock in differently managed *Quercus leucotrichophora* forests along the elevation gradient revealed that the biomass and carbon stock parameters of the tree layer showed the precedence of Reserved Forest > Protected Forest > Unclassified Forest > Musterqua Forest. Aboveground biomass and its associated carbon stock of shrubs decreased significantly in the order of Reserved Forest > Musterqua Forest > Protected Forest > Unclassified Forest. Whereas, its belowground, total biomass and carbon stock decrease as: Reserved Forest > Protected Forest > Musterqua Forest > Unclassified Forest. Aboveground biomass and carbon stock of herbage was recorded as: Reserved Forest > Protected Forest > Unclassified Forest > Musterqua forest. While, belowground biomass, total biomass and its related carbon stock decreased significantly in the order of Reserved Forest > Protected Forest > Musterqua Forest > Unclassified Forest. Along elevation gradient, tree layer had shown significant variation in biomass and carbon stock parameters where it decreased with an increase in elevation but a ziz-zag pattern and non-significance level was recorded for shrubs and herbs layer respectively. Thus, biomass and carbon stock in a forest ecosystem at different layers was influenced greatly by management strategies and elevation.

**Keywords:** *Quercus leucotrichophora*, Protected Forest (PF), Reserved Forest (RF), Musterqua Forest (MF), Unclassified Forest (UF)

With the decrease of forest area and increase of greenhouse gases like CO<sub>2</sub>, it is increasingly important to do quantification of vegetation biomass and carbon stocks so as to evaluate the carbon sequestration potential in the ecosystem. Carbon dioxide (CO<sub>2</sub>) is an important greenhouse gas that influence global climate. Since the beginning of industrial revolution, carbon dioxide concentration in the atmosphere has been rising alarmingly. Forests are an important natural terrestrial ecosystem known to have huge potential of biomass accumulation and carbon sequestration can contribute to mitigate greenhouse effect and global warming which ultimately serve as a natural 'brake' on climate change. They not only fix and store carbon from the atmosphere via photosynthesis but also function as active carbon for the period of many years and continue to store carbon until they are harvested or die. Besides, forests provide a good surface cover which minimizes the loss of nutrients from the surface soil, improves edaphic conditions, increases biomass production, provide a protective ground cover through tree and crop cover and decrease risk of soil degradation by erosion, leaching and nutrient depletion. Thus, the earth's terrestrial vegetation plays a pivotal role in the global carbon cycle, accounting for a significant fraction of the total C pool and nutrient stocks. The most promising regimes for CO<sub>2</sub> mitigation are afforestation, reforestation of

blank areas or by adopting other forest management strategies.

Biomass is present in both aboveground and belowground parts of annual and perennial plants. Biomass associated with annual and perennial herbaceous plants is relatively ephemeral, i.e., it decays and regenerates annually or every few years. Woody plants and trees can accumulate large amounts of carbon (up to hundreds of tons ha<sup>-1</sup>) over their lifespan (IPPC 2006). Forests are the natural storage factory of carbon and the assessment of carbon present in the biomass of forest is the important component to determine the contribution of forestland to global carbon cycle (Gairola et al 2011). Many environmental factors (e.g. temperature, precipitation, atmospheric pressure, solar and UV-B radiation and wind velocity) change systematically with altitude (Korner 2007) and these factors greatly affect floristic composition and structure, which had ultimate reflection in its biomass and carbon stockpile. Therefore, altitudinal gradients are among the most powerful 'natural experiments' for testing ecological and evolutionary responses of biota to environmental changes. Although changes in species composition and distribution, biodiversity and community structure along altitudinal gradients have been well documented in the past few decades (Sharma et al 2009, 2010) in Western Himalaya yet the altitudinal patterns of

biomass and carbon storage in forest ecosystems remain poorly understood. Moreover estimation of biomass and carbon sequestration from the forest under different management strategies is not only necessary for assessing the contribution of forests to the global C cycle but also for reforestation and afforestation type projects, which are currently being supported under international agreements such as the clean development mechanism (CDM) under the Kyoto Protocol and also for emission reduction projects that focus on forest conservation and management. Thus, keeping this in view, the present study was aimed to gauge the variations in biomass and carbon stock and track its trend along different environmental gradients among differently managed forest types of *Quercus leucotrichophora* so as to generate information on biomass, carbon stock and future carbon sequestration potential of the area.

**MATERIAL AND METHODS**

The study was conducted in Rajgarh Forest Division of Himachal Pradesh, which lies between longitude 77° -1'-5" to 77° -26'-13" East and latitude 30° -38'-40" to 31° -1'-14" North in the northwest Himalaya, India during the year 2015-16 (Fig. 1). The altitude range from 540 meters at Preet Nagar to 3402 meters at Chhogtali Dhar amsl. The area is mostly mountainous lying in inner and outer middle Himalaya with little south west portion in Shiwalik. The tract lies in the subtropical zone, areas above the 1500 meters in elevation

experience temperate climate condition and those above 3500 meters experience alpine. When hot, the temperature rises to 42°C and winters are cold, when the temperature hovers around 0°C. In this Rajgarh Forest Division, *Quercus leucotrichophora* forests are managed as: 1) Protected Forests (PF) – in these forests there is limited biotic or anthropogenic interference, 2) Reserved Forests (RF) – in these forests there is no biotic or anthropogenic interference, 3) Musterqua Forests (MF) – in these forests there is unlimited biotic or anthropogenic interference as per the requirements of local inhabitants and 4) Unclassified Forests (UF) – in these forests there is moderate biotic or anthropogenic interference. Their elevation range of existence is 1680 -2322 m, 1400-2000 m, 1500-2000 m and 1200-1950 m, respectively. In the present study, for our comparative analysis of biomass and carbon stock; each of these differently managed *Quercus leucotrichophora* forests were further divided into three elevation zones,  $E_1 < 1650m$ ,  $E_2 = 1651-1900m$  and  $E_3 > 1900m$ .

**Vegetation sampling and biomass estimation:** After survey of the experimental site, four sample plots each of size 31.62m x 31.62 m (0.1 ha) were demarcated in each type of forest at each elevation to study tree parameters. Two sub-plots of size 5m x 5m were marked inside each tree sample plot to analyse shrub parameters and three quadrats of size 50cm x 50cm each from each sample plot in every forest were harvested to study herb parameters. Trees > 10 cm dbh

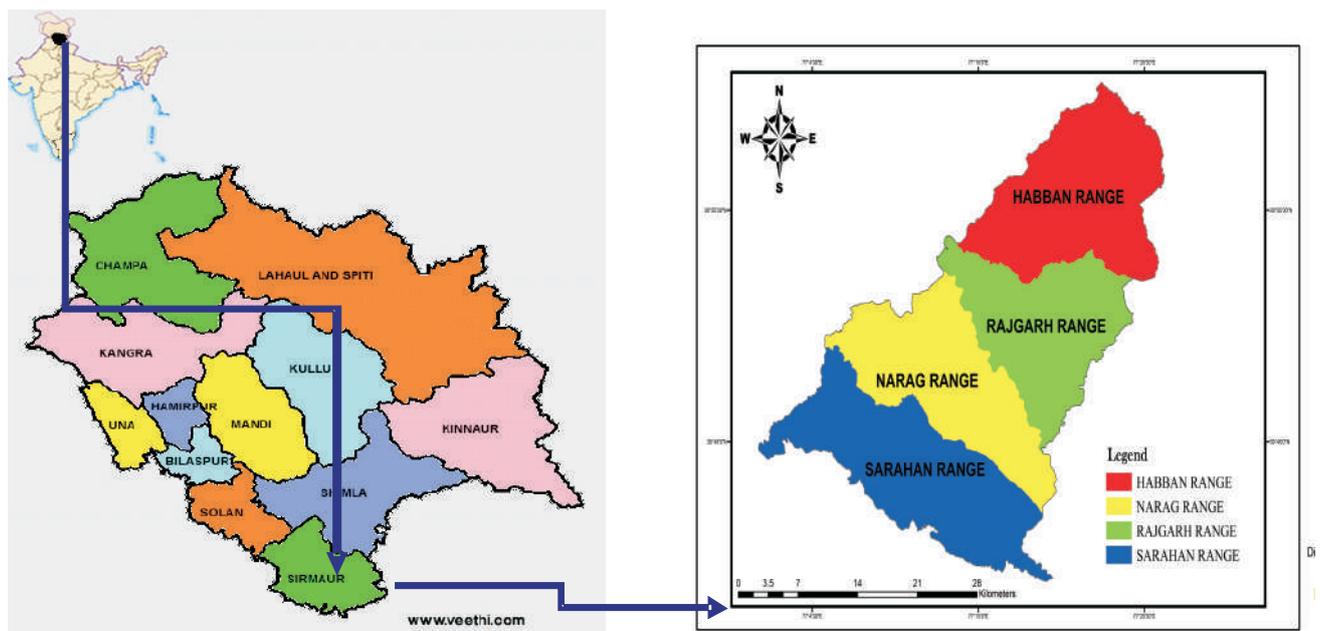


Fig. 1. Map of the study area

were enumerated in each sample plot and considered for calculation. Volume of trees was estimated by non-destructive methods using volume equation given in Forest Survey of India (FSI 1996) Dehradun, India for *Q. leucotrichophora*. The volume of trees was multiplied by its wood density of 8.26 (Rajput et al 1985) to calculate biomass of trees. Belowground biomass of trees was calculated by multiplying the aboveground biomass with a root: shoot ratio of 0.39 specified for this particular tree species (Rana and Singh 1990). The sum of aboveground and belowground biomass was added up to determine total biomass of the tree.

Shrubs biomass was estimated by harvesting them. Shrub samples collected were brought to laboratory, segregated into leaves, branches and stem portion and oven dried at 70°C for 72 hours till the constant dry weight was obtained. Each sample was weighed to determine aboveground biomass (stem + branch + leaves biomass) of each species. Belowground biomass estimations were done by extracting roots of sample plants. These were washed thoroughly and weighed to determine their fresh weight. The root samples for each shrubs species packed in paper bags and dried at  $70 \pm 5^\circ\text{C}$  for 72 hours to determine their dry weight. Total biomass of a sample shrub species was calculated by adding its aboveground and belowground biomass. Herbs biomass was determined by harvesting and segregating species wise. The roots of different species were washed in running water using fine mesh, the shoot and root portions were cut and packed separately in paper bags and oven dried at 70°C for 72 hours till constant dry weight was attained and weighed to determine their dry weight. Total biomass was calculated by adding aboveground and belowground biomass of each species.

Aboveground and belowground carbon content of tree was determined by multiplying aboveground and belowground biomass with conversion factor of 0.50 (Koach 1989). Similarly, for shrub and herbaceous vegetation, it was determined by multiplying their respective aboveground and belowground biomass with carbon conversion factor of 0.45 (Woomer, 1999). The data were analyzed with the help of OPSTAT (<http://14.139.232.166/opstat/default.asp>) in factorial randomized block design.

## RESULTS AND DISCUSSION

**Tree biomass and carbon stock ( $\text{t ha}^{-1}$ ):** Aboveground, belowground and total biomass of trees in *Q. leucotrichophora* forests decreased significantly along the elevation (Table 1). Among differently managed *Q. leucotrichophora* forests, these biomass parameters decreased in the order: reserved forest > protected forest > unclassified forest > musterqua Forest, which is a manifestation of their growth behaviour under

different microclimate and management practices employed in them. The minimum biotic and anthropogenic interference in Reserved Forest have best possible microclimate conditions for growth and hence led to highest aboveground biomass accumulation while severe anthropogenic disturbances in the forms of lopping and livestock grazing in Musterqua Forest adversely affected the microclimatic conditions leading to lowest biomass accumulation in trees. Devagiri et al (2013) reported similar estimates of above ground biomass (AGB) ranged between 7.25 to 287.05  $\text{t ha}^{-1}$  across different vegetation types in south western part of Karnataka. Mean total biomass ( $\text{t ha}^{-1}$ ) of trees in different forests ranged from Musterqua Forest (180.96  $\text{t ha}^{-1}$ ) to Reserved Forest (465.44  $\text{t ha}^{-1}$ ) and exhibited decreasing trend with increase in elevation in all forest types. Gariola et al (2011) have reported similar range (215.5 to 468.2  $\text{Mg ha}^{-1}$ ) of live tree biomass for moist temperate forests of Garhwal Himalaya in Uttarakhand. Comparable values of biomass of trees were given by Sheikh and Kumar (2010) for Central Himalayan Kumaon region; Masoodi (2010) and Sharma (2012) for Solan (HP).

Carbon stock is a derivation from biomass; therefore, a similar trend like that of biomass parameters was seen for aboveground, belowground and total carbon stock in differently managed *Q. leucotrichophora* forests and along an elevation gradient. More carbon stock in Reserved Forest can be related to higher biomass (aboveground and belowground) production of trees (Table 1). The carbon stock in differently managed *Q. leucotrichophora* forests ranged from (57.87 to 275.39  $\text{t ha}^{-1}$ ). Gairola et al (2011) reported comparable range of carbon stock (107.8 to 234.1  $\text{MgC ha}^{-1}$ ) in different forests along an altitudinal gradient in Garhwal Himalaya. Vikrant and Chauhan (2014) too reported comparable (219.86  $\text{Mg ha}^{-1}$ ), carbon stock estimates in oak forests of Garhwal Himalaya. Devi et al (2013) reported vegetational biomass carbon density of ban oak plantation forest ecosystems to the tune of 93.88  $\text{t ha}^{-1}$  and this value is in line with the Musterqua Forest carbon stock. However, Sharma et al (2010a, 2011) reported lower total carbon density (92.06  $\text{Mg ha}^{-1}$ ) and (77.3  $\text{Mg ha}^{-1}$ ) in *Q. leucotrichophora* forests of Garhwal Himalaya. Jina et al (2008) also reported similar estimate of total carbon stockpile in degraded and non-degraded sites of oak forests of Kumaun Central Himalaya which range from 16.73 to 18.54  $\text{t ha}^{-1}$  and 242.56-290.62  $\text{t ha}^{-1}$ , respectively revealing site characteristics are important for tree growth. Nautiyal and Singh (2013) reported very high carbon stock density (2420.54  $\text{Mg ha}^{-1}$ ) in oak forests of Garhwal Himalaya.

Rashid (2010) has given carbon stock estimates of trees in ban oak forest to range from 216.99 to 409.57  $\text{t ha}^{-1}$  at different elevations in Solan District of Himachal Pradesh and

Sharma and Singh (2010) also estimated carbon stock of trees in ban oak as  $635.77 \text{ t ha}^{-1}$ , which are comparatively higher than our estimates. It has been reported by many workers in other parts of the world that tree biomass and carbon stock decline with increasing altitude, interestingly in our study area too, we observed similar pattern but is contradictory to Goirala et al (2011) findings where biomass and carbon stock had positive correlation with increasing altitude. Differences in tree live biomass and carbon stock among forests are the manifestation of inherent growth characteristics of constituent species, their specific ecological niche, climate difference and density of trees. Biomass is also related to human or natural disturbances (Lugo and Brown 1992). Beside these, difference in biomass production in forest can be related to age of trees (Lal and Singh, 2000) and the management strategies adopted for their maintenance.

**Shrubs biomass and carbon stock ( $\text{t ha}^{-1}$ ):** Aboveground biomass of shrubs in differently managed *Q. leucotrichophora* forests showed the precedence: Reserved Forest > Musterqua Forest > Protected Forest > Unclassified Forest (Table 2). Whereas, belowground biomass and total biomass of shrubs decreased significantly in the order: Reserved Forest > Protected Forest > Musterqua Forest > Unclassified Forest. The variation in aboveground biomass along the elevation was not statistically significant but variations in belowground and total biomass exhibited a significant variation along the elevation. Belowground biomass of shrubs increased along the elevation from ( $0.25 \text{ t ha}^{-1}$ ) at elevation  $E_1$  to ( $0.85 \text{ t ha}^{-1}$ ) at elevation  $E_3$ . However, total biomass ( $\text{t ha}^{-1}$ ) of shrubs was significantly higher at elevation  $E_3$  (1.33) as compared to elevation  $E_2$  (0.74) and elevation  $E_1$  (0.83). Linlienfein et al (2001) and Riberio et al (2011) reported much higher respective aboveground biomass of shrubs ( $2.63$  and  $4.68 \text{ t ha}^{-1}$ ) in Brazilian Cerrado.

Among different forests, mean total shrub biomass ranged from  $0.51$  to  $1.98 \text{ t ha}^{-1}$  (Table 2), which is in line with estimate ( $0.2$ - $5.4 \text{ t ha}^{-1}$ ) reported for certain high and mid-elevation forests of Central Himalaya by Rana et al (1989) and Rawat and Singh (1988). Also, shrub biomass ranging from  $2.16$  to  $8.6 \text{ t ha}^{-1}$  in forests located at different altitudes in Solan (HP) reported by Masoodi (2010) was very high compared to our findings. The difference in biomass of shrubs in differently managed *Q. leucotrichophora* forests can be related to different species composition coupled with growth behaviour in the environment influenced by management.

Carbon stock of shrubs followed similar pattern like that of its biomass parameters. Total carbon stock (aboveground + belowground carbon stock) of shrubs component under

different *Q. leucotrichophora* forests ranged from ( $0.23 \text{ t ha}^{-1}$ ) in unclassified forest to ( $0.89 \text{ t ha}^{-1}$ ) in Reserved Forest. While, along the elevation it varied from  $0.33$  to  $0.60 \text{ t ha}^{-1}$  showcasing no definite pattern of change along the elevation. Minimum carbon stock was recorded at middle elevation ( $E_2$ ). In general, the decrease in total carbon stock of shrubs in different *Q. leucotrichophora* forests was the result of corresponding decrease in biomass parameters (aboveground and belowground) of shrubs. Comparing all the forests, Reserved Forest was observed to have higher value of carbon stock in shrubs. This might be related to the higher values of biomass parameter (aboveground, belowground and total biomass) than other forest types. Our present finding is comparable with the work of Mahato (2013) who estimated total carbon stock of shrub to range from  $0.49$ - $1.19 \text{ t ha}^{-1}$  in chir pine forests in Giri catchment of H.P.

**Herbs biomass and carbon stock ( $\text{t ha}^{-1}$ ):** Aboveground biomass of herbage in differently managed *Q. leucotrichophora* forests decreased in the order: Reserved Forest > Protected Forest > Unclassified Forest > Musterqua Forest (Table 3). Whereas, belowground biomass and total biomass of herbage decreased significantly in the order: Reserved Forest > Protected Forest > Musterqua Forest > Unclassified Forest. Aboveground, belowground and total biomass along the elevation was statistically non-significant. In general, the decrease in biomass of herbage was the result of corresponding decrease in biomass production (aboveground and belowground) of herbage component. Our result seems to be very less compared to the findings of Salunkhe et al (2014) in tropical dry deciduous forest of Madhya Pradesh which is  $5.23 \text{ t ha}^{-1}$ . The Reserved Forest surpassed all forests in terms of mean total biomass production of herbage which could be ascribed to non-existence of biotic activities that have resulted good herbage growth while other forests suffer intermediate to severe biotic and anthropogenic pressure.

Differences in herbs biomass in different forests is the manifestation of constituent species and their growth behaviour under specific ecological niche, climate difference and density of trees regulating light underneath. Further, the management strategies adopted for their maintenance. Light underneath tree canopy was inadequate in *Q. leucotrichophora* forests and this might be one of the possible factor responsible for low biomass in herbage. Similar role of climatic variables on growth and development of herbage vegetation has been advocated by Dutt and Gupta (2005) and Kunhikannan (2008). Since carbon stock of any vegetation is reflection of its biomass and the variation of herbs carbon stock parameters amongst forest types and along the elevation can be related



to its changes in biomass as discussed above. In our present study carbon stock in herbs was comparatively very low as compared to other plant categories. Very less contribution of herbage to the ecosystem carbon stock in the forests has been reported by other researchers (Sharma 2012, Dieter and Elsasser 2002).

### CONCLUSION

Highest biomass and carbon stock was recorded in reserved Forest than the other three forests types in all the vegetational components viz., trees, shrubs and herbs. This can be related to the complete restriction imposed in grazing and anthropogenic activities and non-dependency of villagers for their basic requirement (fuel, fodder, timber, etc.). However, this was not the case in Musterqua Forest where dependencies of the villagers were high due to proximity of this forest. Villagers collect fuel, fodder and remove litters for livestock bedding and therefore this forest was highly disturbed. Human disturbance had greatly influenced the biomass and carbon stock of these forests. It also gives an insight of the contribution of managed forests in storage of carbon for mitigating climate change. The results of the present study on biomass and carbon storage across different ecosystem components would pave a way in understanding the sequestration potential of oak forests.

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# Avifaunal Diversity and Status of Jhalawar Forest Division, South-Eastern Rajasthan, India

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**Abstract:** The present study was carried out to explore the seasonal diversity and status of avifaunal Jhalawar Forest Division of Rajasthan, India, during March, 2014 to February, 2015. Line transect method was followed to survey, i.e. forest, farmlands and wetlands areas etc. A total of 181 bird species belongs to 22 orders and 65 families were recorded during the study period. The order Passeriformes most dominant with 72 species and 28 families with highest relative diversity index 43.08. The anatidae family was most dominant with 14 species and relative diversity index of 7.73. Further analysis of data for residential status indicates that 133 bird species were resident, 48 bird species were migrant (41 winter + 3 summer + 4 passage visitor). The maximum numbers of species (63 species) were omnivorous followed by insectivores (54 species), carnivores (42 species), granivores (14 species), frugivores (7 species) and a nectarivorous. Among bird species International Union for the Conservation of Nature categorized as least concern category, three species critically endangered, one endangered, two species vulnerable, seven near threatened and two species were not evaluated by IUCN. The avian diversity was lower during summer (155 bird species) and higher in winter (170 bird species). These results indicate that Jhalawar forest division attracts more number of bird species diversity. The Jhalawar forest division needs to have better management plan in future for conserving the landscape in order to support various floral and faunal diversity.

**Key words:** Birds, Relative diversity, Species richness, Transect

Birds are among the best monitors of environmental changes and play an important role in the control of insect pests, as predators of rodents, scavengers, seed dispersers and as pollinating agents and thus form an important component in natural ecosystem (Manjunath and Joshi 2012). Birds also act as good environmental indicators revealing the state of the ecosystems such as forest edges, wetlands and major river basins. Avian community composition and species richness is associated with biotic (habitat structure) as well as with abiotic factors such as temperature and precipitation. Avifaunal diversity has been decreasing rapidly due to the destruction of natural habitat by human activities. Protection and maintenance of avifaunal diversity is important in maintaining species diversity of plants and animals (Simeone et al 2002). The avian habitat is roughly divided into forest, scrub and wetlands, although many species require a mixed type of habitat. Basic information on the avifaunal diversity from this region is very limited, so that present study was set out to obtain basic information on the presence, richness and diversity of various bird species in Jhalawar forest division, south-eastern Rajasthan both in favorable and adverse climatic conditions.

## MATERIAL AND METHODS

**Study area:** Jhalawar Forest Division is situated in the south-

eastern part of the Hadoti region and located at the edge of Malwa Plateau of Rajasthan in India and is characterized by slight undulation on the west and a vast fertile expanse on the east (Prakash and Singh 2001) spread over an area of about 150-180 sq.km. This forest division falls in the territory (24° 37' to 24° 46' N and 76° 02' to 76° 11' E) extending from the south-east part of the Gagron fort (24° 37' 41.5" N, 76° 10' 52.6" E) along the western bank of Kalisindh River to Khanpura village. Beyond that it forms a strip of an average 10 km width and joins the Mukundara Hill National Park in the north-west. Climate of the area is identical to the Indo-Gangetic plain. The study area receives high temperature generally around 40° C and at maximum can exceed 45° C during summer and fall down up to 1° C in winter. Jhalawar district receives highest annual precipitation in Rajasthan state 890 mm which keeps it cool and gentle breezes ward off the stifling humidity which supports varied numbers of diversity of flora and fauna.

Tropical thorn scrub forest found in the plains towards Kalisindh River and tropical dry deciduous forest on the hills in west of Jhalawar (Champion and Seth 1968). Dominant vegetation types are *Acacia leucophloea*, *Anogeissus pendula*, *Butea monosperma*, *Diospyros melanoxylon*, *Zizyphus* sp., *Prosopis juliflora* and *Madhuca indica* as scattered across a flat landscape. There are small patches of

moderately dense dry deciduous forest dominated by the tree species of *Butea monosperma* and *Anogeissus pendula* in the undulating parts of the forest (Pande 2012).

**Data collection and analysis:** Entire Jhalawar Forest Division was surveyed comprehensively for to understand the presence of the birds during March, 2014 to February, 2015. The line transect method was used, for estimating diversity and abundance which involves moving along a fixed length of 1 km and recording the bird species seen and voice heard on both sides of transect (Bibby et al 1992). A total of 16 permanent transects were laid and surveyed twice in every season that covered most of the study area. Field surveys were carried out every season in the morning from 6.00 to 10.00 hours and evening from 16.00 to 18.00 hours when birds most active. Birds were observed using the Nikon binocular (10x50) and photographs were taken with a Nikon D5200 (70-300 VR KIT, Thailand) and Nikon P520 digital cameras and further identified. Birds were searched extensively in habitat like wetlands, forest areas, human-dominated area (city limits) and agricultural farm lands. The area had a few ruins (remains of old structures/buildings) belonging to the erstwhile princely state, which were searched for the species inhabiting them. The data recorded in each survey analyzed for relative abundance on the basis of the frequency of sightings, as per MacKinnon and Phillipps (1993): very common (VC) sighted more than 10 times; common (CO) sighted from 7-9 times; uncommon (UC) sighted from 3-6 times; rare (RA) sighted 1 or 2 times. Bird species diversity was estimated by recording the number of bird species observed in each season. The residential status of the birds was worked out, and different status categories were used; resident (R), winter visitor (WV) and summer visitor (SV) were assigned strictly with reference to the study area on the basis of the presence or absence method (Grimmett et al 2011). Feeding guilds of birds were recorded as per Ali and Ripley (2007), i.e. omnivorous, carnivorous, insectivorous, granivorous, frugivorous and nectarivorous. The IUCN (2016) status was also used to compare the local status with the global status. During the surveys, other information or threats to birds' conservation were also recorded. Species richness of birds was estimated by recording the number of bird species observed. The relative diversity (RDi) of orders and families was calculated using the following formula (Torre-Cuadros et al 2007):

$$RDI = \frac{\text{Number of bird species in a no order or family}}{\text{Total number of species}} \times 100$$

## RESULTS AND DISCUSSION

A total of 181 birds species belonging to 22 orders and

65 families were recorded during the all seasons from the Jhalawar Forest Division. The non-passerine birds dominated the diversity with 109 species compared to passerine birds (72 species). The present study revealed that the Anatidae family showed highest bird diversity with 14 species, followed by Accipitridae (11 species), Muscicapidae (10 species), Ardeidae (8 species), Cisticolidae, Columbidae (7 species each), Motacillidae, Scolopacidae (6 species each), Alaudidae, Phasianidae, Sturnidae (5 species each), Ciconiidae, Cuculidae, Picidae, Rallidae (4 species each), Campephagidae, Charadriidae, Corvidae, Hirundinidae, Laniidae, Leiotherichidae, Passeridae, Psittaculidae, Threskiornithidae (3 species each), Apodidae, Caprimulgidae, Dicuridae, Estrildidae, Falconidae, Gruidae, Halcyonidae, Jacanidae, Megalaimidae, Paridae, Sternidae, Strigidae and Sylviidae (2 species each). However, 28 families showed vary poor domination with single bird species. The RDi value calculated for the orders and families separately, highest value of RDi was calculated for order Passeriformes with 28 families and 72 species followed by the order Charadriiformes with 6 families and 15 species and the lowest species richness recorded from the orders Podicipediformes, Pteroclidiformes and Turniciformes which were represents by one species belonging to each family (Table 2). The RDi values calculated for families, highest were estimated for Anatidae family (RDi = 7.73) (Table 3).

The data on residential status revealed that among 181 bird species, 133 bird species were resident, whereas the remaining 48 bird species showed migration (44 bird species seasonal and 4 bird species passage migrations). The residential bird species also have showed the differences in their relative abundance (Fig. 3). Altogether forty one bird species were identified as WV (winter visitor), three as SV (summer visitor) and four as PV (passage visitor). Further analysis of relative abundance indicated that 17 species were VC (very common), 59 species were CO (common), 76 Species were UC (uncommon) and 29 species were RA (rare).

The feeding guilds of bird species showed that omnivorous (63 bird species) followed by insectivorous (54 bird species), carnivorous (42 bird species), granivorous (14 bird species), frugivorous (7 bird species) and nectarivorous (1 bird species) (Table 1). A significant number of insectivorous bird species, present in the study area, are important agents of bio-control of insect pests in agriculture, horticulture and forest (Thakur et al 2010). Certain species of birds in the study area that have been IUCN already categorized as critically endangered vultures – *Gyps bengalensis*, *Gyps indicus*, *Sarcogyps calvus* and one endangered *Neophron percnopterus* were recorded from the

**Table 1.** Systematic checklist and status of birds in Jhalawar Forest Division, Rajasthan, India

Common Name	Scientific name	IUCN status	Residential status	Relative abundance	Feeding guild
<b>Accipitriformes: Accipitridae</b>					
Black Kite	<i>Milvus migrans</i> (Boddaert, 1783)	LC	R	CO	C
Black-winged Kite	<i>Elanus caeruleus</i> (Desfontaines, 1789)	LC	R	CO	O
Egyptian Vulture	<i>Neophron percnopterus</i> (Linnaeus, 1758)	EN	R	UC	C
Indian White-backed Vulture	<i>Gyps bengalensis</i> (Gmelin, 1788)	CR	R	RA	C
Long-billed Vulture	<i>Gyps indicus</i> (Scopoli, 1786)	CR	R	RA	C
Oriental Honey-buzzard	<i>Pernis ptilorhyncus</i> (Temminck, 1821)	LC	R	RA	C
Red-headed Vulture	<i>Sarcogyp scalvus</i> (Scopoli, 1786)	CR	R	RA	C
Shikra	<i>Accipiter badius</i> (Gmelin, 1788)	LC	R	CO	C
Short-toed Snake Eagle	<i>Circaetus gallicus</i> (Gmelin, 1788)	LC	R	RA	C
Tawny Eagle	<i>Aquila rapax</i> (Temminck, 1828)	LC	R	RA	C
White-eyed Buzzard	<i>Butastur teesa</i> (Franklin, 1831)	LC	R	CO	C
<b>Accipitriformes: Pandionidae</b>					
Osprey	<i>Pandion haliaetus</i> (Linnaeus, 1758)	LC	WV	RA	C
<b>Anseriformes: Anatidae</b>					
Bar-headed Goose	<i>Anser indicus</i> (Latham, 1790)	LC	WV	RA	O
Comb Duck	<i>Sarkidiornis melanotos</i> (Pennant, 1769)	LC	WV	RA	O
Common Pochard	<i>Aythya ferina</i> (Linnaeus, 1758)	LC	WV	RA	O
Eurasian Teal	<i>Anas crecca</i> (Linnaeus, 1758)	LC	WV	UC	O
Cotton Pygmy-goose	<i>Nettapuscoromandelianus</i> (Gmelin, 1789)	LC	R	UC	O
Eurasian Wigeon	<i>Anas penelope</i> (Linnaeus, 1758)	LC	WV	UC	O
Gadwall	<i>Anas strepera</i> (Linnaeus, 1758)	LC	WV	UC	O
Lesser Whistling Duck	<i>Dendrocygna javanica</i> (Horsfield, 1821)	LC	R	UC	O
Mallard	<i>Anas platyrhynchos</i> (Linnaeus, 1758)	LC	WV	RA	O
Northern Pintail	<i>Anas acuta</i> (Linnaeus, 1758)	LC	WV	UC	O
Northern Shoveler	<i>Anas clypeata</i> (Linnaeus, 1758)	LC	WV	UC	O
Red-crested Pochard	<i>Netta rufina</i> (Pallas, 1773)	LC	WV	RA	O
Ruddy Shelduck	<i>Tadorna ferruginea</i> (Pallas, 1764)	LC	WV	UC	O
	<i>Anas poecilorhyncha</i> (Forster, 1781)	LC	WV	CO	O
<b>Apodiformes: Apodidae</b>					
Asian Palm Swift	<i>Cypsiurus balasiensis</i> (J.E. Gray, 1829)	LC	R	CO	O
Little Swift	<i>Apus affinis</i> (J.E. Gray, 1830)	LC	R	CO	O
<b>Bucerotiformes: Upupidae</b>					
Hoopoe	<i>Upupa epops</i> (Linnaeus, 1758)	LC	R	UC	I
<b>Bucerotiformes: Bucerotidae</b>					
Indian Grey Hornbill	<i>Ocyrceros birostris</i> (Scopoli, 1786)	LC	R	CO	O
<b>Caprimulgiformes: Caprimulgidae</b>					
Indian Nightjar	<i>Caprimulgus asiaticus</i> (Latham, 1790)	LC	R	RA	I
Savanna Nightjar	<i>Caprimulgus affinis</i> (Horsfield, 1821)	LC	R	UC	I
<b>Charadriiformes: Recurvirostridae</b>					
Black-winged Stilt	<i>Himantopus himantopus</i> (Linnaeus, 1758)	LC	R	CO	O
<b>Charadriiformes: Jacanidae</b>					
Bronze-winged Jacana	<i>Metopidius indicus</i> (Latham, 1790)	LC	R	RA	O
Pheasant-tailed Jacana	<i>Hydrophasianus chirurgus</i> (Scopoli, 1786)	LC	R	UC	O

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<b>Charadriiformes: Scolopacidae</b>					
Black-tailed Godwit	<i>Limosa limosa</i> (Linnaeus, 1758)	NT	WV	RA	O
Common Sandpiper	<i>Actitis hypoleucos</i> (Linnaeus, 1758)	LC	WV	UC	O
Common Snipe	<i>Gallinago gallinago</i> (Linnaeus, 1758)	LC	WV	UC	O
Green Sandpiper	<i>Tringa chropus</i> (Linnaeus, 1758)	LC	WV	RA	O
Little Stint	<i>Calidris minuta</i> (Leisler, 1812)	LC	WV	RA	O
Wood Sandpiper	<i>Tringa glareola</i> (Linnaeus, 1758)	LC	WV	RA	O
<b>Charadriiformes: Glareolidae</b>					
Indian Courser	<i>Cursoriuscoro mandelicus</i> (Gmelin, 1789)	LC	R	RA	I
<b>Charadriiformes: Charadriidae</b>					
Little ringed Plover	<i>Charadrius dubius</i> (Scopoli, 1786)	LC	R	CO	I
Red-wattled Lapwing	<i>Vanellus indicus</i> (Boddaert, 1783)	LC	R	VC	O
Yellow-wattled Lapwing	<i>Vanellus malabaricus</i> (Boddaert, 1783)	LC	R	UC	I
<b>Charadriiformes: Sternidae</b>					
River Tern	<i>Sterna aurantia</i> (J.E. Gray, 1831)	NT	R	UC	O
Whiskered Tern	<i>Chlidonias hybrid</i> (Pallas, 1811)	LC	WV	RA	O
<b>Ciconiiformes: Ciconiidae</b>					
Asian Openbill	<i>Anastomus oscitans</i> (Boddaert, 1783)	LC	R	UC	C
White Stork	<i>Ciconia ciconia</i> (Linnaeus, 1758)	LC	WV	RA	C
Painted Stork	<i>Mycteria leucocephala</i> (Pennant, 1769)	NT	R	UC	C
White-necked Stork	<i>Ciconia episcopus</i> (Boddaert, 1783)	VU	R	UC	C
<b>Columbiformes: Columbidae</b>					
Blue Rock Pigeon	<i>Columba livia</i> (Gmelin, 1789)	LC	R	CO	G
Eurasian Collared Dove	<i>Streptopelia decaocto</i> (Frivaldszky, 1838)	LC	R	VC	G
Laughing Dove	<i>Spilopelia senegalensis</i> (Linnaeus, 1766)	LC	R	VC	G
Oriental Turtle Dove	<i>Streptopelia orientalis</i> (Latham, 1790)	LC	WV	RA	G
Red-collared Dove	<i>Streptopelia tranquebarica</i> (Hermann, 1804)	LC	R	CO	G
Spotted Dove	<i>Spilopelia chinensis</i> (Scopoli, 1786)	LC	R	CO	G
Yellow-footed Green Pigeon	<i>Treronp hoenicoptera</i> (Latham, 1790)	LC	R	UC	G
<b>Coraciiformes: Alcedinidae</b>					
Common Kingfisher	<i>Alcedo atthis</i> (Linnaeus, 1758)	LC	R	UC	C
<b>Coraciiformes: Cerylidae</b>					
Lesser-pied Kingfisher	<i>Ceryle rudis</i> (Linnaeus, 1758)	LC	R	UC	C
<b>Coraciiformes: Coraciidae</b>					
Indian Roller	<i>Coracias benghalensis</i> (Linnaeus, 1758)	LC	R	UC	C
<b>Coraciiformes: Halcyonidae</b>					
Stork-billed Kingfisher	<i>Pelargopsis capensis</i> (Linnaeus, 1766)	LC	R	RA	C
White-breasted Kingfisher	<i>Halcyon smymensis</i> (Linnaeus, 1758)	LC	R	CO	C
<b>Coraciiformes: Meropidae</b>					
Green bee-eater	<i>Merops orientalis</i> (Latham, 1801)	LC	R	CO	I
<b>Cuculiformes: Cuculidae</b>					
Asian Koel	<i>Eudynamys scolopaceus</i> (Linnaeus, 1758)	LC	R	CO	O
Common hawk-Cuckoo	<i>Hierococcyx varius</i> (Vahl, 1797)	LC	R	UC	O
Pied-crested Cuckoo	<i>Clamator jacobinus</i> (Boddaert, 1783)	LC	SV	CO	O
Southern Coucal	<i>Centropus sinensis</i> (Stephens, 1815)	LC	R	CO	O
<b>Falconiformes: Falconidae</b>					
Common Kestrel	<i>Falco tinnunculus</i> (Linnaeus, 1758)	LC	WV	UC	C

Laggar Falcon	<i>Falco jugger</i> (J.E. Gray, 1834)	NT	R	UC	C
<b>Galliformes: Phasianidae</b>					
Grey Francolin	<i>Francolinus pondicerianus</i> (Gmelin, 1789)	LC	R	CO	O
Red Spurfowl	<i>Galloperdix spadicea</i> (Gmelin, 1789)	LC	R	RA	O
Indian Peafowl	<i>Pavo cristatus</i> (Linnaeus, 1758)	LC	R	UC	O
Jungle Bush Quail	<i>Perdica asiatica</i> (Latham, 1790)	LC	R	UC	O
Rock Bush Quail	<i>Perdica laargoondah</i> (Sykes, 1832)	LC	R	CO	O
<b>Gruiformes: Gruidae</b>					
Sarus Crane	<i>Grus antigone</i> (Linnaeus, 1758)	VU	R	UC	O
Demoiselle Crane	<i>Grus virgo</i> (Linnaeus, 1758)	LC	WV	RA	O
<b>Gruiformes: Rallidae</b>					
Common Moorhen	<i>Gallinula chloropus</i> (Linnaeus, 1758)	LC	R	UC	O
Eurasian Coot	<i>Fulica atra</i> (Linnaeus, 1758)	LC	R	CO	O
Grey-headed Swamphen	<i>Porphyrio poliocephalus</i> (Latham, 1801)	LC	R	CO	O
White-breasted Waterhen	<i>Amauromis phoenicurus</i> (Pennant, 1769)	LC	R	CO	O
<b>Passeriformes: Acrocephalidae</b>					
Sykes' Warbler	<i>Idunarama</i> (Sykes, 1832)	LC	WV	RA	I
<b>Passeriformes: Aegithinidae</b>					
Common Iora	<i>Aegithina tiphia</i> (Linnaeus, 1758)	LC	R	UC	I
<b>Passeriformes: Alaudidae</b>					
Ashy-crowned Sparrow Lark	<i>Eremopterix griseus</i> (Scopoli, 1786)	LC	R	CO	I
Crested Lark	<i>Galerida cristata</i> (Linnaeus, 1758)	LC	PV	RA	O
Indian Bushlark	<i>Mirafra erythroptera</i> (Blyth, 1845)	LC	R	UC	O
Oriental Skylark	<i>Alauda gulgula</i> (Franklin, 1831)	LC	R	UC	O
Rufous-tailed Lark	<i>Ammomanes phoenicura</i> (Franklin, 1831)	LC	R	UC	I
<b>Passeriformes: Campephagidae</b>					
Black-headed Cuckooshrike	<i>Coracina melanoptera</i> (Ruppell, 1839)	LC	PV	RA	I
Large Cuckooshrike	<i>Coracina macei</i> (Lesson, 1830)	LC	R	UC	I
Small Minivet	<i>Pericrocotus cinnamomeus</i> (Linnaeus, 1766)	LC	R	CO	I
<b>Passeriformes: Cisticolidae</b>					
Ashy Prinia	<i>Prinia socialis</i> (Sykes, 1832)	LC	R	CO	I
Common Tailorbird	<i>Orthotomus sutorius</i> (Pennant, 1769)	LC	R	CO	I
Grey-breasted Prinia	<i>Prinia hodgsonii</i> (Blyth, 1844)	LC	R	CO	I
Jungle Prinia	<i>Prinia sylvatica</i> (Jerdon, 1840)	LC	R	UC	I
Plain Prinia	<i>Prinia inornata</i> (Sykes, 1832)	LC	R	UC	I
Rufous-fronted Prinia	<i>Prinia buchanani</i> (Blyth, 1844)	LC	R	UC	I
Zitting Cisticola	<i>Cisticola juncidis</i> (Rafinesque, 1810)	LC	R	UC	I
<b>Passeriformes: Corvidae</b>					
House Crow	<i>Corvus splendens</i> (Vieillot, 1817)	LC	R	VC	O
Indian Jungle Crow	<i>Corvus macrorhynchos</i> (Wagler, 1827)	LC	R	UC	O
Rufous Treepie	<i>Dendrocitta vagabunda</i> (Latham, 1790)	LC	R	VC	F
<b>Passeriformes: Dicruridae</b>					
Black Drongo	<i>Dicrurus macrocercus</i> (Vieillot, 1817)	LC	R	VC	I
White-bellied Drongo	<i>Dicrurus caerulescens</i> (Linnaeus, 1758)	LC	R	UC	I
<b>Passeriformes: Emberizidae</b>					
Crested Bunting	<i>Melophus lathami</i> (Gray, 1831)	LC	R	CO	G
<b>Passeriformes: Estrildidae</b>					
Indian Silverbill	<i>Lonchura malabarica</i> (Linnaeus, 1758)	LC	R	CO	O

Scaly-breasted Munia	<i>Lonchura punctulata</i> (Linnaeus, 1758)	LC	R	CO	G
<b>Passeriformes: Hirundinidae</b>					
Dusky Crag Martin	<i>Ptyonoprogne concolor</i> (Sykes, 1832)	LC	R	CO	I
Red-rumped Swallow	<i>Cecropis daurica</i> (Laxmann, 1769)	LC	R	CO	I
Wire-tailed Swallow	<i>Hirundo smithii</i> (Leach, 1818)	LC	R	CO	I
<b>Passeriformes: Laniidae</b>					
Bay-backed Shrike	<i>Lanius vittatus</i> (Valenciennes, 1826)	LC	R	CO	C
Long-tailed Shrike	<i>Lanius schach</i> (Linnaeus, 1758)	LC	R	VC	C
Southern Grey Shrike	<i>Lanius meridionalis</i> (Temminck, 1820)	LC	R	UC	C
<b>Passeriformes: Leiothrichidae</b>					
Common Babbler	<i>Turdoides caudate</i> (Dumont, 1823)	LC	R	UC	O
Jungle Babbler	<i>Turdoides striata</i> (Dumont, 1823)	LC	R	UC	O
Large Grey Babbler	<i>Turdoides malcolmi</i> (Sykes, 1832)	LC	R	CO	O
<b>Passeriformes: Monarchidae</b>					
Asian Paradise Flycatcher	<i>Terpsiphone paradisi</i> (Linnaeus, 1758)	LC	PV	UC	I
<b>Passeriformes: Motacillidae</b>					
Citrine Wagtail	<i>Motacilla citreola</i> (Pallas, 1776)	LC	WV	UC	I
Grey Wagtail	<i>Motacilla cinerea</i> (Tunstall, 1771)	LC	WV	UC	I
Paddyfield Pipit	<i>Anthus rufulus</i> (Vieillot, 1818)	LC	R	VC	I
White Wagtail	<i>Motacilla alba</i> (Linnaeus, 1758)	LC	WV	UC	I
White-browed Wagtail	<i>Motacilla maderaspatensis</i> (Gmelin, 1789)	LC	R	CO	I
Western Yellow Wagtail	<i>Motacilla flava</i> (Linnaeus, 1758)	LC	WV	UC	I
<b>Passeriformes: Muscicapidae</b>					
Black Redstart	<i>Phoenicurus ochruros</i> (Gmelin, 1774)	LC	WV	CO	I
Blue Rock Thrush	<i>Monticola solitaries</i> (Linnaeus, 1758)	LC	WV	UC	I
Bluethroat	<i>Luscinia svecica</i> (Linnaeus, 1758)	LC	WV	UC	I
Brown Rock Chat	<i>Cercomela fusca</i> (Blyth, 1851)	LC	R	CO	I
Indian Robin	<i>Saxicoloides fulicatus</i> (Linnaeus, 1766)	LC	R	CO	I
Oriental Magpie Robin	<i>Copsychus saularis</i> (Linnaeus, 1758)	LC	R	CO	I
Pied Bush Chat	<i>Saxicola caprata</i> (Linnaeus, 1766)	LC	WV	CO	I
Red-breasted Flycatcher	<i>Ficedula parva</i> (Bechstein, 1792)	LC	WV	CO	I
Siberian Stonechat	<i>Saxicola maurus</i> (Pallas, 1773)	NE	WV	UC	I
Tickell's Blue Flycatcher	<i>Cyornis tickelliae</i> (Blyth, 1843)	LC	R	UC	I
<b>Passeriformes: Nectariniidae</b>					
Purple Sunbird	<i>Cinnyris asiaticus</i> (Latham, 1790)	LC	R	VC	N
<b>Passeriformes: Oriolidae</b>					
Indian Golden Oriole	<i>Oriolus kundoo</i> (Sykes, 1832)	LC	SV	CO	O
<b>Passeriformes: Paridae</b>					
Cinereous Tit	<i>Parus cinereus</i> (Vieillot, 1818)	LC	R	CO	O
Indian black-tored Tit	<i>Machlolophu saplonotus</i> (Blyth, 1847)	NE	R	UC	O
<b>Passeriformes: Passeridae</b>					
Baya weaver	<i>Ploceus philippinus</i> (Linnaeus, 1766)	LC	R	CO	O
Chestnut-shouldered Petronia	<i>Petronia xanthocollis</i> (E. Burton, 1838)	LC	R	VC	O
House Sparrow	<i>Passer domesticus</i> (Linnaeus, 1758)	LC	R	VC	G
<b>Passeriformes: Phylloscopidae</b>					
Common Chiffchaff	<i>Phylloscopus collybita</i> (Vieillot, 1817)	LC	WV	UC	I
<b>Passeriformes: Pittidae</b>					
Indian Pitta	<i>Pitta brachyuran</i> (Linnaeus, 1766)	LC	SV	UC	I

<b>Passeriformes: Pycnonotidae</b>						
Red-vented Bulbul	<i>Pycnonotus cafer</i> (Linnaeus, 1766)	LC	R	VC	F	
<b>Passeriformes: Rhipiduridae</b>						
White-browed Fantail	<i>Rhipidura aureola</i> (Lesson, 1830)	LC	R	UC	I	
<b>Passeriformes: Stenostiridae</b>						
Grey-headed Canary Flycatcher	<i>Culicicapa ceylonensis</i> (Swainson, 1820)	LC	WV	CO	I	
<b>Passeriformes: Sturnidae</b>						
Asian Pied Starling	<i>Gracupica contra</i> (Linnaeus, 1758)	LC	R	CO	O	
Bank Myna	<i>Acridotheres ginginianus</i> (Latham, 1790)	LC	R	UC	G	
Brahmini Starling	<i>Sturnia pagodarum</i> (Gmelin, 1789)	LC	R	CO	G	
Indian Myna	<i>Acridotheres tristis</i> (Linnaeus, 1766)	LC	R	VC	G	
Rosy Starling	<i>Pastor roseus</i> (Linnaeus, 1758)	LC	PV	UC	O	
<b>Passeriformes: Sylviidae</b>						
Lesser Whitethroat	<i>Sylvia curruca</i> (Linnaeus, 1758)	LC	WV	UC	I	
Yellow-eyed Bbler	<i>Chrysomma sinense</i> (Gmelin, 1789)	LC	R	CO	I	
<b>Passeriformes: Tephrodornithidae</b>						
Common Woodshrik	<i>Tephrodornis pondicerianus</i> (Gmelin, 1789)	LC	R	CO	I	
<b>Passeriformes: Zosteropidae</b>						
Oriental White-eye	<i>Zosterops palpebrosus</i> (Temminck, 1824)	LC	R	VC	O	
<b>Pelecaniformes: Ardeidae</b>						
Black-crowned Night Heron	<i>Nycticorax nycticorax</i> (Linnaeus, 1758)	LC	R	UN	C	
Cattle Egret	<i>Bubulcus ibis</i> (Linnaeus, 1758)	LC	R	VC	C	
Grey Heron	<i>Ardea cinerea</i> (Linnaeus, 1758)	LC	WV	UC	C	
Indian Pond Heron	<i>Ardeola grayii</i> (Sykes, 1832)	LC	R	VC	C	
Intermediate Egret	<i>Mesophoyx intermedia</i> (Wagler, 1827)	LC	R	CO	C	
Large/Great Egret	<i>Ardea alba</i> (Linnaeus, 1758)	LC	R	UC	C	
Little Egret	<i>Egretta garzetta</i> (Linnaeus, 1766)	LC	R	VC	C	
Purple Heron	<i>Ardea purpurea</i> (Linnaeus, 1766)	LC	R	CO	C	
<b>Pelecaniformes: Threskiornithidae</b>						
Black-headed Ibis	<i>Threskiornis melanocephalus</i> (Latham, 1790)	NT	R	UC	C	
Eurasian Spoonbill	<i>Platalea leucorodia</i> (Linnaeus, 1758)	LC	R	UC	C	
Red-naped Ibis	<i>Pseudibis papillosa</i> (Temminck, 1824)	LC	R	UC	C	
<b>Piciformes: Megalaimidae</b>						
Brown-headed Barbet	<i>Megalaima zeylanica</i> (Gmelin, 1788)	LC	R	UC	F	
Coppersmith Barbet	<i>Megalaima haemacephala</i> (S. Muller, 1776)	LC	R	CO	F	
<b>Piciformes: Picidae</b>						
Brown-capped Pygmy	<i>Picooides nanus</i> (Vigors, 1832)	LC	R	UC	I	
Eurasian Wryneck	<i>Jynx torquilla</i> (Linnaeus, 1758)	LC	WV	UC	I	
Black-rumped Flameback	<i>Dinopium benghalense</i> (Linnaeus, 1758)	LC	R	UC	I	
Yellow-crowned Woodpecker	<i>Leiopicus mahrattensis</i> (Latham, 1801)	LC	R	UC	I	
<b>Podicipediformes: Podicipedidae</b>						
Little Grebe	<i>Tachybaptus ruficollis</i> (Pallas, 1764)	LC	R	CO	C	
<b>Psittaciformes: Psittaculidae</b>						
Alexandrine Parakeet	<i>Psittacula eupatria</i> (Linnaeus, 1766)	NT	R	RA	F	
Plum-headed Parakeet	<i>Psittacula cyanocephala</i> (Linnaeus, 1766)	LC	R	CO	F	
Rose-ringed Parakeet	<i>Psittacula krameri</i> (Scopoli, 1769)	LC	R	CO	F	

<b>Pteroclidiformes: Pteroclididae</b>					
Chestnut-bellied Sandgrouse	<i>Pterocles exustus</i> (Temminck, 1825)	LC	R	UC	G
<b>Strigiformes: Strigidae</b>					
Indian Scops Owl	<i>Otus bakkamoena</i> (Pennant, 1769)	LC	R	UC	C
Spotted Owlet	<i>Athene brama</i> (Temminck, 1821)	LC	R	CO	C
<b>Strigiformes: Tytonidae</b>					
Barn Owl	<i>Tyto alba</i> (Scopoli, 1769)	LC	R	UC	C
<b>Suliformes: Anhingidae</b>					
Oriental Darter	<i>Anhinga melanogaster</i> (Pennant, 1769)	NT	WV	UC	C
<b>Suliformes: Phalacrocoracidae</b>					
Little Cormorant	<i>Microcarbo niger</i> (Vieillot, 1817)	LC	R	CO	C
<b>Turniciformes: Turnicidae</b>					
Barred Buttonquail	<i>Turnix suscitator</i> (Gmelin, 1789)	LC	R	UC	O

**Table 2.** Relative diversity (RDi) of various orders of birds in Jhalawar forest division, Rajasthan, India

Order	Rdi of species
Accipitriformes	6.63
Anseriformes	7.73
Apodiformes	1.10
Bucerotiformes	1.10
Caprimulgiformes	1.10
Charadriiformes	8.29
Ciconiiformes	2.21
Columbiformes	3.87
Coraciiformes	3.31
Cuculiformes	2.21
Falconiformes	1.10
Galliformes	2.76
Gruiformes	3.31
Passeriformes	39.78
Pelecaniformes	6.08
Piciformes	3.31
Podicipediformes	0.55
Psittaciformes	1.66
Pteroclidiformes	0.55
Strigiformes	1.66
Suliformes	1.10
Turniciformes	0.55

study area. Two species of vulnerable birds – *Ciconia piscopus* and *Grus antigone* and seven species of near threatened birds – *Limosa limosa*, *Sterna aurantia*, *Mycteria leucocephala*, *Falco jugger*, *Threskiornis melanocephalus*, *Psittacula eupatria* and *Anhinga melanogaster* were observed to be present in the study area. Two bird species (*Saxicola maurus* and *Macholophu saplonotus*) have not been evaluated by the IUCN and 166 bird species were

placed in the least concern category (Table 1) (Birdlife International 2016). The maximum Shannon-Wiener species diversity indices were during winter ( $H' = 4.547$ ) followed by monsoon ( $H' = 4.479$ ) and summer ( $H' = 4.207$ ).

The present study revealed that Jhalawar forest division of Rajasthan, represent sound avifaunal diversity. Numerous ornithological studies on diversity, and its status, have been carried out in Rajasthan (Venkitachalam, 2006, Bhatnagar et al 2007, Sangha 2008, Sivaperuman et al 2009, Singh, 2009, Pande 2012, Koli et al 2013, 2014, Chauhan and Kavita 2014). Pande (2012) recorded 77 species of birds belonging to 14 orders and 44 families were reported between May and June (2011) in Jhalawar Forest Range. The present study results revealed that 181 bird species belonging to 22 orders and 65 families which were very highest during winter season and minimum in summer season. Similarly, bird species richness and diversity was found to be high during winter and low in summer were observed from August 2012 to July 2014 from the lowland riparian forest in Athikadavu Valley, Nilgiri Biosphere Reserve (Manikandan and Balasubramanian 2016). Similarly, Yadav (2014) has recorded 113 terrestrial bird species from forest and urban areas of Coimbatore city, Tamil Nadu.

Jhalawar district is known as the 'Cherapunji of Rajasthan', due to it receiving the highest rainfall in the State. The forest area is dominated with *Anogeissus pendula*, *Butea monosperma*, *Diospyros melanoxylon*, *Lannea coromandelica*, *Madhuca indica*, *Ziziphus* sp. and also has a good number of wetlands. These forest and wetlands support a variety of bird species. Some wetlands are disturbed by the human activities like disposal of wastage material, constructions of the buildings, water pumping for the agriculture, etc. are found during the study period. There is a necessity to conserve these wetlands and manage them

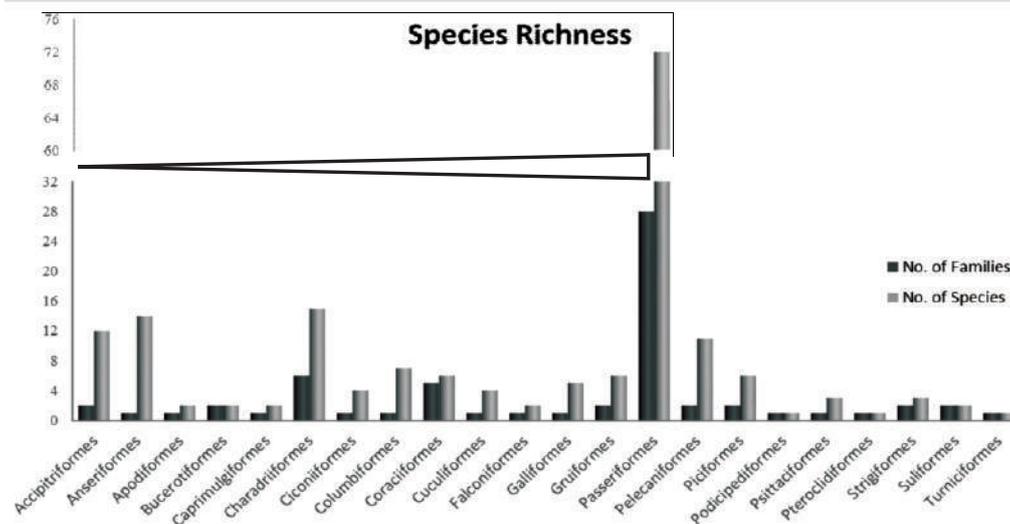


Fig. 1. Species Richness of birds in orders in Jhalawar forest division, Rajasthan, India

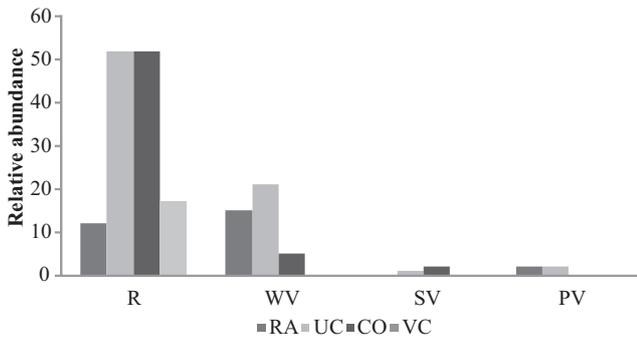


Fig. 2. Residential status (R = resident; WV = winter visitor; SV = summer visitor and PV = passage visitor) and relative abundance (VC = very common; CO = common; UC = uncommon and RA = rare) of birds in Jhalawar forest division, Rajasthan, India

scientifically. Agricultural farmlands also support a good number of bird species due to the availability of the food material and/or suitable microclimate. In some places of the study area illegal felling of the trees and livestock grazing by the villagers living around the forest was observed. Excessive beedi leaves (*Diospyros melanoxylon*) collection is also a major threat to the forest and fauna. Need to conserve local flora and fauna by the extension programs in the villages.

**CONCLUSION**

The present study results revealed that 181 bird species belonging to 22 orders and 65 families which were highest during winter season and minimum in summer season. The different ecosystems of Jhalawar consisted of various species of birds, revealing the importance of the habitat. However, in these ecosystems, bird species diversity

experiencing is under great anthropogenic factors. Therefore is an urgent need to take conservation measure that would aim in the better wildlife habitat management programmes in the division.

**ACKNOWLEDGEMENT**

We thank to the Forests Department of Jhalawar, Government of Rajasthan (India), for giving permission to carry out this study. We also thank to Dr. C. Srinivasulu, Assistant Professor, Department of Zoology, Osmania University and Dr. R. Venkitachalam, Research Associate, ATREE, Bangalore for their valuable comments and suggestions for the improvements of this manuscript.

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**Table 3.** Relative diversity (RDi) of various families of birds in Jhalawar Forest Division, Rajasthan, India

Families	No. of species
Accipitridae	6.08
Acrocephalidae	0.55
Aegithinidae	0.55
Alaudidae	2.76
Alcedinidae	0.55
Anatidae	7.73
Anhingidae	0.55
Apodidae	1.10
Ardeidae	4.42
Bucerotidae	0.55
Campephagidae	1.66
Caprimulgidae	1.10
Cerylidae	0.55
Charadriidae	1.66
Ciconiidae	2.21
Cisticolidae	3.87
Columbidae	3.87
Coraciidae	0.55
Corvidae	1.66
Cuculidae	2.21
Dicruridae	1.10
Emberizidae	0.55
Estrildidae	1.10
Falconidae	1.10
Glareolidae	0.55
Gruidae	1.10
Halcyonidae	1.10
Hirundinidae	1.66
Jacaniidae	1.10
Laniidae	1.66
Leiothrichidae	1.66
Megalaimidae	1.10
Meropidae	0.55
Monarchidae	0.55
Motacillidae	3.31
Muscicapidae	5.52
Nectariniidae	0.55
Oriolidae	0.55
Pandionidae	0.55
Paridae	1.10
Passeridae	1.66
Phalacrocoracidae	0.55
Phasianidae	2.76
Phylloscopidae	0.55
Picidae	2.21
Pittidae	0.55
Podicipedidae	0.55
Psittaculidae	1.66
Pteroclididae	0.55
Pycnonotidae	0.55
Rallidae	2.21
Recurvirostridae	0.55
Rhipiduridae	0.55
Scolopacidae	3.31
Stenostiridae	0.55
Sternidae	1.10
Strigidae	1.10
Sturnidae	2.76
Sylviidae	1.10
Tephrodornithidae	0.55
Threskiornithidae	1.66
Trogonidae	0.55
Tytonidae	0.55
Upupidae	0.55
Zosteropidae	0.55

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Received 12 December, 2017; Accepted 31 January, 2018



## Water Bird Diversity of Madjen Djedj Marsh, Northeastern Algeria

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**Abstract:** The study was conducted (2016-2017) on Madjen Djedj Wetland (Marsh) to determine the seasonal diversity and population dynamics of aquatic avifauna. Seasonal differences in relative species abundance were analyzed from the viewpoint of diversity/dominance. The study revealed the occurrence of 15 species belonging to 6 families, out of which 9 species were passage visitors, 5 species were migratory and 1 species was breeder migrant. The seasonal structure of water bird communities indicates highly dominated assemblages manifesting themselves in reduced species diversity and increased dominance of certain species. The highest number of species (9 species) was found in November and February. The Northern shoveler (*Anas clypeata*) was highly dominant species together accounting for more than 20.68 percent of water bird communities. This study indicates that Madjen Djedj Marsh is a suitable habitat for diverse water birds and thus should be protected in order to enhance the population of water birds species.

**Keywords:** Madjen Djedj, Northern shoveler, Migratory, Breeder migrant, Water birds

Wetlands constitute the most productive ecosystems of the world with specific ecological characteristics, functions and values. Their high productivity places them among the richest and most biologically diverse ecosystems in the world (Kivaisi 2001). Water birds are an important component of almost of the wetland ecosystem as they occupy several trophic levels in the food web of wetland ecosystem. One of the very important functions the wetlands perform is to provide suitable site for the breeding of the resident as well as a wintering ground for short and long distance migratory water birds. A wide variety of birds use wetland habitats for all or part of their life. They form one of the major components of the wetland ecosystems. (Ashis et al 2010). Water birds are only the most prominent groups that attract public to wetlands, but also are good bio-indicators and useful models for studying a variety of environmental problems (Urfi et al 2005). Madjen Djedj Marsh is one of the important wetland of northeastern Algeria as feeding, resting and wintering grounds for large number of migratory water birds during their Palaearctic to Oriental migration. In the present paper, an attempt has been made to evaluate the community structure of aquatic avifauna of Madjen Djedj Wetland in different months of the year, so that proper conservatory measures can be adopted by the wildlife authorities for the preservation of the wetland in accordance with the particular requirements of the avifauna in their habitat.

### MATERIEL AND METHODS

**Study area:** The present study was carried out from

November 2016 to May 2017 in Madjen Djedj Marsh (36° 1'31.38"N, 8° 14'27.41"E) situated in Northeast Algeria; covering approximately an area of 7.5 ha (Fig. 1). Almost 70% of its area is covered by helophytes plants dominated by *Scirpus maritimus* and *Scirpus lacustris*.

**Bird surveys:** Total counts of water bird densities were made for the entire Marsh twice in a month by following method of Spindler (Spindler et al 1981) in order to avoid double counting or missing birds a vantage point was used (Nagarajan and Thiyagesan 1996). A pair of binoculars with magnification 7× 50 was used in identification of birds visually alongside a field guide (Guide Ornitho) and the checklist was prepared using standardized common and scientific names of the birds following Bird Life Checklist Version 7 (2014). Residential status of different species like passage visitors, migratory and breeder migrant have assigned strictly with reference to the study area on the basis of sightings during study period.

**Data analysis:** For each count session, the species richness, relative abundance and local occurrence status (frequency of occurrence) was calculated. The relative abundance (%) of bird species was determined using the expression:  $n/N \cdot 100$  (where n is the number of the recorded bird species and N the total number of observations recorded) (Zakaria et al 2009). To describe the frequency of occurrence (*fi*) according to Dajoz (2006) the number of surveys during which the species was recorded was divided by the total number of conducted surveys. The diversity



Fig. 1. General view of Madjen Djedj Marsh

indices, such as the Simpson index,  $D$  (according to the formula  $D = 1 - \{\sum ni (ni - 1) / N (N - 1)\}$ , where  $ni$  is the total number of birds of each individual species;  $N$  is the total number of birds of all species), the Shannon diversity index  $H'$  (according to the formula  $H' = -[\sum Pi \ln Pi]$ , where,  $H'$  = Diversity Index;  $Pi$  = is the proportion of each species in the sample; and Evenness ( $E$ ) (Pielou index) (Shannon diversity index ( $H'$ ) divided by the maximum diversity ( $\ln S$ ),  $S$  being the total number of species recorded during each visit). The index of evenness shows the number of individuals distributed among species (Okpiliya 2012). All analyses were performed using the computer language R, version 3.2.5 (R Development Core Team 2013). Multivariate analyses such as the correspondence analysis (CA) map were performed using the mean number of individuals per species per month

to illustrate the temporal assemblage of birds in this area.

## RESULTS AND DISCUSSION

A total of 15 species were recorded belonging to 6 families during the study Period (Table 1). The family Anatidae with 9 species was the richest in species number, followed by Scolopacidae (2 species). Rallidae, Pandionidae, Recurvirostridae and Charadriidae with only 1 species each (Fig. 2). Among all the species recorded, 9 species were categorized as passage visitors, 5 species as migrant winter and 1 species as breeder migrant. (Table 1). Passage visitors were northern pintail (*Anas acuta*), mallard (*Anas platyrhynchos*), common pochard (*Aythya ferina*), brant goose (*Branta bernicla*), common moorhen (*Gallinula chloropus*), black-winged stilt (*Himantopus himantopus*), Common scoter (*Melanitta nigra*), Spotted Redshank (*Tringa erythropus*) and wood sandpiper (*Tringa glareola*). They visited the wetland during their Palaearctic to Oriental journey, stayed there and then migrated southwardly. They again visited the wetland during their Oriental to Palaearctic journey. Wintering water birds included those which visited the wetland during their winter migration, utilized the wetland for few months and then returned to their native place 5 species of water birds. Eurasian wigeon (*Anas penelope*), Common Teal (*Anas crecca*), northern shoveler (*Anas clypeata*), gadwall (*Anas strepera*) and little grebe (*Tachybaptus ruficollis*), were recognized as wintering water birds. The little ringed plover (*Charadrius dubius*) are categorized as migrant breeder which utilized the wetland as

Table 1. Ecological status and relative abundance of water birds occurring at Madjen Djedj Marsh

Scientific name (abbreviation)	Phenological status <sup>a</sup>	Conservation status <sup>b</sup>	Local status <sup>c</sup>	Annual relative abundance <sup>d</sup>
<i>Anas acuta</i> (ANAC)	PV	LC	R	1.648
<i>Anas penelope</i> (ANPE)	WV	LC	R	0.778
<i>Anas crecca</i> (ANCR)	WV	LC	UC	7.197
<i>Anas clypeata</i> (ANCL)	WV	LC	UC	20.685
<i>Anas platyrhynchos</i> (ANPL)	PV	LC	R	2.197
<i>Anas strepera</i> (ANST)	WV	LC	UC	8.841
<i>Aythya ferina</i> (AYFE)	PV	LC	R	1.648
<i>Branta bernicla</i> (BRBE)	PV	LC	R	1.442
<i>Melanitta nigra</i> (MENI)	PV	LC	R	1.442
<i>Gallinula chloropus</i> (GACH)	PV	LC	R	3.148
<i>Tachybaptus ruficollis</i> (TARU)	WV	LC	UC	7.646
<i>Himantopus himantopus</i> (HIHI)	PV	LC	R	11.607
<i>Charadrius dubius</i> (CHDU)	MB	LC	UC	11.904
<i>Tringa erythropus</i> (TRER)	PV	LC	R	0.4657
<i>Tringa glareola</i> (TRGL)	PV	LC	UC	19.344

Mb<sup>a</sup> = Migrant breeder; WV = Winter migrant and PV = Passage visitor;

<sup>b</sup>Bird Life Checklist Version\_7 (2014) LC = Least Concern (Common in all);

<sup>c</sup>Species Uncommon (UC) (25% < fi < 50%); Rare (R) (5% < fi < 25%)

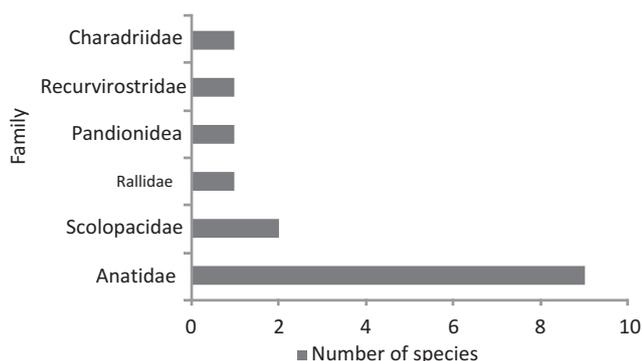


Fig. 2. Species richness of water birds at Madjen Djedj Marsh

stop-breeding site.

Based on the frequency of sightings, 6 species were considered to be common and 9 to be rare species (Table 1). In accordance with the Bird Life Checklist Version\_7 (2014), all species were assigned the status of 'Least Concern' (Table 1). As for the relative abundance of individuals Northern shoveler (*Anas clypeata*) was highly dominant with 20.68 percent of the birds recorded throughout study period, followed by several species such as woods and piper (*Tringa glareola*) (19.34%), little ringed plover (*Charadrius dubius*) (11.90%), black-winged stilt (*Himantopus himantopus*) (11.60%), gadwall (*Anas strepera*) (8.84%), little grebe (*Tachybaptus ruficollis*) (7.64%) and the common teal (*Anas crecca*) (7.19%), while other species had the relative abundance less than 3.

A well-marked seasonal variation in water-bird population was recorded during the present study period. More 20 individuals were counted between November and March (Fig.3), the period during which the average number of species was also the highest ranging from 4 to 9. On the factorial map of CA containing 57.84% of the information, this period was represented by birds showing a positive correlation with the autumn and winter months. Whereas, the second period lasting from April to May exhibited the lowest number of species and individuals (less than 20) (Fig. 3 and 4). Representative of this period were the bird species that are dominant in spring months. In addition, this ordination demonstrates the actual temporal succession of this Marsh occupation by water birds. Aquatic birds were divided into five groups based on their dominance period in the study period. Thus, water bird species that are dominant in winter month (February) (Fig. 4) formed the first group and those showing a positive correlation with month of December fell into the second and third group. The fourth group comprised species that are characteristic of autumn and winter months. (November, January), and the five group included birds that are dominant in early autumn and spring months, i.e. in

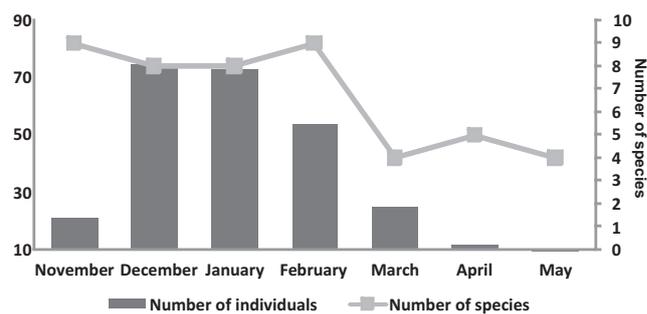


Fig. 3. Monthly variations in individuals and number species of Madjen Djedj Marsh

(October, March, April and May).

The species richness of the wetland fluctuated during the study period, the maximum of 9 species being recorded in the wintering season compared to the minimum of 4 species recorded in the spring period (Table 2). Variation in other diversity metrics was low (H'; D and E). Hence, only the number of species fluctuated between months. Our results revealed a noteworthy community organization during the study period characterized by following patterns: one dominant species (northern shoveler), with the higher proportion of dominance (20.68% of the birds recorded throughout the study period) increasing Simpson's index, which has never been recorded below 0.60, thus indicating an evidently lower evenness. Determining the diversity of water bird species inhabiting Madjen Djedj Marsh are important in order to understand the bird community structure, the health of wetland habitats and to provide an appropriate index to develop an effective bird conservation strategy within the context of ecological and spatial parameters for future management. The surveyed avifauna of Madjen Djedj Marsh was less (23 species) than that identified by Guellati et al (2014). Decline in the water bird number indicated the possibility of degradation of the habitat conditions. The study revealed that the phenological status of the little ringed plover (*Charadrius dubius*) at this Marsh has changed. This species was not reported as breeding in previous water bird studies in eastern Algeria (Baaziz et al 2011, Elafri et al 2016).

The water bird community structures (species richness, distribution and diversity) in autumn-winter months showed less similarity with that in other months. Highest diversity in winter months was attributed to the influx of migratory water birds during this season. Least diversity in other months was ascribed to the departure of all wintering and staging migrant birds that return to their breeding sites in the Palearctic and sub-Saharan Africa (Samraoui et al 2011). Water is a major driven factor that affected aquatic vegetation composition

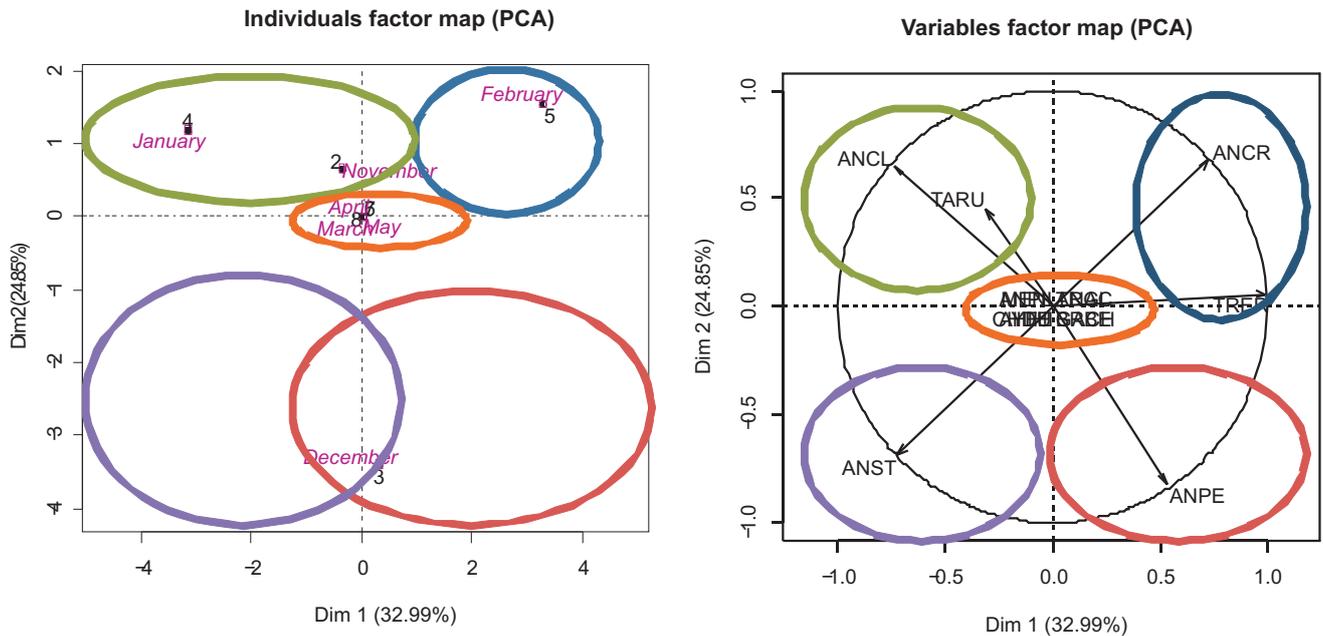


Fig. 4. Correspondence analysis map (CA ) of water birds species abundance at Madjen Djedj Marsh: 6 mean months × 15 species. (Abbreviations in Table 1)

Table 2. Univariate metrics of water bird diversity at Madjen Djedj Marsh

Indices	
Species richness	15
Shannon diversity index(H')	0.76
Simpson index (D)	0.58
Equitability or evenness (E)	0.42

and food resources that influenced bird diversity and distribution (Colwell and Taft, 2000, Quinn, 2002, Wilcox et al 2002). Almost 70 percent of the Marsh area is covered by various helophytes plants, such as *Scirpus maritimus* and *S. lacustris*, which are the main source of food and a major element of their habitats.

It was observed that diversity of wetland habitat such as shallow water, emergent vegetation patches, marsh edges and adjacent vegetated area had attracted different water bird species such as Passage visitor's birds (northern pintail, mallard, wood sandpiper, common pochard, brant goose, common moorhen, black-winged stilt, spotted redshank and wood sandpiper), Wintering water birds(Eurasian wigeon, common teal, northern shoveler, gadwall and little grebe) and migrant breeder (little ringed plover). It has been reported that water depth is an important variable affecting the habitat selection in water birds(Colwell and Taft 2000, Isola et al 2002), because it directly determines the accessibility of prey while foraging (Collazo et al 2002, Darnell and Smith 2004). The little ringed plover heavily utilized this marsh for nesting,

roosting and chick rearing purposes. The reason is that, this vegetated Marsh provide safe nesting and chick rearing site, due to reduce ground predators access to their breeding site and are within the vicinity of ideal foraging site and shallow water.

Low values of diversity indices (Shannon and evenness) and high values of Simpson index were due to the high abundance of the northern shoveler, a wintering migrant species, in all north-eastern Algerian wetlands (Isenmann and Moali 2000). The indices (Shannon and evenness) obtained during this study were much lower than those recorded in other wetlands of North-eastern Algeria during the wintering period, Garaet Hadj-Tahar (H' = 3.5 and E = 0.7) (Metallaoui and Houhamdi, 2010) and Lake Beni-Belaid (H' = 3.58 and E = 0.7) (Mayache 2008). The structural patterns indicate that the ecosystem has suffered an anthropogenic or natural stress or it has reached the ageing state. (Battisti et al 2009). Indeed, it is known that disturbed (anthropogenic or natural stress) habitats are usually dominated by a very small number of species compared to undisturbed sites (Magurran 2004). Illegal hunting, fishing, and domestic activities were the main anthropogenic factors recorded during the study period .

**CONCLUSION**

Madjen Djedj Marsh serves as an important feeding, wintering and breeding ground for large number of migratory water-birds but the continuous anthropogenic stress over the

wetland has resulted into the decline in the number of water-bird species as well as count. Thus, the information generated from this study would be essential from further research aimed at explaining the causes and consequences of increased numbers of widespread species over a broader span of time. This can be of help in various strategies for the conservation of water-birds as well as their habitat.

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## Land Use Effect on Soil Properties in Abakaliki Southeastern Nigeria

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**Abstract:** The effect of different land use in selected soil properties was studied in 2016 at Abakaliki southeastern, Nigeria. Five replicate auger and core soil samples from A – land used for crop production, B –land used for cattle production, C –grass and shrub land and D –forest land were collected and used for the determination of selected soil physicochemical properties. The data obtained was subjected to analysis of Variance (ANOVA) in a CRD and mean that was significant was separated using Fisher's least significant difference (F-LSD). The results showed that land used for animal and crop productions had lower nutrients whereas grass & shrub land and forestry land had higher nutrients. Hence, the importance of encouraging the planting of vegetation in our land to improve soil productivity.

**Keywords:** Degradation, Ecosystem, Erosion, Productivity, Quality

Land use is defined as the activities, arrangements and inputs people undertake in a certain land cover type to produce, change or maintain it (Ajami et al 2006). The anthropogenic changes in land use have altered the characteristics of the Earth's surface, leading to changes in soil physicochemical properties, soil fertility, soil erosion sensitivity and content of soil moisture (Abad et al 2014). Land use changes from natural ecosystems into managed ecosystems resulted in negative effects on soil structure and quality. Abad et al (2014) showed that forest clearing and subsequently cultivation and tillage practices resulted in the decline of the soil quality and these changes affect on soil sensitivity to degradation and erosion. Bernoux et al (1998) indicated that long practices of deforestation and/or replacement of natural forests by agroecosystem and uncontrolled overgrazing have been the major causes for soil erosion and climatic change. Since harvested trees are not replaced and, thus, expose the soil, about 1.9 to 3.5 billion tons of fertile topsoils are washed away annually into rivers and lakes due to deforestation alone (Wasihun, 2015). Studies have shown that land use changes are severe in the last half a century across different countries in Africa. For instance Gete and Hurni (2001) has shown that forest cover has decline by 99% with 95% subsequent expansion in cultivated land area. Similarly, Kebrom and Hodlund (2000) reported a reduction in forest cover by 31% with increase of cultivated land by 2.4% into forest and marginal land within between 1958 – 1986 and has resulted to land degradation and decrease in soil fertility. Similarly, converting forested

and agricultural landscapes into urban land uses greatly alters energy fluxes and the water, carbon, and nutrient cycles of these ecosystems (Pataki et al 2006, Pouyat et al 2007, Yulia et al 2010). Land use and management are influencing not only soil properties but also soil erosion processes. While unsuitable agricultural practices can cause soil erosion, on the contrary use of cover can reduce risk of erosion and improve soil fertility and productivity (García-Orenes et al 2010, García-Orenes et al 2009). The aim of the study is to determine the effect of different land use in selected soil properties.

### MATERIAL AND METHODS

**Study Area :** The study was carried out in Abakaliki the capital of Ebonyi State. Abakaliki lies on Latitude 6° 19' N and Longitude 8° 6' E and in a derived savannah of the Southeastern agro-ecological zone of Nigeria. It occupies an area of approximately 5,939 square kilometer with estimated population of 141,438 people according to the 2006 Nigeria census. The economy of the town is based on Agriculture, informal services and small scale industries. Abakaliki has a tropical climate with distinct dry and wet seasons characterized by the prevalence of the moist South Westerly Monsoon winds that result in heavy rainfall spread between April, July and August, October periods and dry season within November to March. The minimum and maximum temperatures of the area are 27°C and 31°C, respectively. The relative humidity of the area is between 60 – 80%. The area has an annual rainfall range of 1700 –2000mm and the

soil of the area belongs to the order Ultisol classified as typic Haplustult (Federal Department of Agriculture and Land Resources 1985). The land for crop and cattle production, grass and shrub and forest were used for the study. Five replicate samples of both core and auger sample were collected. Auger soil samples were collected at 0 – 30cm depth. Soil auger samples were used for determination of chemical parameters and particle size distribution while core samples were used for physical parameters.

Physical parameters were determined standard methods .

Bulk density –Blake and Hartage (1986)

Total porosity –Obi and Ebo (1995).

Water content on a mass basis –Obi (2000).

Aggregate stability –Kemper and Rosenau (1986).

Particle size distribution –Gee and Bunder (1979).

Mean weight diameter – Kemper and Rosenau (1986).

Dispersion ratio –Kemper and Rosenau (1986).

Chemical parameters determined by using following methods:

Organic Carbon –Nelson and Sommer (1982).

Soil pH was determined –glass electrode pH meter (Mclean, 1982).

Total Nitrogen (TN) – modified Kjeldahl digestion procedure (Bremmer and Mulvaney 1982).

Available phosphorus – by Olsen and Sommers (1982).

Total exchangeable bases (TEB), base saturation (BS), effective cation exchange capacity (ECEC) and exchangeable bases and exchangeable acidity (EA) –Chapman (1982).

**Statistical analysis:** Data was subjected to analysis using Fisher's least significant difference (F-LSD) as recommended by SAS Institute Inc. (1999).

## RESULT AND DISCUSSION

**Physical properties:** The soils were sandy loam and poor in plant nutrients as it is prone to leaching of these nutrients beneath the soil (Table 1). There were significant differences in bulk density, total porosity, water content on mass basis,

**Table 1.** Texture of the soils studied

Site	Sand (gkg <sup>-1</sup> )	Silt (gkg <sup>-1</sup> )	Clay (gkg <sup>-1</sup> )	Texture
Crop production	475	404	121	Sandy loam
Cattle production	445	415	140	Sandy loam
Grass and shrub land	485	407	108	Sandy loam
Forest land	425	420	155	Sandy loam

mean weight diameter and aggregate stability among the sites studied with respect with land use. The lowest bulk density of 1.29gcm<sup>-3</sup> was recorded in forest land while that of other sites ranged between 1.32 – 1.79gcm<sup>-3</sup> with land used for crop production recording the highest bulk density. Similarly, total porosity decreased as bulk density was increasing. The increased in bulk density and decreased in total porosity in this study was in agreement with the study of Bernoux et al (1998), which showed that long practices of deforestation and/or replacement of natural forests by agroecosystem and uncontrolled overgrazing have been the major causes for soil erosion and degradation. The order of increase in water content on mass basis was B < A < C < D. The highest mean weight diameter of 2.40 mm was observed in forest land. This recorded mean weight diameter in forest was higher than the mean weight diameter in A, B and C by 18, 16 and 2 percent, respectively. The order of increase of aggregate stability was B < A < C < D. On the other hand there was non-significant change in dispersion ratio among the difference sites studied. However, forest land recorded the lowest dispersion ratio while land used for cattle production had the highest value. Abad et al (2014) showed that forest clearing and subsequently cultivation and tillage practices resulted in the decline of the soil quality and these changes effects on soil sensitivity to degradation and erosion.

**Chemical properties:** Land use effects on pH, available P, total N and organic C was as shown in Table 3. There was a significant (P < 0.05) change among the different land use with regard to the parameters studied. Lowest pH of 4.73 was observed in land use for cattle production while the pH in other sites ranged between 5.01–5.67 with forest land recording the highest value. The order of increase in

**Table 2.** Physical properties of the soil studied

Site	Bulk density (gcm <sup>-3</sup> )	Total porosity (%)	Water content on mass basis	Means weight diameter (mm)	Aggregate stability (%)	Dispersion ratio
Crop production	1.49	43.77	0.12	1.96	51	0.73
Cattle production	1.79	32.45	0.09	2.01	41	0.76
Grass and shrub land	1.32	50.19	0.17	2.35	62	0.75
Forest land	1.29	51.32	0.18	2.40	63	0.69
CD (p=0.05)	0.09	1.51	0.01	0.02	3.06	NS

**Table 4.** Land use effects on exchangeable bases, total exchangeable bases, exchangeable acidity, effective cation exchange capacity and base saturation of soil studied

Site	(Cmol <sub>(+)</sub> Kg <sup>-1</sup> )							
	Ca	Mg	K	Na	TEB	EA	ECEC	BS (%)
Crop production	3.45	2.01	0.26	0.16	5.88	0.81	6.69	87.89
Cattle production	1.98	1.01	0.23	0.17	3.39	1.05	4.44	76.35
Grass and shrub land	4.76	2.36	0.30	0.17	7.59	0.48	8.07	94.05
Forest land	6.40	3.23	0.30	0.19	10.12	0.87	10.99	92.08
CD (p=0.05)	0.29	0.56	0.04	0.02	0.23	0.07	0.96	2.98

available P was B < A < C < D. Land use for crop production recorded the lowest organic C of 1.3 percent. The observed organic C in land use for crop production was higher than organic C in B, C and D by 44, 52 and 55 percent, respectively. The order of increase in total N was B < A < C < D. Land use for cattle production had C/N ratio of 26.71 while C/N ratio in other land use ranged between 8.67 – 10.42. Land use effects on exchangeable bases, total exchangeable bases, exchangeable acidity, effective cation exchange capacity and base saturation of soil studied are as presented in Table 4. There was also significant change in these parameters among the different sites studied. The order of increase in Ca and Mg was B < A < C < D. Lowest K was observed in land use for crop production while K in other land uses ranged between 0.26 – 0.30 with C and D recording the highest K content. The order of increase in Na was A < B = C < D. Lowest TEB of 3.39 Cmol<sub>(+)</sub>Kg<sup>-1</sup> was observed in land used for cattle production (B). This lowest TEB observed in B was lower than TEB in A, C and D by 74, 124 and 199 percent, respectively. Highest exchangeable acidity of 1.01 Cmol<sub>(+)</sub>Kg<sup>-1</sup> was recorded in land use for cattle production (B), whereas, exchangeable acidity in land used for other purposes ranged between 0.48 – 0.87 Cmol<sub>(+)</sub>Kg<sup>-1</sup>, respectively. The order of increase in ECEC was B < A < C < D. Base saturation was lowest (76.35 Cmol<sub>(+)</sub>Kg<sup>-1</sup>) in B and that of other sites ranged between 87.89–92.08 Cmol<sub>(+)</sub>Kg<sup>-1</sup>, respectively.

From the result, it is observed that unsuitable agricultural practices such as overgrazing caused soil degradation while the use of cover such as grasses, shrubs and trees improve soil fertility and productivity.

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**Table 3.** Land use effects on pH, available P, total N and organic C of the soil studied

Site	pH	Available P (mgkg <sup>-1</sup> )	Organic C	Total N	C/N Ratio
Crop production	5.01	254	1.30	0.15	8.67
Cattle production	4.73	67	1.87	0.07	26.71
Grass and shrub land	5.55	365	1.98	0.19	10.42
Forest land	5.67	387	2.01	0.23	8.74
CD (p=0.05)	0.19	4.67	0.32	0.03	0.35

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## Influence of Mineral Nutrition and Combined Growth Regulating Chemical on Nutrient Status of Sunflower

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**Abstract:** Fertilizers have a radical impact on the level of providing plants with mineral elements. But the practice shows that not only the fertilizers solve all the issues related to the optimization of nutrient regime. The technological cycle of the sunflower has the most stressful situations in the early growing season, after herbicide application or during a long drought, when moisture deficit occurs due to high level of temperature. In these cases it is necessary to treat plants with growth regulators that minimize the impact of stressful conditions and cause intensive consumption of macro – and micronutrients by plants. The present research is focused our research on all these issues and addressed them this article. Field studies were taking during 2015 – 2016 on ordinary soils with poor humus in the Dry Steppe zone. The experience was based on two-factor scheme, where factor A was the background of mineral nutrition (a test plot without fertilizer; N30P45; N60P90); and factor B was foliar feeding of sunflower plants by the integrated growth regulating growth regulator Khelafit Combi® (produced by the company “Khelafit”, Ukraine). The positive effect of the combined growth regulator is always seen in more favorable weather and in climatic conditions of 2016 when the level of the growth regulator influence grew. A double treatment of plants by the Khelafit Combi® showed significant efficiency. In this case, during the use of the growth regulator, the level of the yield was always higher than the indicator HIP05. On average during two years of field research the double processing plants of the sunflower by the growth regulating growth regulator showed that the increase in yield amount on the non fertilized background , N30P45 , N60P90 was 0.22 t ha<sup>-1</sup> (13.6%), 0.27 t ha<sup>-1</sup> (14%) and 0.23 t/ha (11. percent).

**Keywords:** Sunflower, Fertilizer, Growth regulating, Yield, Nutrient status, Khelafit Combi®

The complex multifactorial influence assessment of natural and economic activities provides the opportunity to examine multi-component parts of links of the natural-territorial complex, to determine the spatial-temporal patterns of transformation of agricultural landscapes in terms of intensive and extensive methods of its cultivation and to study the modern soil-climatic and ecological potential of the area for cultivation various crops (Lisetskii 2016, Lisetskii and Pichura 2016). The influence of agro-climatic conditions and farming has a significant impact on the agrochemical condition of the soil, and obtaining the actual crop. Agrochemical principles of qualitative land evaluation are particular relevant in the absence or lack of effective management or of resource-saving economic activities of land users. The main agrochemical parameters, characterize fertility and energy potential of the soil, are the content of humus and mobile elemental forms of power (Lisetskii et al 2017). Regulating the nutrient content in the soil, their absorption by plants at different ratios there is a nutrient regime system. It has a radical impact on the level of plant supply with mineral elements. But the practice shows that not only the fertilizers solve all the issues related to the nutrient

regime optimization. During the vegetation period the plants are under stress for quite a long time and their nutrition under the following environmental conditions is not effective. The farmer's task is to create appropriate conditions for the fastest elimination of plants out from stress conditions (Bazaliy et al 2015). Under these conditions, it is necessary to use multifunctional growth regulating which have a complex of micro-elements, distinguished by a fungicidal action, activate the microorganisms and stimulate the growth processes. From this point of view, the most effective multifunctional growth regulating that meets the requirements of comprehensiveness, is Khelafit Combi®, which contains highly absorbable minerals in balanced for all stages of organogenesis of Khelafit form (Fe, B, Mg, Mn, Zn, Mo, Cu); spores and cell cultures-producers (*Bacillus submiss*, *Pseudomonas* and *Trichoderma*) which gives fungicidal qualities as well as multifunctional stimulators and growth regulators (auxins, cytokine's, gibberellins, humic and fulvic and amino acids) (Bazaliy 2016, Domaratskiy 2017). Balanced formulation also includes effective organic solvents and adhesives which allow to stay longer on the surface of the plant until complete absorption of the solution.

Due to the fact that Khelafit Combi® does not cause resistance in phytopathogens, the growth regulator has a stable effect for many years. The technological cycle of the sunflower has the most stressful situations in the early growing season, after herbicide application or during a long drought, when moisture deficit occurs due to high level of temperature. In these cases it is necessary to treat plants with growth regulators that minimize the impact of stressful conditions and cause intensive consumption of macro – and micronutrients by plants. The present research is focused on all these issues

### MATERIAL AND METHODS

Field studies conducted during 2015–2016 in the Elanetsky district of the Mykolayiv region. Soil research field was ordinary black h with a humus content of hydrolyzed nitrogen 1.5 – 1.8; easy digestible phosphorus 4.5–7.0 and exchangeable potassium 12 – 15 mg 100 g<sup>-1</sup> of soil. The experiment was based on two-factor, where factor A was the background of mineral nutrition (a test plot without fertilizer; N<sub>30</sub>P<sub>45</sub>; N<sub>60</sub>P<sub>90</sub>); and factor B was foliar feeding of sunflower plants (hybrid–Zaklyk) of the integrated growth regulating Khelafit Combi® (produced by the company “Khelafit”, Ukraine). Mineral fertilizers were used during the main processing of the soil by surface spreading using the fertilizer spreader. Treatment of sunflower plants with Khelafit Combi® conducted an aerial sprayer at 4 – 6 real leaves and the budding phase. The growth regulator was used @ 1 l ha<sup>-1</sup>, and a working fluid 250 l ha<sup>-1</sup>. The size of the research plot was 31360 m<sup>2</sup>. The experiment was repeated four times. Soil moisture was determined by the thermostat-weight method. Volume weight of soil was taken from soil acerto and humidity resistant drying was determined experimentally (for soil layer

0 – 30 cm it was equal to 12,5%, and for the layer 0 – 100 cm was 11,8%) (Vadyunina 1986, Gnatenko 2002). Harvesting was performed by the combine threshing method from the accounting area of the plot. It was used a harvester KLAAS with four rows console for sunflower. The collected harvest was counted for the basic presence of humidity (8%) and taking into account the presence of impurities. Experimental data were processed by the method of multifactor variance analysis (Dospikhov 1985). Modeling of yield formation was carried out using the licensed software "Statistica 8.0".

### RESULTS AND DISCUSSION

The Zn and Mn microelements in soil ranged between of 0.4– 0.5 mg<sup>-1</sup> and 9 – 12 mg 1 kg<sup>-1</sup> of soil. Data of soil analysis shows a high need for improving agrochemical indicators by using additional norms of mineral fertilizers. Nitrogen deficiency was observed from the first stages of ontogenesis and in the future, despite the nitrogen fixing activity for the soil micro-flora, the tendency to a shortage of this element remains (Table 1).

Using the complex of growth regulating Khelafit Combi® in foliar feeding for the sunflower was accompanied by the increasing the level of total biomass, at the same time it had not lead to a corresponding decrease of hydrolyzed nitrogen in the soil. There was a tendency to increase the level of this index in the most critical periods of the growing season, due to the anti-stress effect of the Khelafit. Mitigating the negative effects of stress and reducing the time of it allows you to optimize the conditions of supply of agrocenosis in sunflower and reduce the release of nitrogen from the soil. When mineral fertilizers tended to reduce the positive effects of the growth regulating growth regulator on the release of nitrogen from the soil, even though its positive effect did not disappear.

**Table 1.** Dynamics of the hydrolyzed nitrogen content according to fertilizers and the growth regulating growth regulator, mg/100 g soil (Average of 2015–2016)

Fertilizer	Growth regulator	Phenophases			
		Shoots	Beginning of the formation of the baskets	Flowering	Full Ripeness
Without fertilizers	Test	2,91	3,31	2,53	2,40
	Khelafit Combi® (once)	2,91	3,46	2,71	2,58
	Khelafit Combi® (twice)	2,91	3,50	2,68	2,49
N <sub>30</sub> P <sub>45</sub>	Test	3,82	4,01	3,49	3,19
	Khelafit Combi® (once)	3,82	4,24	3,49	3,30
	Khelafit tCombi® (twice)	3,82	4,20	3,58	3,26
N <sub>60</sub> P <sub>90</sub>	Test	4,69	5,27	3,97	3,90
	Khelafit Combi® (once)	4,69	5,21	4,07	3,81
	Khelafit Combi® (twice)	4,69	5,26	4,04	3,87

**Table 2.** Dynamics of the content of easily digestible phosphorous acid depending on fertilizers and the growth regulating growth regulator, mg/100 g soil (Average of 2015-2016)

Fertilizer	The growth regulator	Phenophases			
		Shoots	Beginning of the formation of the baskets	Flowering	Full Ripeness
Without fertilizers	Test	5,5	5,7	5,3	5,1
	KhelaFit Combi® (once)	5,5	5,9	5,6	5,1
	KhelaFit Combi® (twice)	5,5	6,0	5,4	5,2
N <sub>30</sub> P <sub>45</sub>	Test	6,3	6,5	5,7	5,8
	KhelaFit Combi® (once)	6,3	6,8	6,3	6,0
	KhelaFit Combi® (twice)	6,3	6,7	6,0	5,9
N <sub>60</sub> P <sub>90</sub>	Test	6,8	7,0	6,4	6,3
	KhelaFit Combi® (once)	6,8	7,3	6,8	6,2
	KhelaFit Combi® (twice)	6,8	7,2	6,6	6,0

The increase in the crop yield did not affect the reducing of nutrients in the soil. As for the content of easily digestible phosphorus in the soil the results of field studies had different dynamics (Table 2).

When the plants reach the phase of complete ripeness the content of P<sub>2</sub>O<sub>5</sub> in all the variants is aligned and KhelaFit Combi® doesn't lead for increasing the levels of this element of supply in the soil. Important is the fact that the main spending of the analyzed elements of supply, which were spent by the sunflower plants on the formation of 100 kg of dry biomass, had a low level depending on the growth regulatory KhelaFit Combi® (Table 3).

The dependence of major unit costs of nutrients from the growth regulator, but according to this indicator there are no significant changes observed. All these fixing a certain feature of sunflower plants concerning to the removal of nutrients from the soil (Table 3). This plant shapes its level of removal of macro – and micronutrients from the soil depending on the background of the supply. The sunflower

**Table 3.** Cost of nutrients for the formation of 1 kg of dry biomass of sunflower (without making basic fertilizer, (Average of 2015-2016)

Research options	Removal (kg ha <sup>-1</sup> )		Yield of dry biomass, (t ha <sup>-1</sup> )	Cost for 100 kg of dry biomass kg	
	N	P <sub>2</sub> O <sub>5</sub>		N	P <sub>2</sub> O <sub>5</sub>
Test	39,5	12,0	5,38	0,67	0,22
KhelaFit Combi® (once)	35,1	12,6	5,64	0,62	0,22
KhelaFit Combi® (twice)	40,3	11,4	5,78	0,69	0,20

yield is the integrated background impact of the mineral nutrition indicator and the growth regulating growth regulator action of KhelaFit Combi® (Table 4). The results of the studies confirm a clear trend to a positive impact of fertilizers and in all cases it has received an increase of the yield level. The general conclusion is complicated to make regarding to the influence of the growth regulatory growth regulator KhelaFit Combi® because in some versions of the experiment the obtained increase was within the error of experiment (in 2015

**Table 4.** Effect of KhelaFit Combi® application on sunflower yield (t ha<sup>-1</sup>)

Fertilizer	The growth regulator	Year		Average for years of research
		2015	2016	
Without Fertilizers	Test	1,54	1,70	1,62
	KhelaFit Combi® (once)	1,69	1,83	1,76
	KhelaFit Combi® (twice)	1,74	1,93	1,84
N <sub>30</sub> P <sub>45</sub>	Test	1,82	2,01	1,92
	KhelaFit Combi® (once)	1,94	2,11	2,05
	KhelaFit Combi® (twice)	2,12	2,25	2,19
N <sub>60</sub> P <sub>90</sub>	Test	1,95	2,13	2,04
	KhelaFit Combi® (once)	1,99	2,31	2,15
	KhelaFit Combi® (twice)	2,10	2,44	2,27
HIP <sub>05</sub>		A – 0,14	A – 0,15	–
		B – 0,09	B – 0,11	
		AB – 0,16	AB – 0,18	

it was with both fertilizer backgrounds, and in 2016 – with the variant without fertilization).

The positive influence of the combined growth regulator has always been observed. Particularly significant efficiency showed a double treatment of plants by the growth regulator Khelafit Combi®. On average during the two years the increase yield at the control, N30P45 and N60P90 was 0.22 t ha<sup>-1</sup> (13.6%), 0.27 t ha<sup>-1</sup> (14%) and 0.23 t ha<sup>-1</sup> (11.1%).

### CONCLUSION

Analysis of the study results showed that the soil nutrient status at cultivating sunflower can be optimized only when the combination of mineral fertilizers with the double treatment of foliar feeding by the multi-functional combined growth regulator Khelafit Combi®. Further use of the research results will provide the opportunity for multifaceted study and determine the impact of influence of new growth regulator and growth stimulants of plants for the optimization of the nutrient status of sunflower and their application during the crop cultivation in agro-climatic conditions of the Steppe zone of Ukraine.

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## Estimation of Heavy Metal Tolerance and Antibiotic Susceptibility of *Alcaligenes faecalis* Isolated from Polluted Sites of Chambal Region Soil

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**Abstract:** The study was carried out to examine the bacterial flora in soil samples isolated from Chambal region of Madhya Pradesh India. Initially total of 20 isolates were screened on nutrient agar plates containing different heavy metals: CdCl<sub>2</sub>, CsCl and NiCl<sub>2</sub> at 0.25 and, 0.5 µg/ml concentration in their salt form. The morphological, biochemical and phylogenetical characteristics of the most resistant bacterial isolates (Ag-3) were studied. After 16S rRNA gene sequencing, the isolates belongs to species *Alcaligenes faecalis*, and accession number was KU860464. Isolates showed high degree of resistance to heavy metals under investigation, ranging from 10-50 µg/ml. This isolates can further be used for bioremediation of heavy metals from industrial effluent. The microbial growth decreased with the increase in concentration of heavy metals indicating toxic effect on the growth of bacteria Maximum Tolerable Concentration (MTC) of different heavy metals for the growth of isolated strain were evaluated and the pattern of metal tolerance were in the order Ni<sup>2+</sup> > Cd<sup>2+</sup> > Pb<sup>2+</sup> > Cs > Hg<sup>2+</sup> > Co<sup>3+</sup>. Multiple resistance isolates exhibit resistance towards group of antibiotics but increase in heavy metal concentration leads to decrease in antibiotic resistance.

**Keywords:** Heavy metal, Tolerance, Antibiotic susceptibility, Chambal region

Along with industrial progress, environmental pollutants like toxic heavy metals are widely spreading throughout the world. This is especially true for developing countries like China and India (Raja et al 2008). A major environmental concern due to dispersal of industrial and urban wastes generated by human activities which is contaminating the soil. Metals are directly or indirectly affecting all aspects of human and plant life, including growth but also metabolism and differentiation of the biota. The uncontrolled discharges of large quantity of heavy metal-containing wastes develop a large burden affecting economic and health care. Pollution by heavy metals in terrestrial ecosystems has been recognized as a serious environmental concern, due to their non-biodegradability and tendency to accumulate in plants and animal tissues (Otitoloju et al 2009). Some of the heavy metals are essential and are required by the organisms as trace amount (cobalt, chromium, nickel, iron manganese and zinc) (Bruins et al 2000). Some have no biological role and are detrimental to the organisms even at very low concentration (cadmium, copper, lead etc.). Common sources of heavy metal pollution include discharge from industries such as electroplating, mining, smelting, plastics manufacturing, fertilizer and insecticides producing plants. Toxic heavy metals such as lead, cadmium, cesium, nickel and mercury can be differentiated from other pollutants, since they cannot be biodegraded but can be accumulated in

living organisms, thus causing various diseases and disorders even in relatively lower concentrations (Pehlivan et al 2009). Cadmium is one of the most toxic pollutants of the surface soil layer, released into the environment by mining and smelting activities, atmospheric. Nickel (Ni) is the 24th most abundant element in the earth crust and has been detected in different media in all parts of the biosphere. Chemical methods such as precipitation, oxidation or reduction have been widely used to remove metal ions from industrial waste water. Those methods are ineffective or expensive. Biological methods such as bioremediation using microorganisms provide promising alternative to chemical methods.

The present study aims to investigate the ability of natural inhabitant bacteria present in the polluted sites in reducing and detoxifying of heavy metal (Pb, Hg and Cd). This include isolation of naturally occurring bacteria from the polluted soil, screening of the isolates, molecular characterization of that isolates and study their tolerance pattern of different heavy metal at different concentration.

### MATERIAL AND METHODS

**Sample collection:** Soil samples were collected from the soil of three different sites, which were waste and metal dumping area at Chambal Region, Gwalior. The sample was collected in sterilized plastic bags and transported to ITM.

University Gwalior for further analysis. The container was maintained at a temperature of 4°C to ensure minimal biological activity. Processing of the samples for the isolation of bacteria was carried out within 24 hrs of sample collection.

**Isolation and identification of heavy metal resistant bacteria :** Heavy metals incorporated media were used for the selective isolation of heavy metals resistant bacteria. Nutrient agar (NA) incorporated with salts of heavy metals like Cd, Cs, Ni and Co were prepared separately. The concentration of heavy metal was maintained at 0.25 µg ml<sup>-1</sup> and 0.5 µg ml<sup>-1</sup>. After the incubation period (24–48 hrs.) the plates were observed for any kind of growth on the media. The isolated and distinct colonies on these selective media were sub cultured repeatedly on the same media for purification. The pure culture was identified on the basis of their morphology and biochemical characteristics

**Cellular morphological characteristics:** For determining the shape and gram character, bacterial film was stained by Gram's Method. The slide was examined under the microscope.

**Biochemical characterization:** Biochemical tests were performed included indole, methyl red, Voges Proskauer, citrate utilization, H<sub>2</sub>S production, oxidase production, catalase, nitrate reduction and triple sugar iron test.

#### **Physiological Characterization**

**pH:** To determine the pH optimal, nutrient broth medium meant for growth of the isolates was adjusted to different pH ranging from 3.0–11.0 and was seeded with 0.1 ml inoculum. Overnight growth at 37°C under shaking condition was measured in terms of OD at 650 nm by UV spectrometer (Robban et al 2009).

**Temperature:** 0.1 ml inoculum was provided into nutrient broth medium and overnight incubation was done at different temperatures like 4°, 28°, 37° and 55°C. The growth was measured in terms of OD at 650 nm by UV spectrometer (Robban et al 2009).

**NaCl concentration:** Varying concentration of sodium chloride (NaCl) 1, 2, 3, 4 and 5M NaCl and 0.1 ml inoculation were added to nutrient broth medium. Incubated at 37°C for 24 hrs. Optical density was measured at wavelength 650 nm (Robban et al 2009).

#### **Molecular Characterization**

DNA was isolated and evaluated on 1.2% agarose gel, a single band of high-molecular weight DNA has been observed. Fragment of 16S rRNA gene was amplified by PCR from the above isolated DNA. A single discrete PCR amplicon band of 1500 bp was observed when resolved on agarose gel. The purified product was subjected for DNA sequencing and it was carried out GCC Biotech Delhi, India. The PCR amplicon was purified to remove contaminants.

Forward and reverse DNA sequencing reaction of PCR amplicon was carried out with forward and reverse primers. The 16S rRNA gene sequence was used to carry out BLAST tool (<http://www.ncbi.nlm.nih.gov/BLAST>). Multiple sequence alignments were prepared with CLUSTAL-W (<http://www.ebi.ac.uk/clustalw>). Sequences were aligned with the CLUSTAL-X program (Thompson et al 1997) and CLUSTAL-W ([www.ebi.ac.uk/clustalw](http://www.ebi.ac.uk/clustalw)) and by using the Neighbour-Joining algorithm, phylogenetic trees were constructed and viewed with the Tree View program and with MEGA 7.0 (Page 1996). The sequence obtained was submitted to NCBI

**Antibiotic sensitivity:** To detect the antibiotic susceptibility, the bacterial strain was cultured on Muller-Hinton agar plates. The isolated microbes were assayed against eight commercial antibiotics like tetracycline (30 µg disc<sup>-1</sup>), chloramphenicol (30 µg disc<sup>-1</sup>), erythromycin (15 µg disc<sup>-1</sup>), kanamycin (30 µg/disc), rifampicin (5 µg disc<sup>-1</sup>), streptomycin (25 µg disc<sup>-1</sup>), gentamycin (10 µg disc<sup>-1</sup>) and penicillin (2 unit). The bacterial cultured solution was spread on Muller-Hinton agar plates and antibiotic discs were placed. All the plates were incubated at 37°C for 24 hrs. On the basis of their zone diameter, the isolated strain was classified as resistant or sensitive. Control plates were incubated without antibiotic discs.

**Effect of metals on bacterial growth:** Toxicity of the selected metals to the bacterial isolates was determined using five concentrations of each metal (Cd, Cs, Ni, Pb, Hg and Co) prepared with their salt separately in luria bertani broth. These concentrations ranged from 10 to 50 µg ml<sup>-1</sup> medium was amended with each heavy metal and inoculated with exponentially growing cultures 0.1 ml (24 h old, optical density of 0.090 at 650 nm) of bacterial isolates prepared in the same medium. Medium without metal but the bacterial inoculum (bacterial growth control) and medium with metal but without bacteria (abiotic control) served as controls. All the experiments were conducted in triplicate. These cultures were incubated at 37°C in incubator shaker at 30 rpm for 7 days and OD was observed at every 24 hrs interval to obtain standard growth curve for absorbance versus time. The effects of different concentrations of heavy metal ions on growth was recorded

## **RESULTS AND DISCUSSION**

**Isolation of heavy metal tolerant bacteria:** The heavy metal tolerance property of the isolated strain was confirmed by growing it on heavy metal containing media. One of them was selected for our study and the isolated heavy metal tolerant strain was designated as Strain Ag-3. Ag-3 possessed small colony. The colony was circular, convex and

**Table 1.** Biochemical characterizations of isolated strain Ag-3.

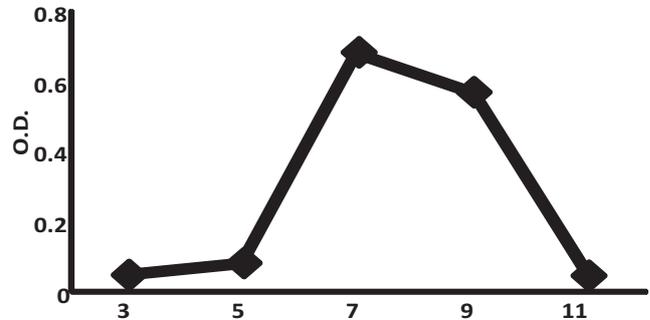
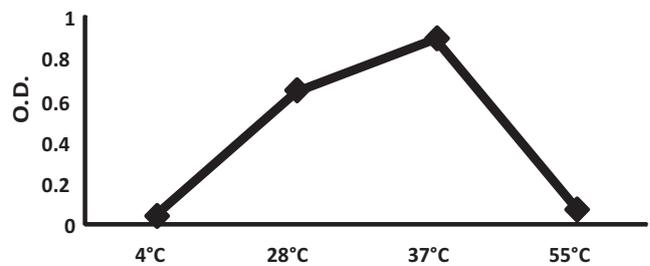
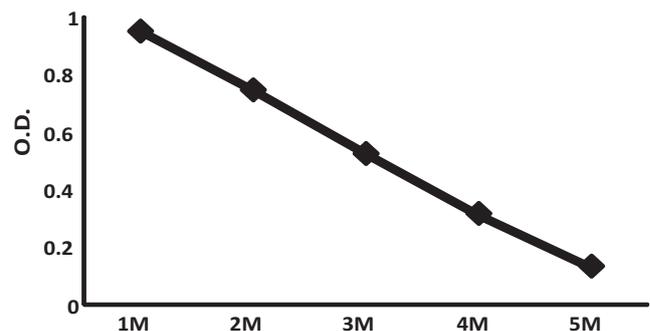
Bacterial strain	Biochemical Test										
	Glucose	Sucrose	Fructose	Indole	Nitrate	H <sub>2</sub> S	MR	VP	Citrate	Catalase	
AG-3 ( <i>Alcaligenes</i> )	Yes	Yes	Yes	-ve	-ve	-ve	-ve	-ve	-ve	+ve	

margin was entire type. Cellular shape of the strain was as rod shape, whereas cellular arrangement was in chain as well as scattered form, and the isolated strain was Gram negative. The results of biochemical characterization are presented in Table 1.

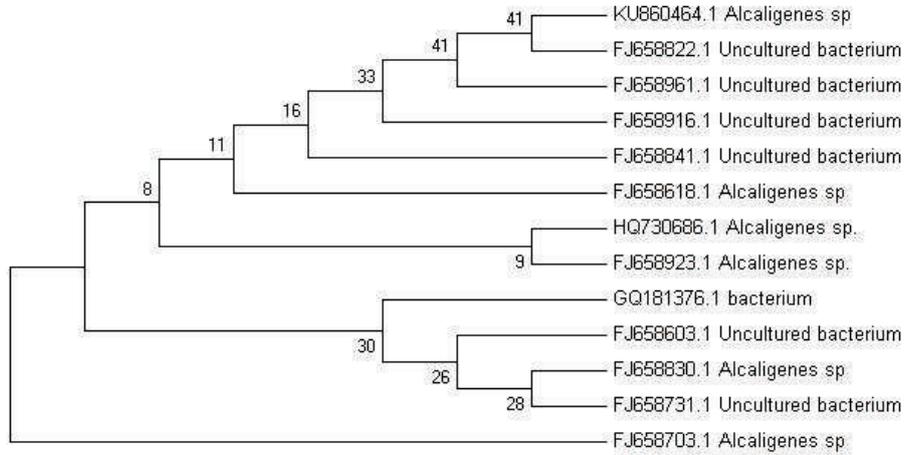
**Physiological characterization:** The isolate strain Ag-3 grow within a pH range of 3.0–11.0. The optimum growth of the isolates at pH 7.0 (Fig. 1). The temperature range found suitable for growth of isolated strain was between 30–40°C, optimum being at 37°C (Fig. 2). The optimum growth for isolated strain was 1M NaCl concentration (Fig. 3). Since survival of a strain depends on salt concentration, temperature and pH profile, it was clear that this strain has ability to survive in adverse condition and in stressed environment tolerance mechanism is develop Ag-3 exhibited maximum growth at 1M & 2M NaCl concentration. Afterwards it showed a declining phase and showed minimum growth at 5M.

**Molecular identification:** Comparative analysis of the sequences of Ag-3 with already available database in NCBI NCBI showed that the strains were closed to the members of genus *Alcaligenes*. nBLAST search of the 16S rRNA sequence of isolated Ag-3 reveals that the isolate was *Alcaligenes faecalis* (Ag-3) Neighbour-Joining (N-J) phylogenetic dendrogram of 16S rRNA gene sequences by using MEGA 7.0. (Gene Bank Accession Number: KU860464) based on nucleotide homology and phylogenetic analysis.

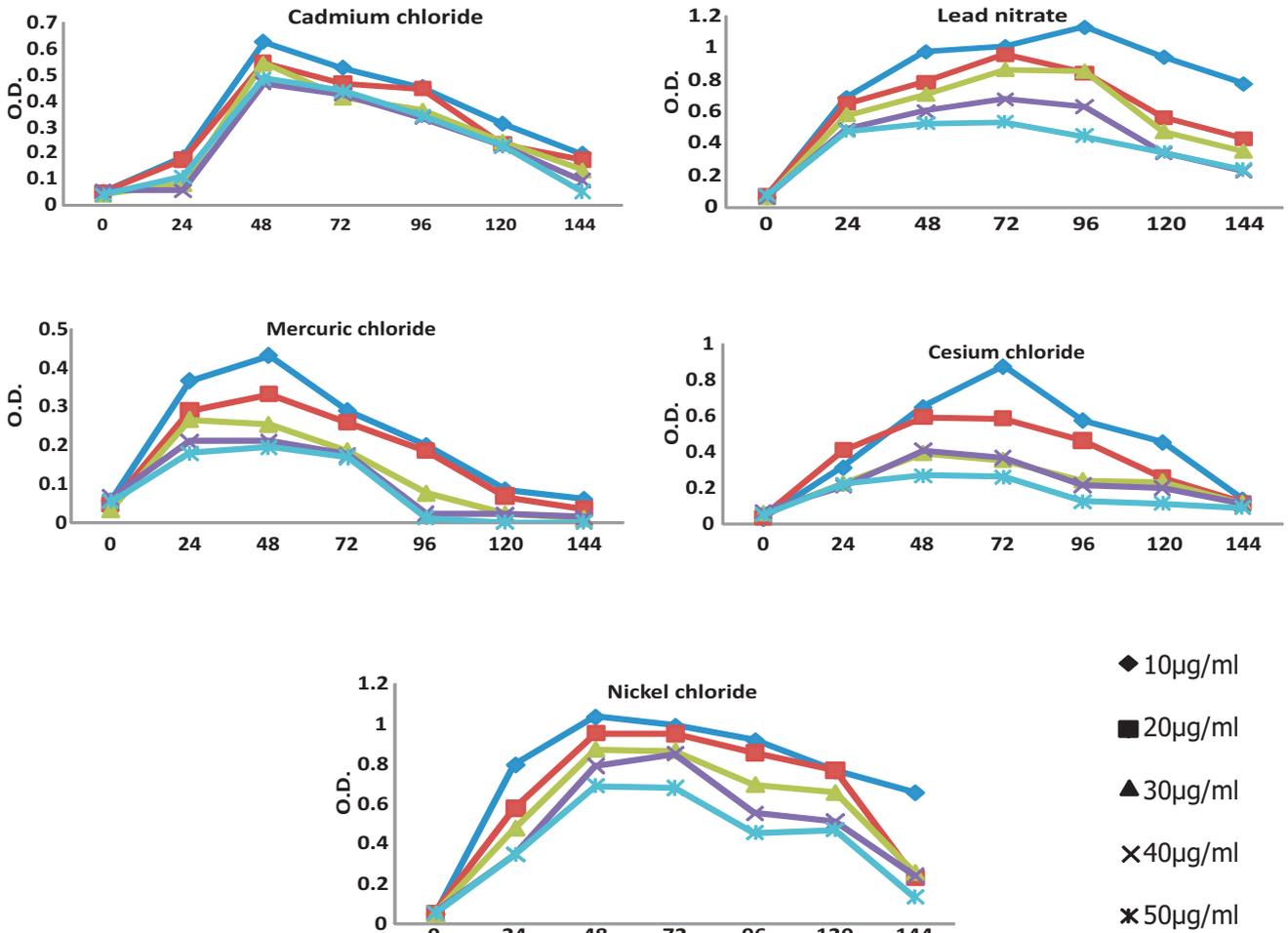
**Effect of heavy metals on bacterial growth:** The Strain Ag-3 exhibited different growth patterns in presence of different heavy metals (Fig. 4). Maximum Tolerable Concentration (MTC) of different heavy metals for the growth of isolated strain were evaluated and the pattern of metal tolerance were in the order  $Ni^{2+} > Cd^{2+} > Pb^{2+} > Cs > Hg^{2+} > Co^{3+}$ . The microbial growth decreased with the increase in concentration of heavy metals indicating toxic effect of the heavy metals on the growth of microorganisms. Multiple resistance isolates exhibit resistance towards group of antibiotics but increase in heavy metal concentration leads to decrease in antibiotic resistance. This furthermore indicates that isolates are fined resistant to tested metals. Growth rate of isolates was little slower in presence of metal than that of control. Such type of results also have been reported earlier (Pal et al 2004, Edward et al 2006). Cadmium showed highest growth at 120 hrs and lead at 96 hrs at  $10\mu g\ ml^{-1}$ . Sudden decrease can be

**Fig. 1.** pH profile for growth of the isolated strain Ag-3 at 650 nm**Fig. 2.** Temperature profile for growth of the isolated strain Ag-3 at 650 nm**Fig. 3.** NaCl concentration profile for growth of the isolated strain Ag-3 at 650 nm

at 120 hrs which gradually decreases in higher concentration of  $40\mu g\ ml^{-1}$  cadmium. In mercuric chloride maximum growth was also at  $10\mu g\ ml^{-1}$  which gradually decrease with increase in concentration of mercuric chloride. In cesium chloride the growth was at  $30\mu g\ ml^{-1}$  after that growth was ceased. Cobalt is highly toxic for the growth of Ag-3.



**Fig. 4.** Neighbour-Joining phylogenetic tree of 16S rRNA gene sequences showing the positions of isolates. The evolutionary history was inferred using the Neighbor-Joining method. The bootstrap consensus tree inferred from 1000 replicates is taken to represent the evolutionary history of the taxa analyzed. Branches corresponding to partitions reproduced in less than 50% bootstrap replicates are collapsed



**Fig. 5.** Growth curves of strain Ag-3 in presence of different concentrations of different heavy metals at different hours

Antibiotics	Concentration	Zone diameter(nm)
Erythromycin	15	R
Chloramphenicol	30	R
Kanamycin	30	R
Gentamycin	10	S
Tetracycline	30	R
Penicillin	2 unit	No Zone
Rifampicin	5	S
Streptomycin	25	S

**Antibiotic susceptibility test:** *Alcaligenes faecalis* (Ag-3) is highly resistance chloramphenicol, kanamycin, tetracycline and rifampicin and also exhibited sensitive to most of the tested antibiotics (Table 2).

### CONCLUSION

The most effective metal which can inhibit the growth of *Alcaligenes faecalis* is mercury and cobalt whereas lead showed least effect at all concentrations. Cadmium is also showing less inhibiting properties. Present study is important because as this will provide pathway to inhibit the growth of non desirable bacteria and also it is providing the information regarding toxicity of various metals.

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## Comparison of Water Requirement and Water Released in Command Area of Branch Canal 70 of Jayakwadi Irrigation Project

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**Abstract:** A study was carried out to determine water requirement of selected crops for the area of Branch canal 70 of Jayakwadi Irrigation Project. Crop water requirement for each of the crop was determined by using 32 years climatic data in CROPWAT software. Reference crop evapotranspiration was determined using FAO Penman Monteith method. The crop coefficient was determined by following the procedure given in FAO 56. The effective rainfall was determined using USDA, SCS method. The result showed that amongst the various crops grown in the study area, sugarcane requires the maximum irrigation water (1385 mm) followed by summer vegetables (671 mm), maize (658 mm), fodder (655 mm), sunflower (399 mm), wheat (342 mm), sorghum (304 mm), pigeon pea (251 mm), gram (217 mm) and cotton (191 mm). Summer crop requires more irrigation water than *rabi* crops. During different irrigation years there was shortage of irrigation water in the command in 2006-07 and 2009-10 of 47.52 and 58.94 per cent, respectively. During 2007-08, 2010-11, 2011-12 and 2014-15, excess irrigation water of 18.95, 53.87, 35.62 and 80 per cent was released than irrigation water requirement, respectively.

**Keywords:** Crop water requirement, CROPWAT, Reference crop evapotranspiration ( $ET_0$ ), Crop coefficient, Effective rainfall

In India water scarcity represents a critical constraint against increasing productivity of crops. Out of 141 million ha net sown area of this country, 86 million ha is under rainfed cultivation. Improved water management holds the key to food security. The availability of water varies abruptly by region, in some areas it is very scarce and causes difficulty in crop production due to shortage of irrigation water. The water table going down drastically and quality of water is deteriorating due to increase in salinity. Water is important for plant growth and food production. Estimating irrigation water requirements accurately is important for water resource planning and management. The primary aim of irrigation is to fulfil the crop water demand when precipitation is not sufficient. The finite total amount of available water is crucial for the economy, health and welfare of a very large part of the developing world. For determining the amount of irrigation and its scheduling it is essential to calculate crop water requirement by considering climatic evaporative demand (Sunil and Shrivastava 2013). Different crops have different water requirements, under the same weather conditions (Adeniran et al 2010). Application of irrigation water as per crop water need is one of the keys to increase crop productivity and improve irrigation efficiency. In the past few decades, several studies have been focused on the development of precise methods for  $ET_0$  estimation

and improving the performance of existing methods, due to wide application of  $ET_0$  data. A few empirical or semi-empirical methods have been developed for estimating daily reference evapotranspiration from weather parameters. The Penman-Monteith method ranked as the best method for all climatic conditions (Allen et al 1998). FAO of United Nations has recommended the use of the Penman-Monteith method as the standard method for estimation of  $ET_0$ .

CROPWAT is a decision support system developed by the Land and Water Development Division of FAO for planning and management of irrigation. CROPWAT is meant as a practical tool to carry out standard calculations for reference evapotranspiration, crop water requirements, crop irrigation requirements and more specifically the design and management of irrigation schemes. Now a day, CROPWAT has been mostly used to estimate the volume of water needed for the most effective irrigation control and to increase the performance of the existing system (Sudarsan and Ashutosh 2016). In order to assess the performance of irrigation canal system of Jayakwadi Irrigation Project, the representative branch-70 was selected for investigation purpose. By using the CROPWAT software the irrigation water requirement was computed and compared with water released amount.

## MATERIAL AND METHODS

**Study area:** The Branch 70 is a tributary of left bank canal of Jayakwadi Irrigation Project which covers most of the area of Parbhani district of Maharashtra state. The climate of the study area is semi-arid. Parbhani is intersected by 19° 16' N latitude and 76° 47' E longitude and located at an altitude of 409 m above mean sea level. It comes under an average annual rainfall of 955 mm. The soil of the command area is medium deep black clay. The mean maximum and minimum temperature of the study area is 44.6°C and 21.8°C, respectively. The mean relative humidity ranges from 30 to 98 percent. The command area of B-70 is divided into 31 distributaries with a total command area of 9802 ha. Data Collection: The every year distributary wise data in respect of canal water released, area irrigated, cropping pattern and canal operation schedule was collected from 10<sup>th</sup> Sub-Division of Jayakwadi Irrigation Project, Parbhani, District Parbhani of State Water Resources Department for a period of six years i.e. 2006-2007 to 2014-2015. However, due to unavailability of water (during the year 2008-2009, 2012-13 and 2013-2014) in reservoir, canal water was not released in the B-70 command area. The weather data of various meteorological parameters was collected from IMD recognized observatory located in Vasntrao Naik Marathwada Krishi Vidyapeeth, Parbhani.

**Estimation of crop water requirement:** Crop water requirement is defined as "the depth of water needed to meet the water loss through evapotranspiration (ET<sub>c</sub>) of a disease-free crop, growing in large fields under non restricting soil conditions including soil water and fertility and achieving full production potential under the given growing environment (Doorenbos et al 1977). The crop water demand for each crop of B-70 was determined using the equation (1) by the CROPWAT software.

$$ET_c = K_c \times ET_o \quad (1)$$

Where, ET<sub>c</sub> = Crop evapotranspiration (mm/day), K<sub>c</sub> = Crop coefficient, ET<sub>o</sub> = Reference evapotranspiration (mm/day).

**Reference evapotranspiration:** Determination of reference evapotranspiration (ET<sub>o</sub>) is an important aspect for computation of crop water requirement. Crop evapotranspiration can be calculated from climatic data, by integrating crop resistance, albedo, and air resistance factors (LIU et al 2013). The daily reference crop evapotranspiration for the study area was estimated using CROPWAT computer software. Penman Monteith (FAO-56) method was used to estimate the reference evapotranspiration. The Penman Monteith (FAO - 56) equation is given as;

$$ET_o = \frac{0.408 (R_n - G) + \frac{900}{T + 273} u_2 (e_s - e_a)}{(1 + 0.34 u_2)} \quad (2)$$

where ET<sub>o</sub> = Reference evapotranspiration (mm/day), R<sub>n</sub> = net radiation at crop surface (MJ/m<sup>2</sup>/day) surface (MJ/m<sup>2</sup>/day), G = Soil heat flux density (MJ/m<sup>2</sup>/day), T = Mean daily air temperature at 2 m height (°C), u<sub>2</sub> = Wind speed at 2 m height (m/s), e<sub>s</sub> = Saturation vapour pressure (k Pa), e<sub>a</sub> = Actual vapour pressure (k Pa), e<sub>s</sub> - e<sub>a</sub> = Saturation vapour pressure deficit (k Pa), delta = Slope of vapour pressure curve (k Pa/°C) and gamma = Psychrometric constant (k Pa/°C).

**Crop coefficient:** For determination of crop water requirement, crop wise crop coefficient was developed by following the guidelines given by Allen et al (1998). The stage wise (i.e. initial, mid and end stage) crop coefficient for the selected area were developed by following the standard procedure.

**Effective rainfall:** The effective rainfall in the study area was estimated by the software using U.S. Department of Agriculture, Soil Conservation Service method (U.S.D.A., SCS method).

The following formulas were used,

$$P_{eff} = P_e \times \frac{125 - 0.2 P_e}{125} \quad \text{for } P_e \text{ is less than 250 mm} \quad (3)$$

$$P_{eff} = 125 + 0.1 P_e \quad \text{for } P_e \text{ is more than 250 mm} \quad (4)$$

Where, P<sub>e</sub> = total monthly rainfall (mm/month), P<sub>eff</sub> = total monthly effective rainfall (mm/month).

**Net irrigation requirements (NIR):** The CROPWAT software computes the net irrigation requirement using following formula, the formula for net irrigation requirement in mm/day is as under:

$$NIR = ET_c - P_{eff} \quad (5)$$

Where, NIR = Net irrigation requirement (mm/day), ET<sub>c</sub> = Crop evapotranspiration (mm/day), P<sub>eff</sub> = Effective rainfall (mm/day).

**Gross irrigation requirements (GIR):** The formula for gross irrigation requirement in mm/day is as under, assumed irrigation efficiency was taken as 60 % for the whole system.

$$GIR = \frac{NIR}{\text{Irrigation efficiency}}$$

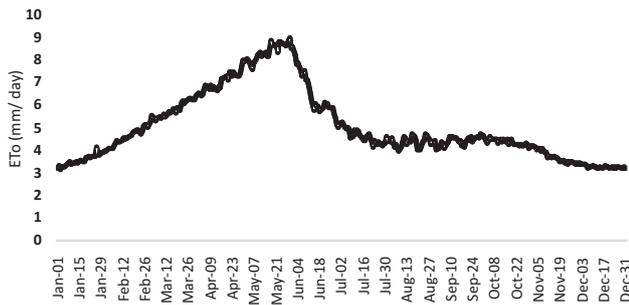
Where, GIR = Gross irrigation requirements (mm/day), NIR = Net irrigation requirements (mm/day).

## RESULTS AND DISCUSSION

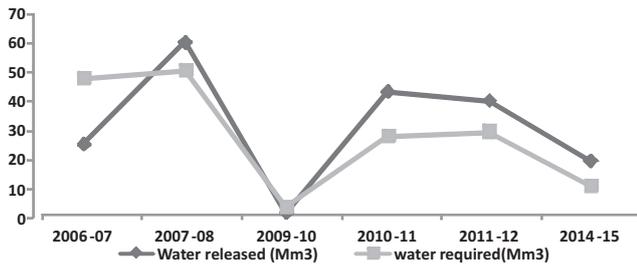
**Reference evapotranspiration (ET<sub>o</sub>):** The daily reference evapotranspiration was estimated using meteorological data of 32 years (1983-2014). The daily average ET<sub>o</sub> values over 32 years are illustrated in Fig. 1. Reference

evapotranspiration was low in December (3.27 mm/day) and it was maximum in May (8.4 mm/day). For most of the period from 30<sup>th</sup> June to 3<sup>rd</sup> March, it was below 5 mm day<sup>-1</sup>. The ET<sub>o</sub> above 7.0 mm day<sup>-1</sup> observed during the period from 15<sup>th</sup> April to 8<sup>th</sup> June.

**Development of crop coefficient:** The developed stage wise crop coefficients are presented in Table 1, which varies



**Fig. 1.** Daily average ET<sub>o</sub> estimated by using Penman Monteith method



**Fig. 2.** Comparison of actually released water and irrigation water requirement in the command area for different years

slightly with crop coefficient suggested in FAO-56 (Allen et al 1998)

**Crop water requirement:** The crop wise water requirement in the command area was estimated by CROPWAT software. The net crop irrigation requirement was determined as the difference of crop evapotranspiration and effective rainfall. The monthly values of effective rainfall were determined by using USDA, SCS method. The net irrigation requirement of each crop was estimated with CROPWAT software. The gross irrigation requirement was determined by assuming the overall application and conveyance efficiency of 60 percent. The month wise water requirement of different crops in command area is presented in Table 2.

**Cropping pattern and irrigated area of the command:** The total area irrigated under each crop during different irrigation years is presented in Table 3. Total area irrigated during an individual year was according to the water release in that year. As per availability of water, rotations were declared by Water Resource Department. Accordingly, cropping pattern was followed by the farmers. The farmer prefers less water required crop when there is shortage of water supply like Sorghum (2009-10 and 2014-15).

**Comparison of actually released water and irrigation water requirement in the command area:** By considering the cropping pattern and effective rainfall, irrigation water requirement of command area during different years was calculated and determined the volume of irrigation water requirement. The estimated irrigation water requirements were compared with actual amount of canal water released in the respective years in the command area. The result shows that there is sudden change in irrigation water requirement of command during 2009-10 and 2014-15 because of less

**Table 1.** Difference of developed and FAO-56 crop coefficients (K<sub>c</sub>)

Crops	Crop coefficient					
	Initial		Mid-season		Late season	
	Developed	FAO-56	Developed	FAO-56	Developed	FAO-56
Sorghum	0.30	0.30	1.05	1.05	0.57	0.55
Wheat	0.33	0.30	1.16	1.15	0.43	0.40
Gram	0.34	0.40	1.00	1.00	0.37	0.35
Groundnut	0.35	0.40	1.19	1.15	0.66	0.60
Sunflower	0.31	0.35	1.06	1.00	0.41	0.35
Maize	0.30	—	1.28	1.20	0.69	0.60
Sugarcane	0.34	0.40	1.30	1.25	0.68	0.75
Pigeon pea	0.30	—	1.12	1.15	0.37	0.30
Cotton	0.20	0.35	1.16	1.20	0.50	0.50
Vegetables	0.35	—	1.19	1.15	0.86	0.80

**Table 2.** Monthly net irrigation water requirement (mm) of crops sown in the command area

Crop/month	Sugarcane	Cotton	Pigeonpea	Wheat	Sorghum	Gram	Groundnut	Maize	Fodder	Sunflower	Vegetables
January	86.2	-	-	121	98.9	102.9	32.7	-	25.2	-	30.8
February	144.3	-	-	90.3	31.5	45.9	105.3	39	78.6	51.7	83.5
March	225.4	-	-	-	-	-	206.5	182	181.1	180.3	200.4
April	271.1	-	-	-	-	-	230	270.2	219.3	163.7	243.9
May	323.9	-	-	-	-	-	59.4	167.4	151.5	3.3	113.1
June	142.3	-	-	-	-	-	-	-	-	-	-
July	48.9	-	-	-	-	-	-	-	-	-	-
August	32.8	5.2	-	-	-	-	-	-	-	-	-
September	22.6	26.5	21.2	-	-	-	-	-	-	-	-
October	31.4	76	78.7	-	4.7	-	-	-	-	-	-
November	13.6	65.6	98.9	26.4	70.5	13.6	-	-	-	-	-
December	42.5	17.7	52	104.2	98.4	55.4	-	-	-	-	-
Total	1385	191	250.8	341.9	304	217.8	633.9	658.6	655.7	399	671.7

**Table 3.** Cropping pattern of command area during different irrigation years

Year/Crops	2006-07	2007-08	2009-10	2010-11	2011-12	2014-15
	Area in ha					
Sugar cane	429	396	35	97	197	0
Cotton	1078	1120.5	52	321	1045	399
Pigeon pea	148	164	0	26	140	371
Wheat	2023.4	2065.2	69	1215	2020	0
Sorghum	846.4	884.6	482	479	785.8	1535
Gram	69	45	0	1263	30	58
Ground nut	1356	1377	0	218	192	0
Maize	12	124	0	0	135	0
Fodder	136	143	0	0	116	0
Sunflower	122	179	0	0	0	0
Vegetables	229	310	0	0	154	0
Total	6448	6808	638	3619	4815	2363

availability of irrigation water during sowing period which reflects on reduction in the cropped area of the command.

During 2006-07 and 2009-10, there were shortage of irrigation water in the command area, whereas, in the years of 2007-08, 2010-11, 2011-12 and 2014-15 there were excess release of irrigation water in the command area. In the year of 2006-07 and 2009-10 there were 47.52 and 58.94 per cent shortage of irrigation water in the command, respectively. While during the year of 2007-08, 18.95 per cent excess quantity of irrigation water was released in the command area. Similarly in the year of 2010-11, 2011-12 and

2014-15, there were 53.87, 35.62 and 80 per cent of excess water released in the command area, respectively. During the year 2007-08, 2010-11, 2011-12 and 2014-15, the excess irrigation water was released than the crop water requirement which could be irrigate additional area of the command.

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Received 16 December, 2017; Accepted 10 February, 2018



## Geochemical Studies on Surface Water Quality in Lower Noyyal Sub – Basin, Cauvery River, Tamil Nadu, India

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**Abstract:** Noyyal River is one of the important tributary of Cauvery River which is a vital source of state of Tamil Nadu. Water quality assessment in lower noyyal river was carried out in the year 2015 for both pre and post monsoon. There are 21 water samples were collected with an interval of 3 kms from lower noyyal river for the stretch of 59.471 kms towards the point where the noyyal river confluence with river Cauvery. The analytical results of  $\text{Ca}^{2+}$ ,  $\text{Mg}^{2+}$ ,  $\text{Na}^+$ ,  $\text{K}^+$ ,  $\text{CO}_3$ ,  $\text{HCO}_3$ ,  $\text{SO}_4^{2-}$ ,  $\text{Cl}^-$ ,  $\text{NO}_3^-$ ,  $\text{F}^-$ ; pH, TDS and EC were compared with the International (WHO) standards to analyze the suitability of water for drinking purposes. The TDS concentration ( $658 \text{ mg L}^{-1}$ ) express large variation, which states that the water chemistry in the study area is not homogeneous and influenced by diverse contamination sources and geochemical process. The parameters Cl ( $397 \text{ mg L}^{-1}$ ) and N ( $45 \text{ mg L}^{-1}$ ) from the locations of 8 & 9 shows larger concentrations due to presence of industrial zone. The parameters of Mg ( $123 \text{ mg L}^{-1}$ ), Na ( $56 \text{ mg L}^{-1}$ ) and K ( $185 \text{ mg L}^{-1}$ ) shows higher concentration in the locations of 18, 19, 20 and 21. It is due to; the sampling stations are located at the place where the river noyyal is confluence with the river Cauvery and it is the place where the discharge of effluents from domestic and industrial processes on various part of the river is deposited. The proper treatment of industrial effluent is necessary before discharging effluent in to the river also stringent laws and regulations are to be implemented to protect the quality of the river water.

**Keywords:** Geochemistry, Surface water quality, Noyyal River, Physico-chemical parameters, Sub-basin

Water is one of the important vital sources for human and other life habitats and most of the people in this world depend greatly on water for their economy and survival without water there is no life. Water is the elixir of life and the beacon for biological activity, the elixir that sustains all life in this planet. River processes form the most important link in the geochemical series. Nearly, 90% of the normal weathered, as well as anthropogenic, materials that are transported in both the dissolved and particulate stage are delivered to the oceans by rivers. Geochemical study of river basins, thus, reveals the nature of weathering on a basin scale and helps us to understand the exogenic cycles of elements in the continent-river-ocean system. The lateral flow from rivers and agricultural irrigation are the mechanisms controlling the groundwater chemistry in the river network area, The agricultural irrigation and river lateral flows are the important mechanisms which controls the chemistry of groundwater (Huang et al 2013).

In India, river chemistry has been studied to understand the process of weathering, denudation, hydrological and environmental characteristics of river basins (Georg et al 2006, Singh et al 2008, Gao et al 2009). The untreated wastewater discharges in to the river bed which was located along the water shed may affects the quality of the river water

in toxic manner (Milovanovic 2007).

A river basin represents a natural unit within which one can examine weathering geochemistry and erosion on a continental scale. The heavy metal contaminations are much higher in sediments of downstream region than the other sites located near the copper mine plant (Varol and Şen 2012). Geochemical approaches to understanding such characteristics have been taken by many researchers (Logeshkumaran et al 2015, Selvam et al 2017). These researchers have studied the relationships among mineral weathering input, runoff output and environmental factors such as bedrock type, relief, climate and vegetation.

Due to the increasing pollution in India, many rivers, that once symbolized their ancient civilization, are vanishing slowly because millions of tons of industrial effluents and domestic wastes flow into them regularly. The present concern for river water quality emphasizes the study of the impact of unusual kinds of pollutants discharged into the rivers. The Lower Noyyal sub-basin region is located in part of the Tamil Nadu in India. It is situated between south-eastern part of Erode District and north-western part of the Karur District. The geographical positions of the study area fall under latitudes  $10^{\circ}54'54.21''\text{N}$  to  $11^{\circ}26'5.74''\text{N}$  and longitudes between  $77^{\circ}31'51.418''\text{E}$  to  $77^{\circ}56'26.91''\text{E}$  (Fig .

1).

The Noyyal River runs over three main districts of Tamil Nadu namely, Erode, Karur and Coimbatore districts, which are very much famous for their textile, weaving and dyeing industries. Most of the industries are located on the banks of river noyyal. The discharging of untreated effluents from those industries leads to contamination in the quality of river. Since, most of the people belongs to study area depends mainly on agriculture for their economic survival. It is a high time to protect and manage the water quality.

### MATERIAL AND METHODS

The river water samples were collected from various places of 21 locations (Fig. 1, Table 1) along the lower Noyyal river for pre–and post-monsoon seasons and were analysed as per the standard procedure (APHA 1999). The analysed results were compared with Indian standards and WHO standards for access the status of pollutant in the study area. The pre-cleaned polyethylene bottles were used for collecting all the water samples from the river. Suitable preservatives were added immediately after collection and analyzed for various constituents. The water samples were

collected from the river in triplicate using pre-cleaned polyethylene bottles for the analysis of Major ions ( $\text{Ca}^{2+}$ ,  $\text{Mg}^{2+}$ ,  $\text{Na}^+$ ,  $\text{K}^+$ ,  $\text{CO}_3^{2-}$ ,  $\text{HCO}_3^-$ ,  $\text{SO}_4^{2-}$ ,  $\text{Cl}^-$ ,  $\text{NO}_3^-$ ) (APHA, 1999). The geochemistry of the surface water is evaluated by the help of type of minerals present in the study area. The pH, electrical conductivity (EC) and TDS are measured with the help of respective pH, EC and TDS meters and calcium (Ca), potassium (K), sodium (Na) and magnesium (Mg) were estimated with the help of flame photometer and all the other major ions are estimated (APHA 1999). The analysis, the results are analysed samples were compared with WHO to assess the status of the pollution in the region of study

### RESULTS AND DISCUSSION

During pre-monsoon, the pH of river water ranges from 7.10 to 8.70 with an average of 7.57, all the stations are alkaline in nature. However, during the post-monsoon, the pH of water ranges from 6.30 to 8.50 with an average of 7.27. Many of the stations are found to be alkaline and of slightly acidic behavior, except at few stations on the upper course of the river. The total dissolved solid (TDS) concentration ranges from 217 to 658  $\text{mg L}^{-1}$  in pre-monsoon and 182 to 490

**Table 1.** GPS locations of the samples sites

Location no.	Location	Longitudes	Latitudes
1	Sangameshwarar temple	77° 40'27"	11° 6'57"
2	Bhavani-Kumarapalayam Bridge	77° 41'32"	11° 5'55.58"
3	River Intake	77° 42'38.59"	11° 4'45.43"
4	Manjula tex backside	77° 43'51.16"	11° 4'39.44"
5	perumal Malai Opposite	77° 45'31.7"	11° 4'14.53"
6	Barrage, Agraharam	77° 45'45.07"	11° 3'51.77"
7	BP Agraharam	77° 38'57.06"	11° 1'17.86"
8	Vairapalayam	77° 40'19.03"	11° 1'44.01"
9	Near Gasific Crematorium	77° 41'22.98"	11° 2'36.51"
10	Near Thiruchengode Bridge	77° 42'28.59"	11° 1'0.842"
11	Near SPB Paper mill	77° 43'31.22"	11° 1'0.71"
12	Before savadipalayam	77° 44'22.6"	11° 2'0.56"
13	Savadipalayam pudur	77° 44'57.13"	11° 3'0.22"
14	Kalmangalam	77° 45'45.06"	11° 3'0.56"
15	Kolanelli	77° 47'41.23"	11° 4'0.12"
16	Karanampalayam	77° 49'30.7"	11° 4'0.36"
17	Jedarpalayam canal	77° 49'46.59"	11° 2'0.87"
18	Kattampatti Bridge	77° 51'8.24"	11° 2'0.28"
19	Thoppampatti palam	77° 52'46.99"	11° 1'0.39"
20	Periavattam	77° 54'33.21"	11° 2'0.20"
21	Noyyal	77° 55'54.05"	11° 4'0.24"

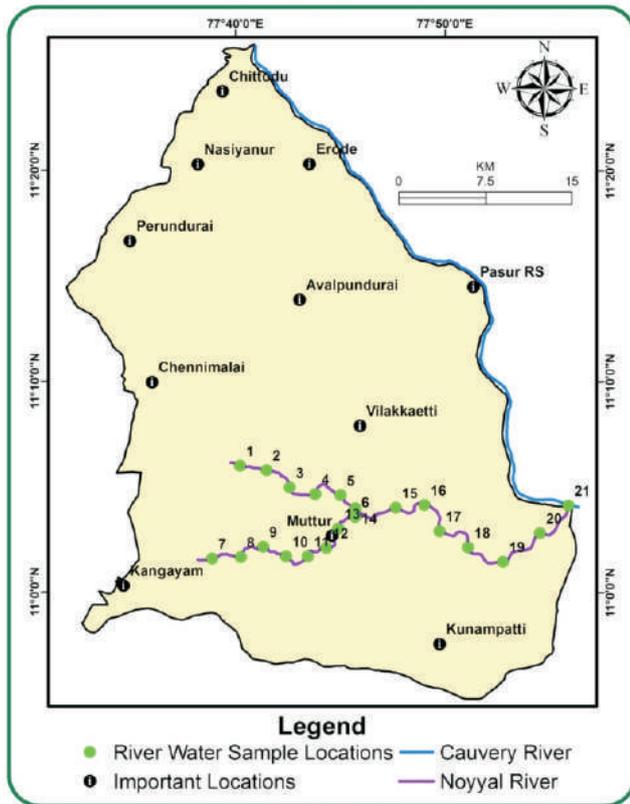


Fig. 1. River water sample location map

mg L<sup>-1</sup> in post-monsoon. There is a substantial amount of dilution in the concentration of ions during the post-monsoon due to precipitation. Higher concentration of TDS is observed in the river water near the confluent part of the Noyyal River to Cauvery Basin at stations 18 to 21 where various industries like dyeing, bleaching industries are situated. During pre-

monsoon, the concentration of cations Ca<sub>2</sub><sup>+</sup>, Mg<sub>2</sub><sup>+</sup>, Na<sup>+</sup> and K<sup>+</sup> ions range from 24 to 88, 16 to 123, 28 to 185 and 3 to 56 mg L<sup>-1</sup> with a mean of 40.76, 43, 78 and 14.57 mg L<sup>-1</sup> respectively. The concentration of ion (based on mmol/L) are 23.02, 24.29, 44.46 and 8.23% and the order of abundance is Na<sup>+</sup> > Mg<sub>2</sub><sup>+</sup> > Ca<sub>2</sub><sup>+</sup> > K but during post-monsoon, average concentration of cations Ca<sub>2</sub><sup>+</sup>, Mg<sub>2</sub><sup>+</sup>, Na<sup>+</sup> and K<sup>+</sup> was 35.48, 38.19, 62.76 and 9.81 mg L<sup>-1</sup>. The concentrations of ion (based on mmol L<sup>-1</sup>) are 24.26, 26.11, 42.92 and 6.71%. The order of abundance among the cations is Na<sup>+</sup> > Mg<sub>2</sub><sup>+</sup> > Ca<sub>2</sub><sup>+</sup> > K<sup>+</sup>. Similarly, in the case of anions during pre-monsoon, HCO<sub>3</sub><sup>-</sup>, SO<sub>4</sub><sup>2-</sup>, Cl<sup>-</sup>, F<sup>-</sup> and NO<sub>3</sub><sup>-</sup> having a mean of 342.81, 53.43, 113.71, 0.64 and 8 mg L<sup>-1</sup>, respectively. The concentration of ions (based on mmol L<sup>-1</sup>) is 67.60, 8.49, 22.23, 0.13 and 1.56%. The order of abundance of anions is HCO<sub>3</sub><sup>-</sup> > Cl<sup>-</sup> > SO<sub>4</sub><sup>2-</sup> > NO<sub>3</sub><sup>-</sup> > F<sup>-</sup>. During post-monsoon, HCO<sub>3</sub><sup>-</sup>, SO<sub>4</sub><sup>2-</sup>, Cl<sup>-</sup>, F<sup>-</sup> and NO<sub>3</sub><sup>-</sup> are having a mean of 234.62, 24.19, 56.10, 0.63 and 2.86, respectively. The ionic concentrations (mmol L<sup>-1</sup>) are 73.69, 7.60, 17.62, 0.20 and 0.90%. The order of abundance is HCO<sub>3</sub><sup>-</sup> > Cl<sup>-</sup> > SO<sub>4</sub><sup>2-</sup> > NO<sub>3</sub><sup>-</sup> > F<sup>-</sup>. The seasonal effect is found to be apparent in the chemical budget of water though it does not affect the order of abundance of ions during pre and post-monsoon periods.

Major elements enter into river water from a variety of sources, such as chemical weathering of rocks and soils, dead and decomposing vegetation and animal matter, the wet and dry fallout of atmospheric matter and from man-made activities, including the discharge of various domestic and industrial effluents.

For both the pre-and post-monsoon seasons, the

Table 2. Statistical results of river water physico-chemical parameters

Chemical parameters	Minimum		Maximum		Average		Std.Dev.	
	Pre-monsoon	Post-monsoon	Pre-monsoon	Post-monsoon	Pre-monsoon	Post-monsoon	Pre-monsoon	Post-monsoon
EC (μS cm <sup>-1</sup> )	310.00	260.00	940.00	700.00	550.24	346.81	142.68	101.95
TDS (mg L <sup>-1</sup> )	217.00	182.00	658.00	490.00	385.19	242.81	99.88	71.39
pH	7.10	6.30	8.70	8.50	7.57	7.27	0.56	0.56
Calcium (mg L <sup>-1</sup> )	24.00	23.00	88.00	80.00	40.76	35.48	22.48	15.73
Magnesium (mg L <sup>-1</sup> )	16.00	2.00	123.00	219.00	43.00	38.19	39.10	55.54
Sodium (mg L <sup>-1</sup> )	28.00	17.00	185.00	164.00	78.71	62.76	46.68	42.81
Potassium (mg L <sup>-1</sup> )	3.00	2.00	56.00	38.00	14.57	9.81	19.64	13.57
Bi-carbonate (mg L <sup>-1</sup> )	134.00	128.00	775.00	647.00	342.81	234.62	223.37	178.74
Carbonate (mg L <sup>-1</sup> )	0.00	0.00	9.00	5.00	1.14	0.48	2.56	1.21
Nitrate (mg L <sup>-1</sup> )	1.00	1.00	45.00	12.00	8.00	2.86	9.84	3.66
Chloride (mg L <sup>-1</sup> )	25.00	22.00	397.00	156.00	113.71	56.10	115.53	48.04
Fluoride (mg L <sup>-1</sup> )	0.16	0.10	1.68	1.54	0.64	0.63	0.45	0.41
Sulphate (mg L <sup>-1</sup> )	8.00	10.00	179.00	88.00	53.43	24.19	51.87	23.69

concentration of Ca is within the WHO allowable limit of 200 mg L<sup>-1</sup>. The range obtained is lower than the permissible value, and hence adverse effects from domestic use are not expected as far as this element is concerned. The stations 19 and 20 show high Ca in pre-monsoon and station 18 in both the seasons (Fig. 2). Mg concentrations of both the seasons are within maximum allowable limit except one station, sample location 21. As per the WHO standard, the high concentration stations are situated near by the junction of two rivers Noyyal sub-basin and Cauvery River basin (Fig. 3).

The concentration of sodium in water during both the seasons has not crossed the prescribed limit of 200 mg L<sup>-1</sup>. The relatively higher concentrations of Na (Fig. 4) in some of the stations of the study area may be attributed to the presence of unused remains of sodium chloride, which is an important constituent of fertilizers used in the region. The concentration of K in many of the stations is higher than the WHO permitted limit of 10 mg L<sup>-1</sup>. The high concentration of K in these waters may be assigned to the soil-water interaction, especially in the middle part and in the end part of the river stretch (Fig. 5). It is observed that the water is almost stagnant facilitating the dissolution and concentration of the ions in the river.

The concentration of Cl in natural water increases mainly through anthropogenic activities. In that most of the stations show the concentration of Cl within the WHO allowable limit of 200 mg L<sup>-1</sup> in both the seasons (Fig. 6). The concentration of SO<sub>4</sub> and NO<sub>3</sub> in both the seasons has not crossed the prescribed limit of 400 mg L<sup>-1</sup> and 45 mg L<sup>-1</sup>. The concentration of SO<sub>4</sub> and NO<sub>3</sub> gradually increases towards downstream direction (Fig. 7 and 8).

Fe concentrations of both the seasons are within maximum allowable limit except two stations (sample location 18 and 19). As per the WHO standard, the high concentration stations are located in the confluent point of Noyyal river with Cauvery River (Fig. 9).

For both the pre- and post-monsoon seasons, the concentration of pH is within the WHO allowable limit of 6.5 to 8.5. The range obtained is lower than the permissible value, and hence adverse effects from domestic use are not expected as far as this element is concerned. The stations 18, 19 and 20 show high pH in pre-monsoon and sample location 18 in both the seasons (Fig. 10).

The evaluation of water quality is carried out in order to identify its suitability for drinking and irrigation purposes. In the study area, the rock-water interaction and agricultural activities near the upper part of the river, manmade activity at the middle and lower part of the river and confluence point are

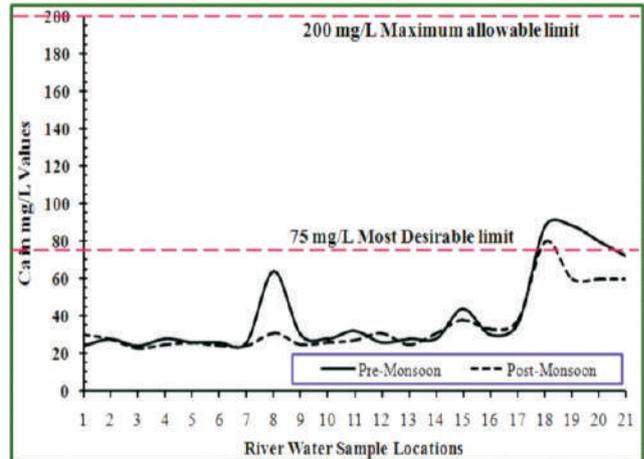


Fig. 2. Seasonal variation of Ca

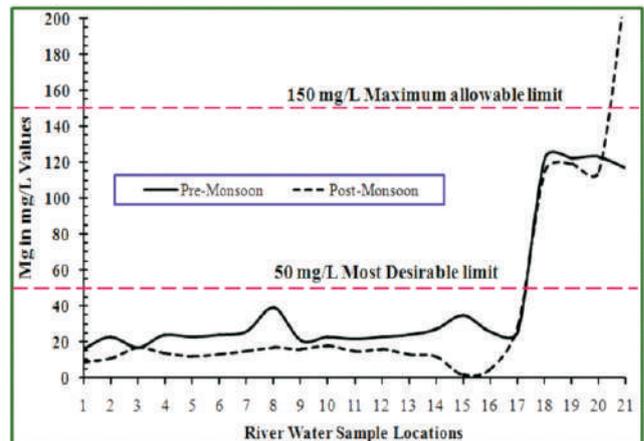


Fig. 3. Seasonal variation of Mg

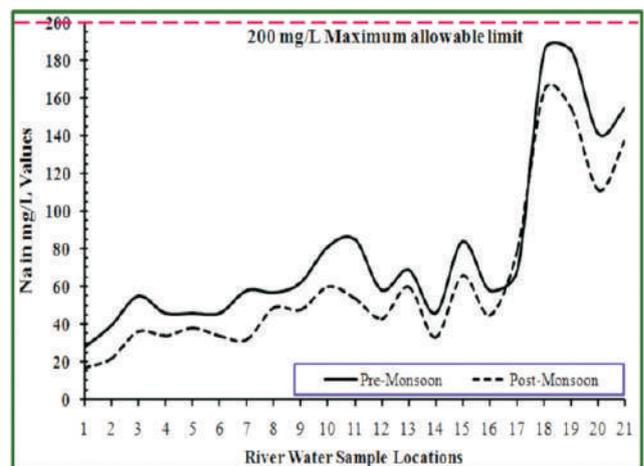


Fig. 4. Seasonal variation of Na

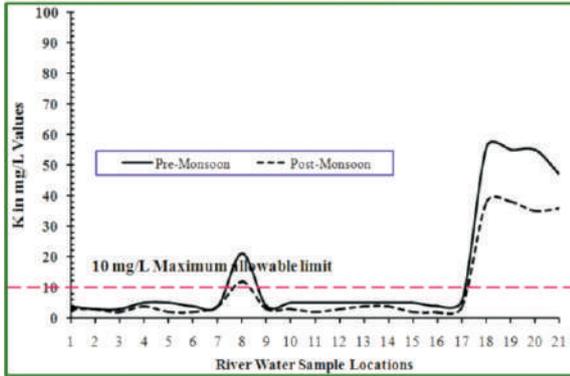


Fig. 5. Seasonal variation of K

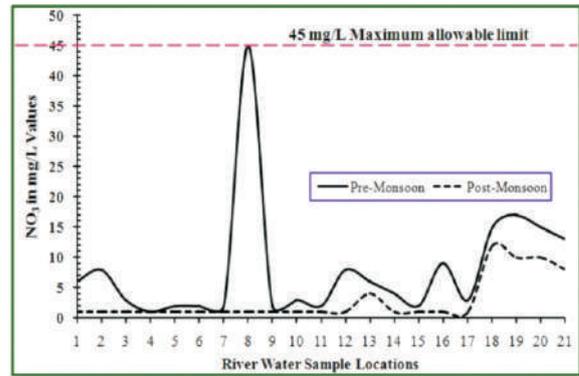


Fig. 8. Seasonal variation of  $\text{NO}_3$

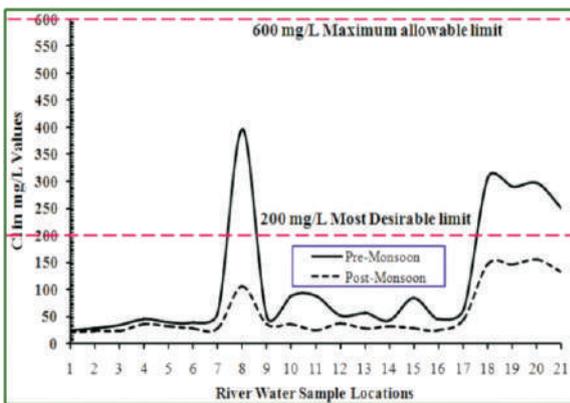


Fig. 6. Seasonal variation of Cl

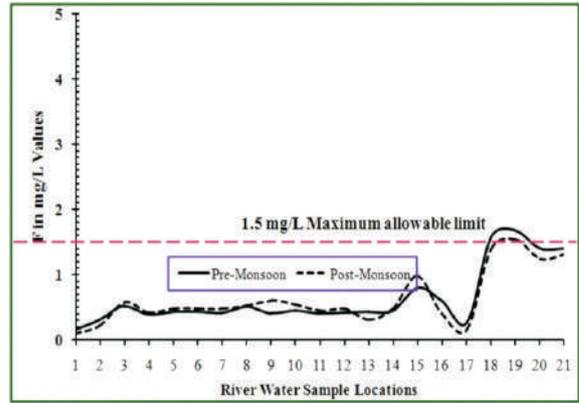


Fig. 9. Seasonal variation of F

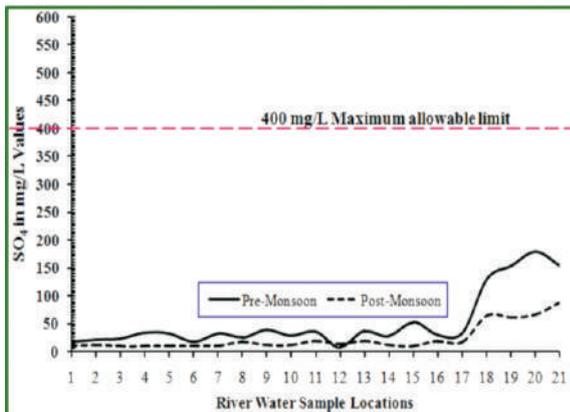


Fig. 7. Seasonal variation of  $\text{SO}_4$

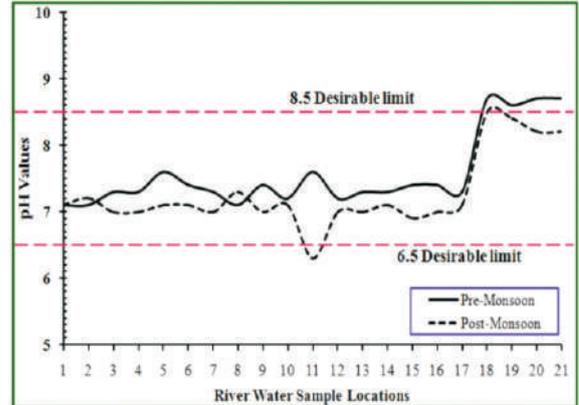


Fig. 10. Seasonal variation of pH

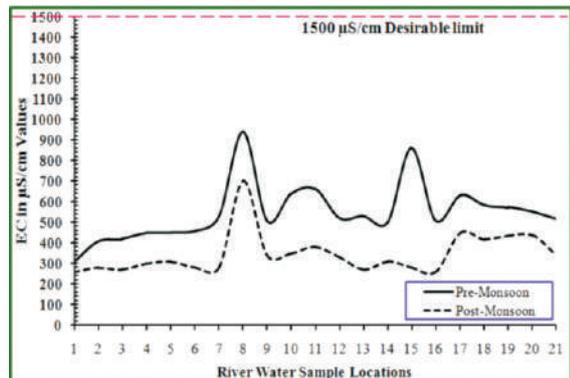


Fig. 11. Seasonal variation of EC

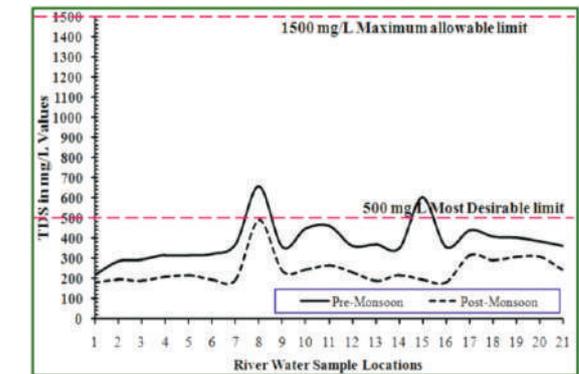


Fig. 12. Seasonal variation of TDS

the major factors that affect the quality of water. In all the stations, the concentration of EC and TDS is less than the recommended limit of 1500 mg/L (WHO 2004) in all the water samples during both the seasons (Fig .11 and 12). The highest value is recorded in the downstream side and the lowest value is recorded in the upper part of the river. The highest value is found to be more in many stations of the downstream that may be due to the effluents from the industries that are directed into the river.

### CONCLUSION

The river water quality assessment shows that the water near the upstream is good for drinking and irrigation and the contamination are found to be high near the downstream. The calcium, potassium and iron concentration of river water samples are greater than the WHO permissible limits for both the pre-and post-monsoon. In the study area the rock-water interaction and agricultural activities near the upper part of the river, man-made activity at the middle and lower part of the river and confluence point are the major factors which affect the quality of water. The proper treatment of industrial effluent is necessary before discharging effluent in to the river also stringent laws and regulations are to be implemented in protect the water quality of the river.

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# Molecular Diversity Analysis based on Microsatellite Markers in Pearlmillet Hybrids [*Pennisetum glaucum* (L.) R. Br.] and their Parental Lines

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**Abstract:** To assess the genetic diversity among three pearlmillet hybrids and their parents, 55 microsatellite markers were used in the present study. Out of 55 markers, 37 amplified producing 162 alleles. The number of amplified alleles among the genotypes ranged from 1-9 per locus with a mean value of 4.38 alleles per locus. The highest PIC value obtained was for PSMP 2263 (0.837) with a range of 0 to 0.837 with an average PIC of 0.598. UPGMA cluster analysis differentiated all the genotypes in 2 clusters containing all the three hybrids. One A-line namely ICMA 94555 and both the R-lines (HBL 11 and H77/833-2-202) remained ungrouped. The results have revealed presence of considerable amount of genetic diversity among the pearlmillet genotypes and indicated the ability of SSR markers in recognizing the molecular diversity.

**Keywords:** Pearlmillet hybrids, A-lines, R-lines, SSRs, Genetic diversity

Pearlmillet [*Pennisetum glaucum* (L.) R. Br.] crop considered very important for its ability to grow in harsh environmental conditions and for providing staple diet and fodder for the majority of poor farmers and their livestock in arid and semi-arid regions of the world (Verma et al 2016). During the last more than five decades, enormous progress has been made in the genetic improvement of pearl millet and India becomes the largest producer. The rise in the production can be attributed to the development of superior hybrid varieties in this era. In the present scenario, hybrid development programmes are extensive in nature and put a much greater attention towards genetic diversification of both seed and pollinator parents (Yadav and Rai 2013). Moreover, Pearlmillet exhibits high out-cross breeding behavior which results in enormous amount of diversity at both phenotypic and genotypic levels. Therefore, estimation of genetic diversity in the available germplasm and released hybrids is of considerable importance. Genetic variation in pearl millet has been studied mainly by morphological descriptors and isozyme markers, but they are not reliable sometimes because they can easily get affected by environmental conditions and stages of development (Yadav et al 2007). With the development of DNA based marker systems, estimation of genetic diversity at genomic level becomes possible and additionally it provides a reliable and vigorous tool for diversity analysis.

SSRs, also known as microsatellites, are repeated

sequences of DNA and they are excellent tool to study the genetic relationship between closely related plant species due to some advantages over other markers i.e. codominant inheritance, automated detection and high level of polymorphism etc. (Hernandez et al 2002). The objective of the present study was to evaluate genetic diversity among three newly released pearlmillet hybrids and their parental inbred lines by using microsatellite markers.

## MATERIAL AND METHODS

The experimental material for this study comprised of three pearl millet hybrids (HHB 223, HHB 226 and HHB 234) and their parental lines which included three A-lines (HMS-7A, ICMA 843-22, ICMA 94555) and two R-lines (H77/833-2-202, HBL 11). The seeds were obtained from Bajra Section, Department of Genetics and Plant Breeding, CCS Haryana Agricultural University, Hisar.

**DNA isolation:** Total genomic DNA was extracted from young leaves of pearlmillet genotypes using CTAB (Cetyl Trimethyl Ammonium Bromide) extraction method following the protocol of Sagahai Maroof et al (1984) with minor modifications. Then the quality of isolated DNA was checked on 0.8% agarose gel. Working stocks of 20 ng/μl were prepared from the isolated DNA, which were used for the polymerase chain reaction (PCR).

**Amplification:** SSR primers were selected from previous studies on the development of SSR markers in pearl millet (Qi

et al 2004, Senthilvel et al 2008). Each optimized PCR reaction mixture consisted of 20ng template DNA, 10X PCR buffer [10 mM Tris-HCl (pH.8.3), 50 mM KCl], 1.5 mM MgCl<sub>2</sub>, one unit of *Taq* polymerase, 200 μM of each dNTP (all chemicals from Sigma-Aldrich, USA) and 0.5 μM primers in a total volume of 20 μl. PCR was performed in a thermocycler (BioRad) using following conditions: A denaturation step of 3 min at 94°C followed by 35 cycles each composed of 1 min at 94°C, 1 min at 44-61°C and 1 min at 72°C, and final extension step of 10 min at 72°C. The amplified fragments were separated on 6.0% polyacrylamide gels using 0.5X TBE buffer at 220 V for 3 hrs, stained with ethidium bromide and band sizes were estimated with a 20 bp ladder and then recorded under UV in gel documentation system.

**Data analysis:** Presence or absence of each amplified band was scored as 1 and 0, respectively, for all markers to generate a binary data matrix which was analyzed for genetic relationships among the genotypes using SIMQUAL module of software NTSYS-pc (version 2.02e) (Rohlf 2002). Jaccard's similarity coefficients were calculated for all pair wise comparisons among all the genotypes. Based on the similarity values, UPGMA cluster analysis was performed to generate a dendrogram using SAHN module. Jaccard's similarity values were also used for the principal component analysis to generate a two and three dimensional plots showing genetic relationship among the hybrids and their parents. The genetic diversity of each microsatellite locus was assessed by calculating frequency of the microsatellite

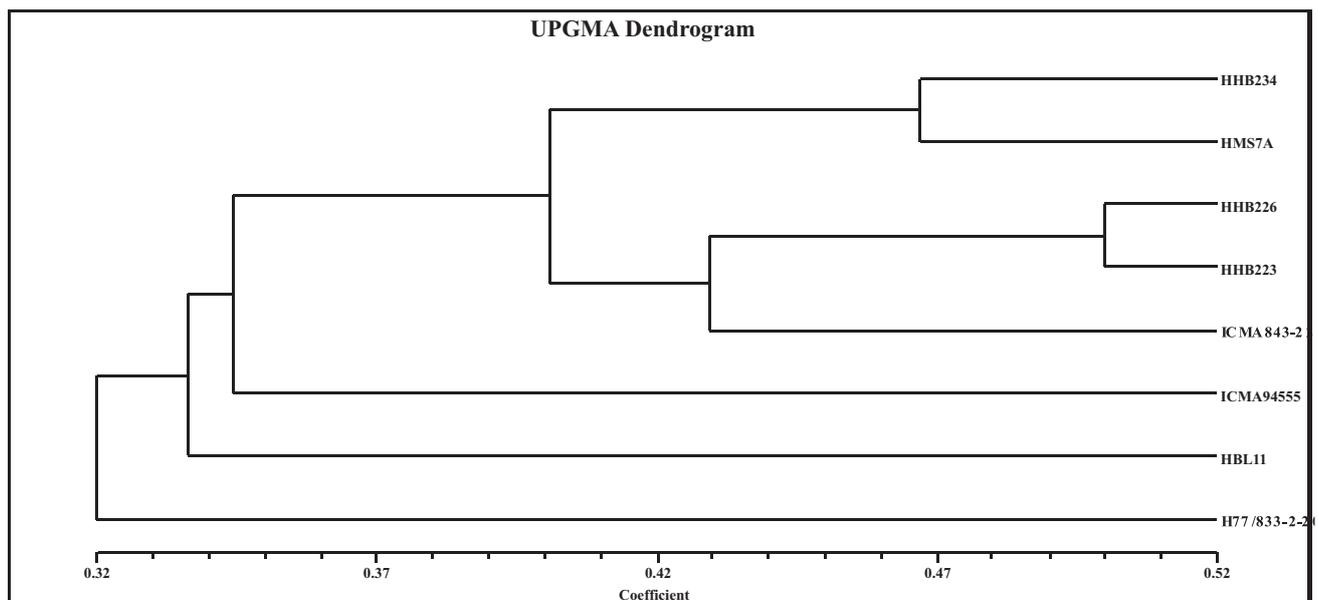
alleles based on polymorphic information content (PIC) using the formula, suggested by Anderson et al (1993):

$$PIC_i = 1 - \sum_{j=1}^n p_j^2$$

Where,  $p_j$  = frequency of the  $j^{th}$  allele for marker  $i$

## RESULTS AND DISCUSSION

In the present study, total 55 SSR markers were used, among them 37 primers amplified (Table 1). These markers produced a total of 162 alleles which ranged from 1 (*PSMP 2027*, *ICMP 3018*, *XCUMP 006* and *XCUMP 0017*) to 9 (*PSMP 2232* and *PSMP 2263*) with a mean of 4.38 alleles per locus. This value is near to 5.17 as reported by Elsi and Hancer (2014) in maize, but higher than 3.36 in rice (Sundaram et al 2008), 2.6 in pigeonpea (Saxena et al 2010) and 3.4 as reported by Arya et al (2014) in sorghum. But, the value observed by us is much lesser than the values obtained by Gupta et al (2015) and Bashir et al (2015) in pearlmillet. The higher values in these studies might be due to the large number of genotypes from diverse backgrounds. Polymorphic information content (PIC) value ranged from 0 (*PSMP 2027*, *ICMP 3018*, *XCUMP 006* and *XCUMP 0017*) to 0.837 (*PSMP 2263*) with an average of 0.598 (Table 1). This value is comparable to 0.69 (Elsi and Hancer 2014) in maize but higher than 0.34 (Saxena et al 2010) in pigeonpea and 0.459 (Arya et al 2014) found for sorghum hybrids and parents. Higher PIC value can be credited to the better resolution power of polyacrylamide gel electrophoresis than



**Fig. 1.** UPGMA dendrogram showing relationship among three pearlmillet hybrids and their parents based on similarity matrix data using 37 SSR markers

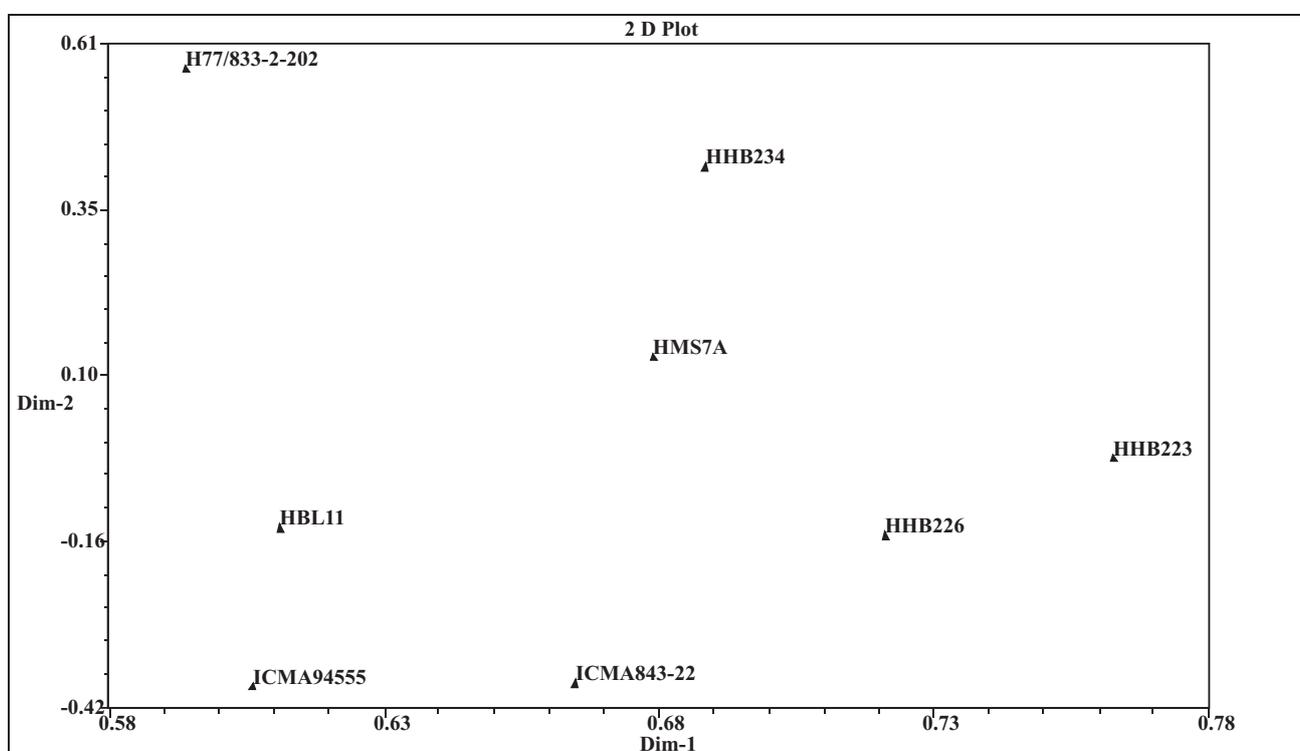
**Table 1.** Amplification results of 37 SSR markers for hybrids and their parents

SSR locus	Sequence (5' to 3')	Linkage group	SSR motif	No. of Alleles	PIC
PSMP 20	F CATTACACGTTTCTTCAAACGC R TCTTCGGCCATAATAGCTCTAAC	NA	NA	5	0.786
PSMP 2008	F GATCATGTTGTATGAATCACC R ARACTACACCTACATACGCTCC	5	(GT) <sub>37</sub>	6	0.803
PSMP 2027	F AGCAATCCGATAACAAGGAC R AGCTTTGGAAAAGGTGATCC	7	(GT) <sub>31</sub>	1	0
PSMP 2059	F GGGGAGATGAGAAAACACAATCAC R TCGAGAGAGGAACCTGATCCTAA	2	(AC) <sub>11</sub>	4	0.680
PSMP 2084	F AATCTAGTGATCTAGTGTGCTTCC R GGTTAGTTGTTTGAGGCAAATGC	4	(AC) <sub>42</sub>	3	0.560
PSMP 2090	F AGCAGCCCAGTAATACCTCAGCTC R AGCCCTAGCGCACAAACAAACTC	1	(CT) <sub>12</sub>	5	0.702
PSMP 2201	F CCCGACGTTATGCGTTAAGTT R TCCATCCATCCATTAATCCACA	2	(GT) <sub>6</sub>	4	0.694
PSMP 2224	F GGCGAAATTGGAATTCAGATTG R CGTAATCGTAGCGTCTCGTCTAA	7	(TG) <sub>10</sub>	4	0.660
PSMP 2227	F ACACCAAACCAACCATAAA R TCGTCAGCAATCACTAATGACC	3	(GT) <sub>7</sub>	2	0.469
PSMP 2229	F CCCTACCTTCGTTCCCTCCATTC R GTCCGTTCCGTTAGTTGTTGCC	5,7	(GT) <sub>5</sub>	6	0.773
PSMP 2232	F TGTTGTTGGGAGAGGGTATGAG R CTCTCGCCATTCTTCAAGTTCA	1,2	(TG) <sub>8</sub>	9	0.836
PSMP 2233	F TGTTTTCTCTCTTAGGCTTCGTTT R ACCTTCTCCGCCACTAAACAACT	5	(TG) <sub>9</sub>	5	0.702
PSMP 2237	F TGGCCTTGGCCTTTCCACGCTT R CAATCAGTCCGTAGTCCACACCCCA	2	(GT) <sub>8</sub>	5	0.742
PSMP 2263	F AAAGTGAATACGATACAGGAGCTGAG R CATTTCAGCCGTTAAGTGAGACAA	7	(AG) <sub>33</sub>	9	0.837
PSMP 2271	F CTTTATATTGGACCGACTGCTGAC R CTCCCCATACAGAGCGAGAA	7	(GA) <sub>11</sub>	4	0.532
PSMP 2273	F ACCCCACCAAGTAAAGTTGTGCTGC R GATGACGACCAAGACTTCTCTCC	1	(GA) <sub>12</sub>	8	0.794
PSMP 2274	F CACCTAGACTCTACACAATGCAAC R AATATCAAGTGATCCACCTCCCAA	5,7 <sub>B</sub>	(GA) <sub>13</sub>	5	0.679
ICMP 3016	F GTCAACCATTTGGGCTCACT GGGAGAAATGTGGGAGAGA	6	(CA) <sub>17</sub>	6	0.775
ICMP 3017	F CACCAAACAGCATCAAGCAG R AGGTAGCCGAGGAAGGTGAG	1	(CAG) <sub>7</sub>	6	0.773
ICMP 3018	F ACGAGGACAAGCTCTTGGAA ACGGCGCATACTCGATCATA	NA	(CATG) <sub>4</sub>	1	0
ICMP 3019	F GCGCACCACTGTGTCTAT R CATGCAGAGAAAAATCAAGCA	NA	(CGTA) <sub>4</sub>	2	0.408
ICMP 3029	F ATCGATCTGTTCCACCCAGT R GGACTGGTACTGTGCTGCT	4	(GCA) <sub>6</sub> (GCA) <sub>5</sub>	2	0.397
ICMP 3050	F ATGTCCAGTGTGACGGTGA CGGGGAAGAGACAGGCTACT	6	(TA) <sub>8</sub>	6	0.725
ICMP 3056	F ACGGAGCTACGGTTGGAATA R CACAAGGGACCCACGATA	2	(TGG) <sub>5</sub>	3	0.653
XCUMP 001	F GCACGAGGCTTATCTGTGTTTC R CAACTCTTGCCTTTCTTGGCCT	NA	(AG) <sub>9</sub>	2	0.500
XCUMP 006	F GAAATCGGCAGAGGGGCAT R CAATGAGTATGTGCACGCTGCA	NA	(TATG) <sub>9</sub>	1	0
XCUMP 0016	F CATTCTCTCGCCAGTGCTC R ATCTCCAGAACCGAGCGCA	NA	(CT) <sub>9</sub>	4	0.667
XCUMP 0017	F TGCTTTCTTCCCAACCAAGTGG R TGCTGAGTGGGGTGTGCT	NA	NA	1	0
XCUMP 0018	F TGCTTTCTTCCCAACCAAGTGG R TGCTGAGTGGGGTGTGCT	NA	(GCA) <sub>7</sub>	2	0.219

Cont...

CTM 8	F GCTGCATCGGAGATAGGGAA R CTCAGCAAGCACGCTGCTCT	7	(CT) <sub>8</sub> (CT) <sub>11</sub>	4	0.660
CTM 10	F GAGGCAAAAGTGAAGACAG R TTGATTCCCGGTTCTATCGA	3	(CT) <sub>22</sub>	6	0.810
CTM 25	F GCGAAGTAGAACACCGCGCT R GCACTTCCTCCTCGCCGCTCA	5	(CT) <sub>34</sub>	8	0.836
CTM 26	F GCAAGTGATCCATGACATTACGA R ACTTGCTAGCTGCTGCTCTTG	NA	(CT) <sub>10</sub>	5	0.775
CTM 27	F GTTGCAAGCAGGAGTAGATCGA R CGCTCTGTAGGTTGAACTCCTT	1	(CT) <sub>71</sub>	5	0.731
PGIRD 46	F GAACAATTGCTTCTGTAATATTGCTT R GCCGACCAAGAACTTCATACA	NA	(CTC) <sub>6</sub>	2	0.490
PGIRD 50	F CTCTCGGTTTGACGGTTTGT R GGGGAAAACAAAGTTGCTCA	NA	(TGT) <sub>6</sub>	6	0.694
PGIRD 54	F GCCTGGGATGTGTTTCTTCT R GCCTTTCATTTCCACCATGA	NA	(GT) <sub>5</sub>	5	0.757

\*NA-Not Available

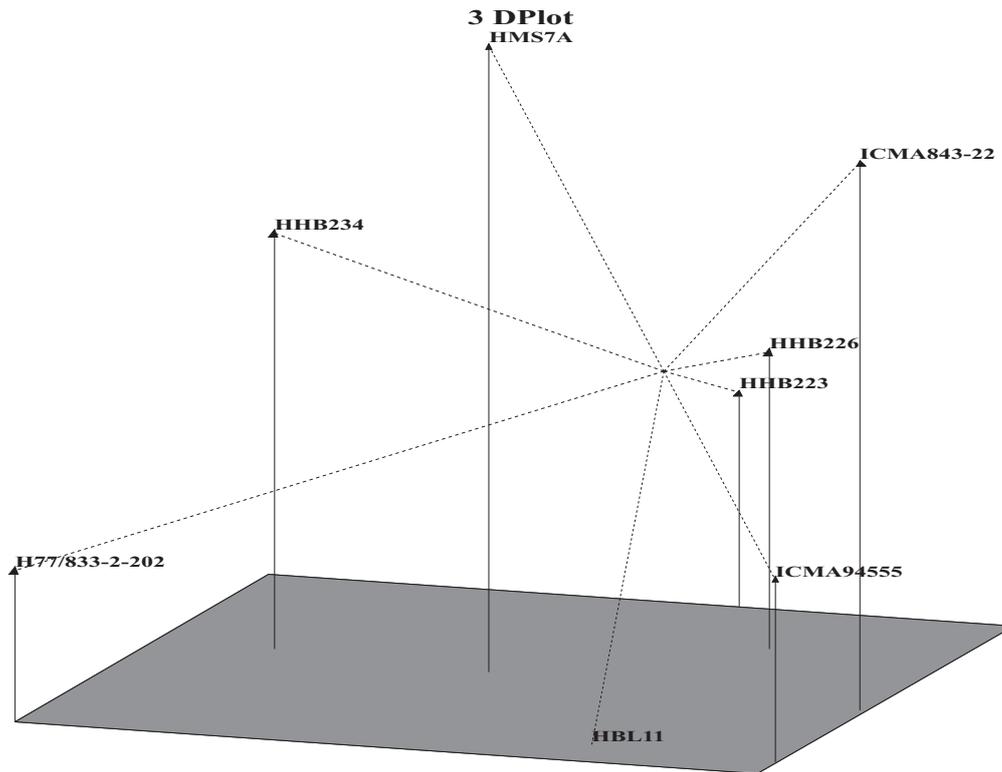


**Fig. 2.** Two dimensional PCA (principal component analysis) scaling of three pearlmillet hybrids and their parents using similarity matrix data using 37 SSR markers

agarose gel electrophoresis which was used in previous studies. The range of PIC value showed the significance of locus specific PCR-based microsatellite markers and confirmed that SSR markers are highly elucidative and would be useful in hybrid breeding.

Dendrogram was constructed based on the Jaccard's similarity coefficient (Fig. 1). In this dendrogram, two clusters were formed at the similarity coefficient of 0.32 which consisted all the three hybrids and two A-lines. One A-line namely ICMA 94555 and both the R-lines (HBL 11 and

H77/833-2-202) remained ungrouped. This shows that restorer lines are quite distinct from other genotypes at genetic level. Cluster-1 consisted of hybrid HHB 234 and its female parent (HMS 7A). Cluster-2 comprised of two hybrids namely HHB 223 and HHB 226 followed by female parent of HHB 226 as an out group. The reason might be that both hybrids have same male parent (HBL 11). Among all the genotypes, R-line namely H77/833-2-202 was found most diverse as it separated from all other genotypes at a very low similarity coefficient of 0.32. Principal component analysis



**Fig. 3.** Three dimensional PCA (principal component analysis) scaling of three pearl millet hybrids and their parents using similarity matrix data using 37 SSR markers

(PCA) based on Jaccard similarity matrix also showed the similar trend. The groupings of 8 genotypes using 2-D (Fig. 1) and 3-D (Fig. 2) scaling followed the same pattern as depicted in the dendrogram with minor differences.

### CONCLUSION

The 3 hybrids and their parents altogether shared 32 percent similarity on the basis of Jaccard similarity coefficient. The highest similarity percentage was shared by HHB 226 and HHB 223 (50%) followed by HHB 234 and HMS 7A (46.5%). The similarity coefficient varied from 0.32 to 0.52, this broad genetic diversity detected within the genotypes demonstrates the genetic purity and potentials of SSR markers for genetic diversity analysis in pearl millet.

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Received 08 October, 2017; Accepted 20 February, 2018



## Per Se Performance of Parents and Hybrids of Cowpea (*Vigna unguiculata* L.)

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**Abstract:** Pod characters like pod length, pod weight, number of pods per cluster and number of pods per plant are very important yield component which determines the marketable green pod yield in vegetable cowpea. Ten parents involving six lines and four testers of cowpea and their respective hybrids generated through L x T fashion were evaluated for their per se performance for sixteen characters. The maximum pod yield per plant was in 2014/COPBVAR-6 among lines followed by 2014/COPBVAR-5, 2012/COPBVAR-3, whereas Gomti out yielded all the testers in terms of pod yield per plant. Genotype 2012/COPBVAR-3 had the highest pod length and mean pod weight as well among the lines. Genotype 2014/COPBVAR-4 was the earliest in flowering among the lines. Genotype 2014/COPBVAR-6 had the lowest plant height and the highest number of branches per plant among the lines. These parents can be used for hybridization program for future improvement of the respective characters in cowpea. Among the crosses, the highest marketable green pod yield per plant was in 2014/COPBVAR-6 x Pusa Komal which was followed by 2014/COPBVAR-6 x Kashi Kanchan, 2014/COPBVAR-6 x Gomti, 2014/COPBVAR-5 x Pusa Komal and 2014/COPBVAR-5 x Gomti. Number of pods per plant and 100-seed weight were also higher in these crosses and the average maximum number of pods per plant was when line 2014/COPBVAR-6 was used as female parent. Among other attributes the cross 2014/COPBVAR-5 x Pusa Komal recorded the maximum pod length whereas 2012/COPBVAR-2 x Gomti recorded the maximum pod width. The maximum mean pod weight was in 2012/COPBVAR-3 x Kashi Kanchan and the earliest flowering was in 2012/COPBVAR-3 x Kashi Kanchan. The lowest plant height was in 2012/COPBVAR-5 x Arka Garima and the highest number of branches per plant was in 2012/COPBVAR-3 x Kashi Kanchan indicating the scope for selection of suitable initial breeding material for further improvement as per the requirement such as high yielding, early and bushy type varieties/hybrids.

**Key Words:** Cowpea, Hybrids, Per se performance, *Vigna unguiculata*

Cowpea botanically known as *Vigna unguiculata* (L.) Walp. is an important legume crop and forms an important component of farming systems throughout the tropics and warm sub-tropics. Cowpea cultivars grown for the immature green pods which are used as vegetable are variously known as yard-long bean, asparagus bean and snake bean. Cowpea belongs to the family Leguminosae; sub family fabaceae and genus *Vigna* with chromosome number,  $2n = 22$ . Among legumes, cowpea is one of the most important vegetable crops grown during rainy and summer seasons. It is also suitable for green manuring, fodder cover and catch crop.

Per se performance is still the most simple and effective way to get first hand information on the genotypes. Crosses between parents with good per se performance are expected to yield desirable recombinants in the segregating generations and the potentialities of such genotypes will also reflect in the performance of hybrids. The selected genotypes can be further utilized to exploit recombination breeding or heterosis (Valarmathi and Surendran 2007). The cultigen cowpea is cultivated between 35°N to 30°S,

covering Asia and Oceania, the Middle east, Southern Europe, Africa and Central and South America. In the cultigen cowpea, four cultigroups have been identified: (1) *unguiculata* grain type, which is the major group; (2) *biflora* or *catjang*, which is differentiated mainly by its small erect pods and is grown in Southeast Asia; (3) *sesquipedalis*, the yard long bean, which is differentiated mainly by its very long pods and climbing growth habit, and is grown for its fresh pods in Asia; and (4) *textilis*, which was grown in West Africa for the textile fibres obtained from its long peduncles. Exploitation of genetic potential of wild and close relatives of cowpea for enhancing cowpea productivity had not been well documented. With this objective in view, ten parents and their resultant hybrids were evaluated based on mean per se performance. The average productivity of cowpea is low as compared to other pulse crops due to the lack of availability of high yielding genotypes and also susceptibility of the genotypes to major biotic stresses. Hence, there is a paramount importance to improve the yield potential along with improving the resistance/tolerance to pest and diseases.

## MATERIAL AND METHODS

Ten diverse genotypes which included six lines viz., 2012/COPBR/2012-2, 2012/COPBR/2012-3, 2012/COPBR/2012-5, 2014/COPBR/2012-4, 2014/COPBR/2012-5, 2014/COPBR/2012-6 and four testers viz. Gomti, Pusa Komal, Kashi Kanchan and Arka Garima were crossed in a L x T fashion during *Kharif* 2014 and evaluated in *Kharif* 2015. Thus, line x tester mating was carried out between these six lines and four testers and the experimental materials, Lines (6), Testers (4) and their crosses (24) were grown in a randomized block design with three replications at JNKVV, Jabalpur, India. Each plot (3.0 x 2.4 sq. m) consisted of three rows and 7 plants in each row. The spacing given was 60 cm between rows and 30 cm within a row. Observations were recorded on ten randomly chosen plants in each replication both for parents (10) and hybrids (24) for the twelve quantitative characters viz., plant height (cm), number of branches per plant, days to 50% flowering, number of flowers per cluster, number of pods per cluster, pod setting percentage, days to first harvest, days to last harvest, pod length (cm), pod width (cm), pod weight (g), number of seeds per pod, 100-seed weight (g) and green pod yield per plant (g).

## RESULTS AND DISCUSSION

There was significant variability among parents and hybrids for all the sixteen characters (Table 1). These results are similar with the findings of Sarutayophat et al (2007)

which showed highly significant difference for pod length, number of pods/plant and pod yield/plant among 37 accessions and Stoilova and Berova (2009) in cowpea. The lower mean values for days to 50% flowering, days to maturity and plant height indicate better performance because early flowering and maturity and dwarf bushy types are preferred. For other traits high value indicate better performance. Early flowering is the important trait and an advantageous feature in cowpea to have early access to market. In parents, duration ranged from 46.73 to 59.17 days. Reasons attributed for difference in days to flowering among the genotypes is that, the character is dependent on a minor gene complex and tendency for dominance of early flowering in cowpea. The results are in accordance with Nkouannessi (2005) and Lingaraj (2009) in cowpea who reported that analysis of variance revealed significant difference among the genotypes for all the characters. Taking the overall mean as criteria, top ranking superior parents were identified for different characters. They were 2014/COPBVAR-4 and Kashi Kanchan for days to first flowering and 2014/COPBVAR-4 and Pusa komal for days to maturity and all the lines (female parents) for plant height and 2014/COPBVAR-6, 2012/COPBVAR-3 and 2012/COPBVAR-5 for number of branches per plant and all the testers (male parents) for clusters per plant and 2014/COPBVAR-4, 2014/COPBVAR-5 and Gomti for pods per cluster and all the testers for pod weight, green pod yield, seeds per pod. The highest yield per plant was in

**Table 1.** Analysis of variance for sixteen quantitative traits in genotypes of cowpea

Character	Mean sum of squares		
	Replications (df = 2)	Treatments (df = 9)	Error (df = 18)
Plant height (cm)	1.783	1,920.29**	3.933
Number of branches plant <sup>-1</sup>	0.216	2.893*	0.986
Days to first flowering	0.7285	38.148**	3.36
Days to 50% flowering	0.8965	58.304**	3.344
Number of flowers cluster <sup>-1</sup>	0.702	3.989**	0.283
Number of pods cluster <sup>-1</sup>	0.001	1.147**	0.11
Pod setting percentage	62.768	374.736**	17.139
Days to first pod harvest	1.9355	110.774**	3.745
Days to last pod harvest	0.092	521.486**	7.865
Number of pods plant <sup>-1</sup>	8.6075	260.484**	4.338
Pod length (cm)	1.063	45.638**	1.569
Pod width (cm)	0.0005	0.05*	0.01
Pod weight (g)	9.704	455.635**	3.14
Number of seeds pod <sup>-1</sup>	0.767	6.193**	0.329
100 seed weight (g)	1.5995	32.885**	0.66
Marketable pod yield plant <sup>-1</sup> (g)	58.173	4,852.20**	19.713

\*, \*\* = significant at 5% and 1% levels of significance respectively

2014/COPBVAR-6 followed by 2014/COPBVAR-5 among female parents and Gomti followed by Kashi Kanchan among male parents. The variation in these characters may be due to genotypic ability of plant itself and varied response to environmental conditions as evidenced by the results of Stoilova and Pereira (2013), who evaluated 48 accessions of cowpea by 24 morphological descriptors and identified the accessions with specific behaviour based on best performance for the development of new varieties and more interesting for inclusion in cowpea breeding programme.

**Mean performance of hybrids:** The maximum mean height among crosses was significantly higher in 2014/COPBVAR-4 x Gomti (114.0 cm) followed by 2012/COPBVAR-3 x Gomti. Crosses mean for number of branches per plant ranged from 6.25 (2014/COPBVAR-4 x Pusa Komal) to 9.32 (2012/COPBVAR-3 x Kashi Kanchan) with an overall average of 7.80 and the crosses viz, 2012/COPBVAR-3 x Arka Garima, 2012/COPBVAR-5 x Arka Garima and 2012/COPBVAR-3 x Gomti were significantly superior based on critical difference. The number of primary branches determines ultimately, the pod bearing ability of plant which will intern contributes to the yield, hence identification and selection of genotypes with more branching ability is necessary in cowpea (Nkouannessi 2005). Lingaraj (2009) observed relatively high level of dissimilarity among the accessions for most of the morphological traits analysed, especially for accessions from different countries indicating better possibilities for genetic improvement of the crop through selection and cross breeding. Days to first flowering,

among the crosses, ranged from 46.05 days (2014/COPBVAR-5 x Pusa Komal) to 61.00 (2012/COPBVAR-5 x Arka Garima) with an overall mean of 54.23 days. Minimum days to first flowering was observed in crosses involving 2012/COPBVAR-3 as female parent while, maximum 56.56 days was in crosses having 2014/COPBVAR-6 as female parent. Among the crosses earliest days to 50% flowering was in 2012/COPBVAR-3 x Kashi Kanchan (52.00 days) whereas, maximum 65.08 days in 2012/COPBVAR-2 x Arka Garima with an overall crosses average of 58.88 days. Number of flowers per cluster ranged from 2.97 (2012/COPBVAR-5 x Arka Garima) to 5.13 (2014/COPBVAR-5 x Pusa Komal) which was followed by 2014/COPBVAR-5 x Gomti and 2014/COPBVAR-6 x Pusa Komal. In crosses number of pods per cluster varied from 1.76 (2012/COPBVAR-2 x Arka Garima) to 4.03 (2014/COPBVAR-6 x Pusa Komal) which was followed by 2014/COPBVAR-6 x Gomti, 2014/COPBVAR-4 x Gomti and 2014/COPBVAR-6 x Kanchan with an overall average of 2.91. A wide range of variation from 57.44 (2012/COPBVAR-5 x Pusa Komal) to 81.25 per cent (2014/COPBVAR-6 x Pusa Komal) with an overall mean of 66.66 was noted for per cent pod set and total seven crosses were significantly superior to overall mean. The average maximum number of pods per plant (72.22) was when line 2014/COPBVAR-6 was used as female parent. Minimum days to first picking was observed for 2012/COPBVAR-3 x Kashi Kanchan (57.00 days) whereas, maximum days to first picking was recorded in 2012/COPBVAR-2 x Arka Garima (71.21 days) with an

**Table 2.** Mean performance of parents (lines and testers)

Lines	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
2012/COPBVAR	74.68	8.40	55.3	62.4	2.97	1.93	64.9	71.2	98.30	26.0	21.5	0.89	50.0	10.5	9.56	129.7
2012/	72.37	8.55	54.2	63.0	4.16	2.11	50.7	73.3	124.3	44.2	29.0	0.69	60.5	12.4	15.3	198.5
2014/	54.55	8.80	58.5	66.2	4.07	3.20	78.6	76.1	130.5	57.0	26.1	0.67	57.3	11.5	18.6	232.7
2014/	92.80	6.47	52.6	60.6	5.29	3.37	63.7	68.5	94.60	36.3	21.5	0.77	40.6	9.40	11.5	181.3
2012/	67.53	6.67	54.6	64.5	3.33	2.00	60.0	75.4	120.7	37.5	16.0	1.04	37.5	11.0	10.4	141.3
2014/	62.88	7.73	57.4	64.9	4.97	3.27	65.7	74.2	126.4	49.3	24.5	0.69	56.0	10.9	16.3	225.6
<b>Testers</b>																
Gomti	133.2	7.73	56.1	63.2	5.98	3.60	60.2	77.2	128.8	45.0	22.3	0.82	48.3	11.0	18.5	214.6
Pusa Komal	56.80	6.60	46.7	51.7	5.17	2.57	49.7	58.6	106.4	39.9	23.0	0.76	28.2	14.6	14.3	203.5
Kashi Kanchan	56.30	6.93	53.2	63.3	4.20	2.37	56.4	76.1	104.3	34.0	26.5	0.99	60.1	10.7	11.2	152.9
Arka Garima	103.0	8.27	59.1	68.0	6.67	2.47	37.0	80.6	116.2	29.5	18.3	0.88	29.3	10.2	12.4	126.7
Grand mean	77.44	7.62	54.8	62.8	4.68	2.69	58.7	73.2	115.0	39.8	22.9	0.82	46.7	11.2	13.8	180.7
CV	2.561	13.03	3.34	2.91	11.35	12.32	7.04	2.64	2.437	5.22	5.46	12.01	3.79	5.09	5.86	2.456
CD (p=0.05)	3.428	1.717	3.16	3.16	0.919	0.573	7.15	3.34	4.848	3.60	2.16	0.170	3.06	0.99	1.40	7.675
1.	Plant Height (cm)				2.	No. of branches/ plant				3.	Days to first flowering					
4.	Days to 50% flowering				5.	No. of flowers/cluster				6.	No. of pods/cluster					
7.	Pod setting percentage				8.	Days to first harvest				9.	Days to last harvest					
10.	No. of pods per plant				11.	Pod length (cm)				12.	Pod width (cm)					
13.	Pod weight (g)				14.	No. of seeds/pods				15.	100 seed weight (g)					

overall average of 64.92 days. Days to last harvest ranged from 99.81 days (2012/COPBVAR-5 x Arka Garima) to 137.65 days (2014/COPBVAR-6 x Pusa Komal) with an overall average of 121.14 days. Maximum days to final picking were observed in crosses 2014/COPBVAR-6 x Pusa Komal (137.65 days) followed by 2014/COPBVAR-6 x Kashi Kanchan, 2014/COPBVAR-5 x Pusa Komal and 2014/COPBVAR-6 x Gomti.

The mean for number of pods per plant ranged from 30.13 (2012/COPBVAR-5 x Arka Garima and 2012/COPBVAR-3 x Arka Garima) to 61.14 (2014/COPBVAR-6 x Pusa Komal). Total five crosses viz, 2014/COPBVAR-6 x Kashi Kanchan, 2014/COPBVAR-6 x Arka Garima, 2014/COPBVAR-5 x Pusa Komal and 2014/COPBVAR-5 x Gomti had significantly superior to overall average of 42.70 based on CD values. The average maximum number of pods per plant (58.04) was noted when line 2014/COPBVAR-6 was used as female parent. Among the crosses pod length varied from 16.94 cm (2012/COPBVAR-5 x Arka Garima) to 30.00 cm (2012/COPBVAR-3 x Gomti) which was followed by 2012/COPBVAR-3 x Pusa Komal, 2014/COPBVAR-5 x Kashi Kanchan, 2014/COPBVAR-5 x Pusa Komal and 2012/COPBVAR-3 x Kashi Kanchan with an overall cross mean of 23.17 cm. The importance of these characters for the improvement in yield was stressed by Idahosa et al (2010), Manggoel et al (2012) and Thorat and Gadekar (2013). Mean for pod width varied from 0.78 cm (2014/COPBVAR-5 x Kashi Kanchan) to 1.06 cm (2012/COPBVAR-2 x Gomti and 2012/COPBVAR-3 x Gomti) with an average of 0.90 cm. The range for pod weight varied from 23.73 g (2014/COPBVAR-5 x Arka Garima) to 62.24 g (2012/COPBVAR-3 x Kashi Kanchan) which was followed by 2012/COPBVAR-3 x Gomti, 2012/COPBVAR-3 x Pusa Komal and 2014/COPBVAR-6 x Pusa Komal with an overall average of 45.61 g. Number of seeds per pod ranged from 9.34 (2014/COPBVAR-4 x Arka Garima) to 15.12 (2014/COPBVAR-5 x Pusa Komal) with an overall cross mean of 11.44. Cobbinah et al (2011) opined that cowpea accessions with longer pods were easily visible and firmly held during harvesting. Attention should therefore be paid to such accessions since they enhance the rate of harvesting of cowpea. Similar difference in seed number was noticed by Nkouannessi (2005) and Makanur et al (2013) in cowpea. The 100-seed weight ranged from 10.73 g (2012/COPBVAR-5 x Arka Garima) to 19.84 g (2014/COPBVAR-6 x Kashi Kanchan) followed by 2014/COPBVAR-4 x Gomti, 2012/COPBVAR-3 x Gomti, 2014/COPBVAR-5 x Gomti and 2014/COPBVAR-6 x Gomti and 2014/COPBVAR-5 x Pusa Komal with an overall average of 15.10 g. The crosses mean

value for marketable green pod yield per plant ranged from 128.42 g (2012/COPBVAR-5 x Arka Garima) to 256.47 g (2014/COPBVAR-6 x Pusa Komal) which was followed by 2014/COPBVAR-6 x Kashi Kanchan and 2014/COPBVAR-6 x Gomti, with an overall cross mean of 195.11 g and total seven crosses were significantly superior to overall mean. Maximum green pod yield per plant was observed in most of the crosses when line 2014/COPBVAR-6 was used as female parent. The best parents and their crosses identified may be used for further study of heterosis and combining ability and based on that new varieties/hybrids could be released (Singh et al 2006, Sharma et al 2010).

Out of ten parents, 2014/COPBVAR-6, 2014/COPBVAR-5, Gomti and Kashi Kanchan recorded significantly high marketable pod yield per plant than the other parents. Line 2014/COPBVAR-6 was superior to all the lines for marketable pod yield due to more number of pods per plant, mean pod weight, pod setting percentage 100 seed weight, whereas Gomti out yielded all the testers in terms of pod yield per plant. Other attributes like number of pods per plant, pod setting percentage, days to last pod harvest and hundred seed weight were also higher in this parent. Thus, the genotypes with higher mean performance for desired plant characters can be used as potential parents as lines (*i.e.* 2014/COPBVAR-6 and 2014/COPBVAR-5) and testers (*i.e.* Gomti and Kashi Kanchan) and hybridization can be taken up for future improvement in cowpea. Genotype 2012/COPBVAR-3 had the highest pod length and mean pod weight as well among the lines. Genotype 2014/COPBVAR-4 was the earliest in flowering among the lines. Genotype 2014/COPBVAR-6 had the lowest plant height and the highest number of branches per plant among the lines. Hence, these genotypes can be used as donor parents for the respective characters

The significance of mean squares due to parents vs. hybrids for all the traits proved that the differences in the performance of parents and hybrids were real and manifested the presence of heterosis for most of the characters studied. The maximum number of pods per plant was reported in 2014/COPBVAR-6 x Pusa Komal followed by 2014/COPBVAR-6 x Kashi Kanchan. The average maximum number of pods per plant was when line 2014/COPBVAR-6 was used as female parent. Among the crosses 2014/COPBVAR-5 x Pusa Komal recorded the maximum pod length, whereas, in 2012/COPBVAR-2 x Gomti pod width was maximum. The maximum mean pod weight was in 2012/COPBVAR-3 x Kashi Kanchan followed by 2012/COPBVAR-3 x Gomti. The earliest flowering was in 2012/COPBVAR-3 x Kashi Kanchan, which may be utilized to develop early varieties. The lowest plant height was in

Table 3. Mean performance of F1's of cowpea

Hybrids	Characters															
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
2012/COPBVAR-5xGomti	98.00	7.10	56.20	62.00	4.70	2.82	60.00	67.00	129.25	40.00	24.60	0.91	51.00	10.75	14.67	203.24
2012/ COPBVAR-5xP. Komal	78.00	6.40	54.00	59.00	4.84	2.78	57.44	63.50	107.56	38.00	23.50	0.89	49.00	10.27	12.12	176.50
2012/ COPBVAR-5x K. Kanchan	60.70	7.25	52.00	57.20	3.05	2.46	80.66	59.69	101.64	32.00	19.78	0.94	53.00	10.64	10.56	140.50
2012/ COPBVAR-5x A. Garima	59.80	9.20	61.00	64.00	2.97	2.31	77.78	68.00	99.81	30.00	16.94	0.86	39.60	10.37	10.73	128.42
2012/ COPBVAR-3 xGomti	110.00	9.16	55.00	59.00	4.79	2.93	61.17	61.75	129.86	47.00	30.00	1.06	60.72	11.02	19.38	218.37
2012/ COPBVAR-3 xP. Komal	81.56	8.90	50.00	56.00	4.87	2.94	60.37	58.35	128.27	45.67	28.97	1.02	60.64	12.67	16.84	221.84
2012/ COPBVAR-3 xK. Kanchan	79.50	9.32	49.30	52.00	4.25	2.61	61.41	57.00	124.45	39.00	26.57	0.98	62.24	11.56	13.96	198.53
2012/ COPBVAR-3 xA. Garima	102.00	9.27	56.00	60.00	3.98	2.34	58.79	64.40	121.24	30.00	21.20	0.81	33.14	10.43	14.26	129.77
2014/ COPBVAR-6 xGomti	108.85	8.26	57.00	63.00	5.43	3.98	73.30	70.00	131.78	58.12	24.12	0.83	54.00	11.25	19.37	246.38
2014/ COPBVAR-6 xP. Komal	92.73	7.47	56.12	62.00	4.96	4.03	81.25	67.00	137.65	61.00	18.12	0.94	58.00	13.26	20.67	256.47
2014/ COPBVAR-6 x K. Kanchan	89.65	7.76	55.08	58.00	4.80	3.56	74.17	64.07	133.48	59.00	28.03	0.86	56.04	10.27	19.84	250.18
2014/ COPBVAR-6 x A. Garima	91.20	8.80	58.03	62.04	4.27	2.56	59.95	66.23	118.23	54.05	25.10	0.81	32.20	11.13	16.67	196.42
2014/ COPBVAR-4 x Gomti	114.00	6.98	52.46	58.36	4.79	3.60	75.16	68.32	130.85	47.21	23.20	0.92	48.79	11.98	19.64	226.41
2014/ COPBVAR-4 x P. Komal	98.50	6.25	51.67	57.20	4.75	3.44	72.42	65.64	108.68	40.30	24.21	0.80	34.30	10.54	15.43	198.60
2014/ COPBVAR-4 x K. Kanchan	93.40	6.75	53.20	55.10	4.67	3.12	66.81	64.38	105.36	42.11	22.40	0.87	45.20	10.26	11.41	207.30
2014/ COPBVAR-4 x A. Garima	96.51	7.84	54.11	58.20	3.76	2.56	68.09	66.27	102.98	38.23	19.26	0.89	32.40	9.34	11.98	175.73
2012/ COPBVAR-2 xGomti	89.50	6.93	55.08	60.10	4.75	3.09	65.05	67.30	131.65	42.00	19.24	1.06	49.36	12.33	15.43	198.62
2012/ COPBVAR-2 x P. Komal	81.40	6.97	50.09	53.20	4.62	2.86	61.90	59.41	127.39	37.43	19.78	1.02	41.23	14.57	13.28	178.45
2012/ COPBVAR-2 x K. Kanchan	79.50	7.36	53.40	57.12	3.25	2.13	65.54	64.30	117.34	36.00	23.24	0.94	40.32	11.93	11.14	162.56
2012/ COPBVAR-2 x A. Garima	84.20	7.95	59.07	65.08	2.98	1.76	59.06	71.21	116.98	34.00	18.25	0.91	36.28	10.86	11.42	133.67
2014/ COPBVAR-5 xGomti	87.50	8.16	55.23	62.21	5.12	3.38	66.02	70.00	130.75	50.70	25.65	0.89	49.34	11.37	19.37	232.68
2014/ COPBVAR-5 x P. Komal	79.60	7.61	46.05	52.06	5.13	3.56	69.40	62.07	133.29	52.40	26.68	0.83	46.51	15.12	18.57	240.56
2014/ COPBVAR-5 x K. Kanchan	71.40	7.83	52.14	56.15	4.27	2.69	63.00	61.13	119.46	40.50	28.12	0.78	35.48	11.25	13.38	205.73
2014/ COPBVAR-5 x A. Garima	85.46	8.05	58.31	63.23	3.98	2.40	60.30	71.16	118.37	31.20	19.84	0.81	23.73	10.86	12.96	196.23
Overall Mean	88.14	7.80	54.23	58.88	4.37	2.91	66.66	64.92	121.04	42.74	23.17	0.90	45.61	11.44	15.10	195.11
CD (p=0.05)	3.59	6.54	2.25	2.52	0.38	0.28	3.70	3.58	4.29	2.81	1.69	0.08	2.89	0.78	2.45	22.80

2012/COPBVAR-5 x Arka Garima and the highest number of branches per plant was in 2012/COPBVAR-3 x Kashi Kanchan which can be exploited to develop busy type cowpea. None of the parents or their hybrids exhibited consistently higher performance for all the sixteen characters studied. However, the high performing parents and hybrids for green pod yield per plant also exhibited high *per se* performance for most of the yield components.

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# Optimization of Onion, Garlic and Tomato Fortification in Dehusked Mungbean Preparation for Enhanced Iron Bioaccessibility

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**Abstract:** The usage of onion, garlic and tomato in legume preparations is vogue in India but the amounts of these should be optimized to enhance iron bioavailability from legumes. Onion and tomato were added at four levels i.e. 25, 50, 75 and 100g each while garlic was added at the levels of 5, 10, 15 and 20g to 100 g of base legume (Mungbean dehusked) cooked in a traditional manner. The maximum *in vitro* iron bioaccessibility was when legume was fortified with garlic (224 to 344%) followed by tomato (204 to 284%) and onion (89 to 227%). Maximum increase in ascorbic acid was there when base legume was fortified with tomato while  $\beta$ -carotene and cysteine was increased to maximum when garlic was added. The fortification of onion (100g), tomato (100g) and garlic (20g) enhanced the bioaccessibility of iron from a legume preparation to 3.3, 3.8 and 4.4 folds, respectively.

**Keywords:** *In vitro* iron bioaccessibility, Onion, Tomato, Garlic, Total iron, Dialyzable iron

Eradication of iron deficiency anemia is an important goal of international community in order to improve nutritional and health status of the populations subsisting on cereal-legume based diets. This can be achieved by enhancing the bioavailable iron of habitual meal patterns through fortification of common food preparations with optimized proportions of key foods known to enhance the bioavailability of iron. Inclusion of onion, garlic and tomatoes in legume and vegetable preparations is practiced in Indian diets from times immemorial. These additives have the evidence of being the enhancers of iron bioavailability (Gautam et al 2010a, 2011a, Bing et al 2014). There is emerging evidence that dietary sulphur amino acids influence the status of iron. The sulphur compounds of allium species are likely to chelate the iron and keeps it soluble, thus facilitates its absorption (Gautam et al 2011b). Garlic (*Allium sativa*) and onion (*Allium cepa*), which are liberally consumed in Indian diets, are rich sources of sulphur compounds such as thiosulfinates, sulfides, polysulfides, mercaptans and other odoriferous sulphur compounds. Both the *allium* species caused an increase in iron bioaccessibility ranging from 10–73% in different cereals and legumes (Gautam et al 2010a). The healthy biological effects of addition of garlic to common preparations are attributed to its organosulfur compounds including those with  $\gamma$ -glutamyl moiety in their structures.  $\beta$ -carotene, lycopene, lutein, beta cryptoxanthin and zeaxanthin are some of the carotenoids present in appreciable amounts in tomatoes. These carotenoids have been demonstrated to improve iron absorption *in vitro* and in human absorption studies (Garcia-

Casal, 2006) by providing a more soluble source of iron which is ready to be absorbed by regular pathways as well as by absorption through a carotenoid-iron complex. Tomato is used as an acidulant to impart a desirable sour taste to Indian legume preparations. These are rich in organic acids which are known to promote the absorption of iron from plant foods (Hemalatha et al 2005).

The usage of onion, garlic and tomato in legume preparations is a common practice in North India but the amounts of these three additives individually or in combination need to be optimized to enhance iron bioavailability from the legumes which otherwise have lower iron bioavailability. This study is an endeavor to improve iron bioavailability of legumes through a scientific approach and subsequently educating the general population regarding the usage of appropriate amounts of these key foods which can play a pivotal role in addressing the problem of iron malnutrition.

## MATERIAL AND METHODS

De-husked mungbean was chosen as base legume for optimizing the levels of onion, garlic and tomato for enhanced *in vitro* iron bioaccessibility. One hundred gram of legume i.e. mungbean dehusked was pressure cooked (15psi) in 350 ml of water for 5 minutes. Salt, turmeric and red chilli powder were added at the rate of 2, 1.5 and 1.5g/100g, respectively. The cooked samples were homogenized in a stainless steel mixer and used for the chemical analysis. Inclusion of onion, garlic and tomato was made through pan

frying (oil, 15g). Experiments were carried on independent sets for mungbean (dehusked) using additives namely onion and tomato @ 25,50,75 and 100g and garlic @ 5,10,15 and 20g to the base legume. The fresh homogenized samples were used for dialyzable iron, ascorbic acid and  $\beta$ -carotene estimations. A portion of homogenized sample was dried in hot air oven at  $\pm 60^\circ\text{C}$  until constant weight. The dried samples were ground and stored in decontaminated zip lock bags for the analysis of total iron and cysteine. The experimental samples were prepared in three replicates. Fresh and dried samples were examined for moisture (AOAC 1990), ascorbic acid (AOAC 1995),  $\beta$ -carotene (Rangana 1995), cysteine (Liddell and Saville 1959), total iron and dialyzable iron. Total iron was determined by Atomic Absorption Spectrophotometer after wet digestion. Bioaccessibility of iron from the samples was determined using an *in vitro* method (Luten et al 1996). All of the determinations for *in vitro* iron bioaccessibility were performed in four replicates and the average values are reported.

## RESULTS AND DISCUSSION

Inclusion of onion at the levels of 25, 50, 75 and 100g to the base legume resulted in a significant increase in ascorbic acid (1.60, 2.61, 3.04 and 3.60mg/100g, respectively). Tomato showed a higher increase as compared to onion, the ascorbic acid content being 3.0, 3.38, 4.01 and 4.29 mg/ 100 g when they were added in the base legume at the levels of 25, 50, 75 and 100 g. Garlic also improved the ascorbic acid content when added in the base legume at 5, 10, 15 and 20 g/100 g, the corresponding values being 2.15, 2.45, 2.59 and 2.72 mg. The results indicated that inclusion of all the three additives namely onion, tomato and garlic resulted in a significant increase in ascorbic acid when added to base legume. The maximum ascorbic acid was in tomato (31 mg %) followed by garlic (13mg %) and onion (11mg %). According to Food Composition Tables (ICMR 2017) the ascorbic acid content of raw dehusked mungbean is almost negligible, the addition of onion, tomato and garlic contributed significantly to enhance ascorbic acid in the legume preparation in the present study. Ascorbic acid has been reported as a strong promoter of iron bioaccessibility in several studies (Thankachan et al 2008, Lane, Richardson, 2014). Various scientists reported that use of additives namely lemonade, amla juice, guava fruit, citrus fruit juices, potato, cauliflower or cabbage which are good sources of citric acid and ascorbic acid can enhance the iron bioaccessibility (Singh 2013, Venkatasubramanian et al 2014). In addition to ascorbic acid, tomatoes also had 0.194 mg % of organic acids. Citric and malic acids are organic

acids that contribute most to the typical taste of tomato fruit. The organic acids have been reported to enhance iron bioaccessibility in legumes by Hemlatha et al (2005). Therefore, the inclusion of tomatoes as a source of ascorbic acid and other organic acids may prove beneficial in enhancing the iron bioaccessibility from the food grains.

The  $\beta$ -carotene determined by column chromatography revealed that the base legume had a very low value of  $\beta$ - carotene i.e.  $13.64\mu\text{g } 100\text{g}^{-1}$  on fresh weight basis. The addition of onion to the base legume at the levels 25, 50, 75 and 100 g  $100\text{g}^{-1}$  resulted in a significant reduction in  $\beta$ - carotene when compared to base legume, the values being 9.08, 8.08, 6.20 and  $5.52\mu\text{g } 100\text{g}^{-1}$ , respectively. The reduction has been attributed to even poor  $\beta$ - carotene content of onion than the base legume. The oil added in preparations of experimental samples further contributed to reduction in  $\beta$ - carotene content. On the other hand, tomatoes being a good source of  $\beta$ - carotene resulted in a significant increase in  $\beta$ -carotene content of the legume preparation. Further, with the increase in the level of tomato from 25 to 100 g, a significant increase i.e. 15.44 to  $32.2\mu\text{g}$  in  $\beta$ - carotene content has been observed, thus, indicating that higher level of tomatoes are desirable to enhance the  $\beta$ - carotene in legume preparations. The results showed that garlic contributed higher  $\beta$ -carotene to the base legume when compared to tomatoes. The levels of  $\beta$ - carotene were 17.2, 37.6, 58.16 and  $76.36\mu\text{g}$  at the levels of 5, 10, 15 and 20 g. The results revealed that though onion, tomato and garlic are poor to fair source of  $\beta$ -carotene still they were capable to enhance the  $\beta$  - carotene content in the base legume.  $\beta$ -carotene has been reported as a strong promoter of iron bioaccessibility in many reported studies (Garcia-Casal et al 2000, Gautum et al 2010b). Inclusion of garlic was most beneficial followed by tomatoes in order to enhance  $\beta$ -carotene content in legume preparations. Nambiar and Sharma (2014) stated that  $\beta$ -carotene content of garlic is  $2377\mu\text{g g}^{-1}$ , whereas, Ahamad et al (2007) reported  $1610\mu\text{g } 100\text{g}^{-1}$  of  $\beta$ - carotene in tomatoes in fresh weight basis. The inclusion of tomato and garlic at different levels enhanced the  $\beta$ -carotene in the base legume, therefore the results of the present study are in line with the findings reported in literature. Cysteine has peptides responsible for enhancement of bioaccessibility of iron. Legumes are deficient in sulphur containing amino acids. A significant increase in cysteine content was observed when base legume was fortified with onion, tomato and garlic, however the increase was maximum by garlic followed by onion and tomato. The reported studies revealed that two  $\gamma$ - glutamyl-cysteine peptides ( $\gamma$ -GCPs), (SC2RC7)- $\gamma$ -L- glutamyl-S-allyl-L-cysteine and (SC2RC7)- $\gamma$ -L-glutamyl-S-

propyl-L-cysteine present in allium species i.e. onion and garlic had a promoting effect on the bioaccessibility of iron from food (Bing et al 2014). Methionine another sulphur containing amino acid was reduced with fortification of onion, tomato and garlic at different levels. The least reduction in methionine was found in legume samples added with onion followed by tomato and garlic.

Legumes have been reported as fair source of iron. The selected legumes i.e. dehusked mungbean had a total iron content of 5.19 mg 100g<sup>-1</sup> dry matter (DM). There was a significant reduction in total iron on the addition of onion to the base legume. Similarly, tomato and garlic fortified the base legume at all four levels showed a significant reduction in total iron. The content of total iron of base legume fortified with onion, tomato and garlic at four levels ranged between 4.35 to 4.42, 4.40 to 4.79 and 4.60 to 4.85 mg 100g<sup>-1</sup> DM, respectively. The reduction in iron content could be due to poor iron content of additives i.e. onion, tomato and garlic as well as addition of oil in the legume preparation. The dialyzable iron represents the iron available to the human body. Promoters and inhibitors present in legumes influence the dialyzable iron content. The promoters of iron bioaccessibility present in the selected additives namely onion, tomato and garlic are identified as ascorbic acid,  $\beta$ -carotene and cysteine peptides present in allium species. The dialyzable iron of base legume was 0.31 mg 100g<sup>-1</sup> DM which was increased to 0.50 mg (61%), and 0.85 mg (174%) when fortified with onions at the levels of 25 and 100 g respectively. The increase in the dialyzable iron with onion fortification can be attributed to rich content of thiosulfinates, sulfides, polysulfides, mercaptans, and other odoriferous sulfur compounds that has positive effect on iron bioaccessibility. Gautam et al (2010a) found that onion had a significantly positive effect on the bioaccessibility of iron from green gram as inclusion of onion (1.5 and 3 g 10 g<sup>-1</sup>) in raw green gram and chickpea enhanced the bioaccessibility of iron to an extent of about 17% at both of the levels, while in cooked green gram, the same was 17.2 and 32% at the two levels of onion, respectively. Onion also increased the bioaccessibility of iron from chickpea, the percent increase being 39.3 and 48.1 percent and in cooked chickpea to an extent of 21.2 and 26.3% at the two levels, respectively. Another study conducted by Gautam et al (2011a) showed that phytic acid decreased the bioaccessibility of iron from raw green gram by 30%, while onion increased it by 28%. The positive effect of onion was predominant even in the presence of phytic acid and this combination produced a net increase in iron bioaccessibility by 21%. Similarly, the combination of onion and phytic acid had a net positive influence of 30% in iron bioaccessibility from cooked green

gram, whereas phytic acid independently had a negative influence by 27%, and onion had a positive influence by 31%. Thus, onion completely overcame the negative influence of phytic acid on iron bioaccessibility from green gram, and also retained the extent of its positive influence. Tomato as a source of ascorbic acid, organic acids, carotenoids and specifically  $\beta$ -carotene also increased dialyzable iron when base legume was fortified with tomatoes at 25, to 100 g levels, the values of dialyzable iron were 0.87 and 1.01 mg, respectively. The corresponding increase in dialyzable iron was 181 and 226% respectively at the four levels. Garcia-Casal (2006) reported that lycopene, lutein, and zeaxanthin without provitamin-A activity in presence of different concentrations significantly increased *in vitro* iron absorption in human absorption studies from corn and wheat meals.

Dialyzable iron in garlic fortified legume samples was 0.88 and 1.22 mg at level of 5 and 20 g. The percent increase was found to be 184 and 342 % at these levels, respectively (Table 1). Garlic had two  $\gamma$ -glutamyl-cysteine peptides ( $\gamma$ -GCPs) which had a promoting effect on the bioavailability of iron was reported by Bing et al (2014). The results clearly indicated that inclusion of onion, tomato and garlic increased the dialyzable iron however, the maximum effect was found for garlic > tomato > onion. The *in vitro* iron bioaccessibility from base legume was 5.97 which was increased to and 19.54 % when fortified with 25 and 100 g of onion. The corresponding values of *in vitro* iron bioaccessibility for the same levels of tomato were 18.16 and 22.95%. On the other hand 5 and 20 g of garlic added to base legume had *in vitro* iron bioaccessibility of 18.14 and 26.52 %, respectively. Fortification of onions at the levels of 25, 50, 75 and 100 g resulted in 89 and 227 % increase in the bioaccessibility of iron and the corresponding values for tomato were 204 and 284 %. Garlic fortification at the levels of 5, 10, 15 and 20 g increased iron bioaccessibility by 204 and 344 %, respectively. The results clearly indicated that garlic was most beneficial followed by tomato and onion.

Bing et al (2014) revealed that upon the addition of 0.01 mmol compound  $\gamma$ -L-glutamyl-S-allyl-L-cysteine, the bioavailability of iron in mung bean was increased from 2.52 to 12.04% with the percentage increase in the bioavailability of iron from mung bean being 380%. Garlic enhanced iron bioaccessibility from raw green gram to 15.6 and 20.5 at the two levels (0.25 and 0.5 g/10 g of grain), respectively. This positive effect of garlic was much higher in the case of cooked green gram, the percent increase being 60.6 and 73.3 at the two levels respectively. In the case of chickpea, garlic enhanced the bioaccessibility of iron by about 12.3% (higher level) in the raw grain and 10 and 17.2% in cooked grains at the two levels, respectively (Gautam et al 2010 a). In another

**Table 1.** Ascorbic acid,  $\beta$ -carotene, cysteine, total iron, dialyzable iron and *in vitro* iron bioaccessibility of a legume preparation with inclusion of different levels of onion, tomato and garlic

Experimental sample	Ascorbic acid (mg 100g <sup>-1</sup> FW)	$\beta$ -carotene ( $\mu$ g 100g <sup>-1</sup> FW)	Cysteine (mg 100g <sup>-1</sup> DM)	Total iron, (mg 100g <sup>-1</sup> DM)	Dialyzable iron (mg 100g <sup>-1</sup> DM)	In vitro iron bio accessibility (%, DM)
Legume + no additive	0.26	13.64	9.10	5.19	0.31	5.97
Legume + 25 g onion	1.60	9.08	11.41	4.42	0.50	11.31
Legume + 50 g onion	2.61	8.08	11.89	4.41	0.55	12.47
Legume + 75 g onion	3.04	6.2	11.91	4.38	0.72	16.55
Legume + 100 g onion	3.60	5.52	11.94	4.35	0.85	19.54
CD (p=0.05)	0.21	0.28	0.31	0.12	0.12	0.48
Legume + 25 g tomato	3.00	15.44	10.64	4.79	0.87	18.16
Legume + 50 g tomato	3.38	17.76	10.90	4.65	0.96	20.64
Legume + 75 g tomato	4.01	19	10.92	4.52	0.98	21.68
Legume + 100 g tomato	4.29	32.2	10.94	4.40	1.01	22.95
CD (p=0.05)	0.22	0.47	0.23	0.09	0.13	0.39
Legume + 5 g garlic	2.15	17.2	11.86	4.85	0.88	18.14
Legume + 10 g garlic	2.45	37.6	12.34	4.78	1.02	21.34
Legume + 15 g garlic	2.59	58.16	12.47	4.69	1.13	23.64
Legume + 20 g garlic	2.72	76.36	12.88	4.60	1.22	26.52
CD(p=0.05)	0.20	0.39	0.34	NS	0.08	0.78

Dehusked mungbean was used as base legume in all the experimental samples  
FW: Fresh weight, DM: Dry matter

study conducted by Gautam et al (2011b), the results revealed that the promoting effect of the combination of *amchur* and garlic (183% increase) on iron bioaccessibility was synergistic with respect to their individual effects (86 and 81% increase by *amchur* and garlic, respectively) in raw green gram.

The study concluded that maximum increase in ascorbic acid was there when base legume was fortified with tomatoes at different levels. The maximum enhancement in  $\beta$ -carotene was observed when garlic was added followed by tomato and onion at different levels. Cysteine was maximally contributed by garlic at all the four levels followed by onion and tomato. The maximum *in vitro* iron bioaccessibility was found when legume was fortified with garlic (224 to 344%) alone followed by tomato (204 to 284%) and onion (89 to 227%). The study recommended that the fortification of onion (100g), tomato (100g) and garlic (20g) can enhance the bioaccessibility of iron to 3.3, 3.8 and 4.4 folds, respectively. The optimum use of three additives can significantly improve the bioaccessibility of iron from legumes which are integral part of the daily meals of the Indian population. Educating the general population regarding the usage of appropriate amounts of these key foods can play a pivotal role in addressing the problem of iron malnutrition.

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## Modeling Rice-Wheat Yield Estimation over a Sub-Humid Climatic Environment of Bihar, India

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**Abstract:** A study was carried out to forecast the yield of rice and wheat in six districts of two agro-climatic zones of Bihar. The daily weather data viz. maximum and minimum temperature, morning humidity, afternoon relative humidity and rainfall were arranged week-wise from sowing to harvesting and the relations between weather parameters and yield were determined using statistical tools like stepwise correlation and regression. The model for each district was selected based upon higher  $R^2$  and lower model error values. The models developed were validated for independent data sets. The  $R^2$  varied from 0.63 to 0.97 with error less than 10% for accepted model. The comparison between simulated and observed yield over different districts exhibited a close agreement. Thus, the model developed could be used for forecasting the yield of rice and wheat for six districts of agro-climatic zone IIIA and B of south Bihar. The climatic parameters and technological factors influenced the yield of rice and wheat differently in different districts.

**Keywords:** Long term weather data, Stepwise regression technique, Model validation, Yield simulation

Crop yield forecasts are widely recognized an important input for climate-related risk management (CRM) through an efficient delivery system that can alert policy makers and food officials to assure food security long before the actual natural hazard sets in and can be useful elements of the decision-making process in CRM (Challinor 2009). In addition, almost all major food security programs such as, food aid imports, strategic food reserves, granting of licenses for private firms to import or export, local procurement by the government and donors, emergency food assistance, and distribution through social safety net programs rely on crop forecasts for strategic planning (Jayne and Rashid 2010). India agriculture is largely influenced by monsoon-weather conditions right from preparatory tillage to the stock of the produce (Kumar et al 2004, Prasanna 2014, Singh et al 2014). Weather variables affect the crop differently during different stages of development and the extent of weather influence on crop yield depends not only on the magnitude of weather variables, but also on the distribution pattern of weather over the crop season. Once the detailed knowledge has been acquired of how, and at what growth stages, climatic factors influence the yield, it is possible to derive complex variants that give appropriate weight to the different factors for correlation with yield in naturally varying climates, and use them to predict yield from meteorological records. Forecasting of crop yields based on relatively simple weather variables using regression type model make it simple to use

in large scale yield predictions and is becoming essential in mitigating food price instability and climate risks. Therefore, models based on weather parameters can provide reliable forecasts of crop yield in advance of harvest (Agrawal and Mehta 2007, Vashisth et al 2014).

Earlier, many workers have utilized regression models, discriminant function analysis, agro-meteorological models for crop yield forecasting (Kumar and Bhar 2005). Agro-meteorological models developed by Mehta et al (2000), Agarwal et al (2001) and Ahmad and Kathuria (2010) were successfully used for forecasting yields of various crops at the district as well as at the agro-climatic zone level in different states of India. Kumari and Kumar (2014) have used ordinal logistic model based on weather data for forecasting wheat yield in Kanpur district of Uttar Pradesh. However, models developed are depend to a high degree on the specific crop and on the specific region. Bihar ( $24^{\circ}$ - $27^{\circ}$  31 N latitude and  $82^{\circ}$  19- $88^{\circ}$  17 E longitude) with an area of 9.36 million hectares is a state in eastern India. Rice-wheat rotation is the principal cropping system of state. Out of 6.06 million hectares of cereal area, rice and wheat comprise 3.10 and 2.25 million hectares, respectively, which is 88.28 percent of the total cereal area of the state (Anonymous 2014). The uncertainties in weather often lead to losses to the farmers, making productivity forecasts difficult. In this study, an attempt was made to develop the forecast models to predict the yield of rice and wheat in six districts falling in

agro-climatic zone IIIA and B of Bihar.

**MATERIAL AND METHODS**

Rice and wheat crop yield data at farmer's level for the period of recent 27 years (1987-2014) of agro-climatic zone- IIIA and B of Bihar were used to develop yield forecasting models. The daily weather data collected from the National Data Centre, Indian Meteorological Department, Pune were arranged in a standard meteorological week (SMW) wise and was used starting from 22<sup>nd</sup> to 41<sup>th</sup> SMW of each year, i.e. the period from transplanting to harvest of rice and from 44<sup>th</sup> SMW of current year to 11<sup>th</sup> SMW of next year from the date of sowing to harvesting of wheat. The variables used in this study were weekly of rainfall (mm), maximum and minimum temperature (°C), RHI i.e. morning relative humidity (%), RHII i.e. afternoon relative humidity (%). For selecting the best regression equation among a number of independent variables, stepwise regression procedure was adopted. Statistical Package for Social Science (SPSS v 22.0) computer software was used for the analysis of data with a probability level of 0.05 to enter and 0.1 to remove the variables. A regression model was fitted considering the entered variables obtained from individual stepwise regression analysis to predict the yield of rice and wheat for the subsequent years. The multiple linear stepwise regression analysis has been developed on the basis of examination of coefficients of determination (R<sup>2</sup>), standard error (SE) of estimate values resulted from different weather variables. Two statistical tests, percent Mean Bias Error (MBE) and percent Root Mean Square Error (RMSE) are used to the degree of accuracy of each considered correlation to fit the measured data. MBE and RMSE provide information on the long and short term performance of the model.

To study the joint effect of weather variables on rice and wheat yield, the model used for studying the effect of individual weather variables (Jain et al 1980) has been extended by including interaction terms. The modified model is given as:

$$Y = A_0 + \sum_{i=1}^p \sum_{j=0}^2 a_{ijz} z_{ij} + \sum_{i=1}^p \sum_{j=0}^2 a_{ii'j} z_{ii'j} + bT + e$$

Where,

$$Z_{ij} = \sum_{w=1}^m r_{iw}^j X_{iw}$$

$$Z_{ii'j} = \sum_{w=1}^m r_{iw}^j X_{iw}$$

r<sub>iw</sub> = Correlation coefficient of yield with i<sup>th</sup> weather variable in w<sup>th</sup> period

r<sub>ii'</sub> = Correlation coefficient of yield with product of i<sup>th</sup> and i'<sup>th</sup> weather variables in w<sup>th</sup> period

m= Number of meteorological weeks considered for forecast

p= Number of weather variables used

e= Random error distributed as N(0,σ<sup>2</sup>)

In this model, for each weather variable, two types of indices were developed, one as a simple total of values of weather variable in different periods (un-weighted index-Z<sub>10</sub>) and the other one as a weighted total (weighted index-Z<sub>11</sub>), weights being correlation coefficients between yield/de-trended yield (if trend is present) and weather variables in the respective period. On similar lines, for studying joint effects, un-weighted and weighted indices for interactions were computed with products of weather variables (taken two at a time). The various notations of various indices are given in Table 1. Yield forecast models for all six districts falling in agro-climatic zone-III A and B of Bihar have been developed and their performances have been validated against observed yields in 2012-13 and 2013-2014.

**RESULTS AND DISCUSSION**

**Rice yield forecast:** Coefficient of determination (R<sup>2</sup>) has been significant at 5% probability level for rice in all the six districts of Agro-climatic Zone-III A and B of Bihar (Table 2). The R<sup>2</sup> was ranged between 69 (Bhagalpur) and 76% (Rohtas). The percent MBE was ranged between -3.42 (Bhagalpur) and 3.88 (Banka). However, the percent RMSE was ranged between 6.28 (Jamui) and 11.11 (Gaya). The best agro- meteorological indices to incorporate in the agro-meteorological yield model for rice was selected as T<sub>min</sub> × Rain (Z231) for Bhagalpur district, T<sub>max</sub> × RHI (Z141) and Rain (Z30) for Banka district, Rain × RHI (Z340) for Jamui, T<sub>max</sub> × RHI (Z141) and T<sub>max</sub> × Rain (Z131) for Patna, T<sub>max</sub> × T<sub>min</sub> (Z121) and T<sub>min</sub> × RHI (Z241) for Gaya, T<sub>max</sub> × T<sub>min</sub> (Z121) and T<sub>min</sub> × RHI (Z241) for Rohtas.

**Model validation:** Results revealed that in 2013 the models for Bhagalpur (-0.79%) and Banka (-5.33%) districts have underestimated the yield while overestimation was observed in Jamui (3.08%), Patna (0.38), Gaya (6.44%) and Rohtas (2.35%). Whereas, during 2014, all the six district models over estimated viz. Bhagalpur (9.18%), Banka (2.12%), Jamui (3.63%), Patna (0.87%), Gaya (4.44%) and Rohtas (0.60%) the rice yield. Models developed had less than ±10% error in rice yield prediction for all districts during both the years (Table 3). This indicates that the model can be used for prediction of rice yield in the above districts. The results revealed that agro-meteorological yield model explained the yield variability due to variations in temperatures, rainfall and relative humidity during the different stages (tillering, panicle initiation, booting and physiological maturity). Maximum and minimum temperatures were common agro-meteorological

indices for most of the districts of this region. However, rainfall with relative humidity is also important agro-meteorological indices for some of the districts of southern Bihar.

**Wheat yield forecast:** Coefficient of determination ( $R^2$ ) has been significant at 5% probability level for wheat in all the six districts of Agro-climatic Zone-IIIA and B of Bihar (Table 2). The  $R^2$  was ranged between 71 (Jamui) and 97% (Rohtas). The percent MBE was ranged between -2.05 (Patna) and 3.02 (Jamui). However, the percent RMSE was ranged between 3.98 (Rohtas) and 10.98 (Jamui). The best agro-meteorological indices to incorporate in the agro-meteorological yield model for wheat was selected as  $T_{min} \times RHI$  (Z241) for Bhagalpur district,  $T_{min}$  (Z21) for Banka and Jamui district,  $T_{max} \times T_{min}$  (Z121) and  $T_{min}$  (Z21) for Patna,  $T_{min} \times RHI$  (Z241) and  $T_{max}$  (Z10) for Gaya,  $T_{min} \times RHI$  (Z241) and  $T_{max} \times T_{min}$  (Z121) for Rohtas.

**Model validation:** The validation of model wheat for year 2013 and 2014 revealed that models underestimated in Patna (-7.39) and in Rohtas (-8.47), whereas, overestimation was observed for Bhagalpur (3.50%), Banka (4.65%), Jamui (7.22%) and Gaya (9.90%) in 2013. During year 2014, models underestimated in all three districts viz. Bhagalpur (-2.90%), Banka (-2.00%) and Jamui (-0.75%) falling in agro-climatic zone-IIIA and overestimated in all three districts viz. Patna (1.54%), Gaya (3.13%) and Rohtas (5.10%) falling in agro-climatic zone-IIIB (Table 3). The model has predicted the wheat yield within  $\pm 10\%$  error in all six districts of southern Bihar. Maximum and minimum temperatures, RHI and RHII were the important agro-meteorological indices for wheat yield forecast. Predicted yield was closed to observed yield, therefore, models developed can be used in the forecasting and planning purpose. The results showed that agro-meteorological yield model explained the yield

**Table 1.** Notations of various meteorological indices

Indices	Notations for un-weighted index (Z0)	Notations for weighted index (Z1)	Indices	Notations for un-weighted index (Z0)	Notations for weighted index (Z1)
Tmax	Z10	Z11	Tmax-RHII	Z150	Z151
Tmin	Z20	Z21	Tmin-RF	Z230	Z231
Rain	Z30	Z31	Tmin-RHI	Z240	Z241
RHI	Z40	Z41	Tmin-RHII	Z250	Z251
RHII	Z50	Z51	Rain-RHI	Z340	Z341
Tmax -Tmin	Z120	Z121	Rain-RHII	Z350	Z351
Tmax-RF	Z130	Z131	RHI-RHII	Z450	Z451
Tmax-RHI	Z140	Z141			

**Table 2.** Yield forecast equations of rice and wheat for different districts of Agro-climatic zone-IIIA and B of Bihar, India

Crops	Zone	Districts	Regression equation	$R^2$	Standard error	MBE (%)	RMSE (%)
Rice	Agro-climatic zone-IIIA	Bhagalpur	$Y = 1877.99 + 622 T + 0.89 Z231$	0.69*	312	-3.42	9.10
		Banka	$Y = -4046.96 + 1317 T + 0.79 Z141 + 14.41 Z30$	0.63*	349	3.89	10.89
		Jamui	$Y = 1956.77 + 0.02 Z340$	0.72*	289	-2.87	9.28
	Agro-climatic zone-IIIB	Patna	$Y = 4254.65 + 26.18 T + 0.62 Z141 + 0.08 Z131$	0.73*	365	2.58	9.10
		Gaya	$Y = 2454.20 + 1.75 Z121 + 0.03 Z241$	0.69*	456	3.59	11.11
		Rohtas	$Y = 2780.79 + 1.27 Z121 + 69.01 Z21$	0.76*	289	-3.26	9.89
Wheat	Agro-climatic zone-IIIA	Bhagalpur	$Y = 1782.15 + 93.80 T2 + 0.173 Z241$	0.76*	478	-1.89	7.45
		Banka	$Y = 2183.83 + 166.86 T2 + 17.75 Z21$	0.72*	278	2.63	6.78
		Jamui	$Y = 2275.45 + 36.48 Z21$	0.71*	189	3.02	10.98
	Agro-climatic zone-IIIB	Patna	$Y = 3241.85 + 3.244 Z121 + 216.15 T2$	0.81*	378	-2.05	5.56
		Gaya	$Y = 1500.92 + 0.278 Z241 - 7.10 Z10$	0.85*	227	1.67	4.49
		Rohtas	$Y = 2200.78 + 0.873 Z241 + 1.70 Z121$	0.97*	291	-1.23	3.78

\*Significant at 5% probability

**Table 3.** Validation of the model for forecast of rice and wheat for different districts of Agro-climatic zone-III A and B of Bihar, India

Zone	Districts	Rice yield (kg ha <sup>-1</sup> )						Wheat yield kg ha <sup>-1</sup>					
		2013			2014			2013			2014		
		Observed	Forecasted	Error (%)	Observed	Forecasted	Error (%)	Observed	Forecasted	Error (%)	Observed	Forecasted	Error (%)
Agro-climatic zone-III A	Bhagalpur	3900	3869	-0.79	3876	4232	9.18	2713	2809	3.50	2703	2624	-2.90
	Banka	4776	4521	-5.33	4843	4946	2.12	2703	2828	4.65	2522	2470	-2.00
	Jamui	3890	4010	3.08	4130	4280	3.63	2560	2745	7.22	2632	2612	-0.75
Agro-climatic zone-III B	Patna	4198	4214	0.38	4574	4614	0.87	2990	2769	-7.39	3300	3350	1.54
	Gaya	5074	5401	6.44	5092	5319	4.44	1909	2098	9.90	2360	2234	-5.33
	Rohtas	5090	5210	2.35	4960	4990	0.60	2890	2645	-8.47	2980	3132	5.10

variability due to variation in minimum, maximum temperature together with relative humidity with respect to the major wheat growing districts of Bhagalpur, Gaya and Rohtas.

According to Singh et al (2011, 2014), over the past few years, the per hectare yield of wheat in India has fallen due to the temperature rising steadily in January, February and March (a period most crucial for the wheat crop). Duncan et al (2014) findings also highlight the vulnerability of India's wheat production system to temperature rise, which is predicted to continue in the coming decades as a consequence of climate change. Maximum and minimum temperatures are very sensitive weather parameters for the wheat crop, a rise by 0.5°C in winter temperature is projected to reduce wheat yield by 0.45 t ha<sup>-1</sup> in India (Kalra et al 2007). Wheat growing belts of this region are also largely influenced by the maximum and minimum temperatures prevailed during the cropping season. This indicates that maximum and minimum temperatures together with relative humidity were more relevant weather parameters for deciding wheat productivity in the region.

### CONCLUSION

Yield forecast has been done for rice and wheat crops for six districts of southern part of Bihar. The developed models have less Mean Bias Error (MBE) (below ±5%) and Root Mean Square Error (RMSE) (below ±12%) and reasonably good R<sup>2</sup> (between 63 and 97%). The models are validated with ±10% error in all the six districts of southern Bihar. Therefore, it could be used for yield forecasting satisfactorily for both crops and in all the six districts of agro-climatic zone-III A and B. Further, by and large, the maximum and minimum temperatures in combination with rainfall have formed most important agro-meteorological indices, which can be useful in forecasting of yield of rice and wheat crop in the region.

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# Micro-climatic Variations in Maize (*Zea mays* L.) as Affected by Agronomic Interventions and their Relationship with Biological Parameters

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**Abstract:** The field experiments were conducted to study the microclimatic parameters as affected by the agronomic interventions in *kharif* and spring season maize at the Students' Research Farm, Punjab Agricultural University, Ludhiana during 2014-15 and 2015-16. Leaf area index (LAI) and photosynthetically active radiation (PAR) interception by the crop was significantly higher in minimum tillage than conventional tillage. Application of 75 % RDF + 25 % N through FYM plus mulch recorded significantly higher LAI, higher PAR interception and lower canopy temperature. Minimum tillage produced 5.1 and 5.9 per cent higher grain yield in *kharif* maize and 6.2 and 7.2 per cent higher grain yield in spring maize than conventional tillage. The 9.0 and 7.5 per cent higher yield in *kharif* maize and 4.9 and 6.7 per cent higher yield in spring maize were obtained with application 75 % RDF + 25 % N through FYM plus mulch over 100% RDF. Grain yield of *kharif* and spring maize was significantly correlated with dry matter production ( $r=0.95$  and  $0.97$ ), plant height ( $r=0.97$  and  $0.96$ ) and leaf area index ( $r=0.92$  and  $0.96$ ).

**Keywords:** Canopy temperature, Fertilizers, Grain yield, Maize, Mulch, PAR, Spring Maize

Tillage and fertilizer management are important agronomic practices that influence the growth and yield of crops. Tillage is one of the greatest fossil fuel consumers and consumes about 30 per cent of the total energy use in crop production (Singh et al 2008) and in turn increases the green house gas emissions (Soni et al 2013). There is a growing concern to reduce the cost of cultivation by minimizing the expenditure on land preparation. Conservation agriculture based tillage and crop establishment practices have the potential to improve the crop adaptation to climate change due to altered moisture balance in the field. The efficiency of input use, viz; water, fertilizers, herbicides depends on tillage and crop establishment practices (Parihar et al 2015). It is therefore, essential that the soil environment be manipulated suitably for ensuring a good crop stand and improved resource-use efficiency. Mulching, a practice for conserving soil and water, changes the microclimate within fields and reduces soil temperature variations (Sharratt 2002). The more favourable water regime manifested in higher yields makes mulching not only soil protective, but economically favourable as well. The positive effect of mulch on hydrothermal properties of soil is well established. In dual challenge of climate change and low water availability, soil and agronomic interventions leading to modification of soil micro-environment need to be studied for improving the productivity of maize and spring maize to popularise in the

state of Punjab. However, only a limited number of studies have evaluated the interaction of mulching with different tillage methods on growth and microclimate of crops. In view of above consideration the present study was conducted to study the effect of tillage, mulching and fertilizer management practices on growth and microclimatic parameters of maize and spring maize.

## MATERIAL AND METHODS

A field experiment was conducted during 2014-15 and 2015-16 at Punjab Agricultural University, Ludhiana (30°56'N, 75°52'E; 247 m above sea level) to study the effect of different agronomic interventions (tillage systems, mulching and fertilizer management) on the performance of *kharif* and spring maize. The region is characterized by a sub-tropical and semi-arid climate with a hot dry summer (March-June), wet monsoon season (late June-mid September) and a cool, dry winter (October-February). The experiment was laid out in split-plot design with four replications. The main plot treatments consist of combination of tillage viz. minimum tillage (MT) and conventional tillage (CT) and cropping systems viz. rice-wheat, maize-vegetable pea-spring maize, maize-toria-spring maize, maize-potato-spring maize, whereas, sub plots consist of combination of fertilizer and mulch viz. 100% recommended dose of fertilizers (100% RDF), 75 % RDF + 25 % N through FYM,

100% RDF plus mulch and 75 % RDF + 25 % N through FYM plus mulch. The soil of experimental site was loamy sand in texture, medium in organic carbon (0.42%), poor in available N (225.9 kg/ha) and available potassium (128.8 kg/ha) and high in available phosphorus (23.6 kg/ha). The soil was slightly alkaline in reaction with pH 7.76. The weekly mean maximum air temperature during *kharif* season (SMW 23 to 42) ranged between 30.1 to 44.5 °C during 2014–15 and 31.2 to 38.7 °C during 2015–16. The weekly mean minimum temperature ranged between 15.7 to 29.7 °C and 19.2 to 27.9 °C during year 2014–15 and 2015–16, respectively. A total of 417.6 and 528.8 rainfall was received during *kharif* 2014–15 and 2015–16, respectively. The mean weekly maximum temperature ranged between 27.6 °C and 27.8 while minimum temperature ranged between 17.4 and 16.5 °C during spring season (SMW 7 to SMW 22) of 2014–15 and 2015–16, respectively. Total rainfall received during spring season was 159.6 and 76.3 mm during 2014–15 and 2015–16, respectively. The sowing of crop was done on 13 and 15<sup>th</sup> June of 2014 and 2015 in *kharif* season and 16 and 18<sup>th</sup> February of 2015 and 2016 during spring season. Fertilizers (100% RDF– 125 Kg N, 60 kg P<sub>2</sub>O<sub>5</sub> and 30 kg K<sub>2</sub>O/ha) were applied as per treatment through urea, diammonium phosphate and muriate of potash. Nitrogen was applied as per treatment in three equal splits at sowing, knee high stage and at pre-tasselling stage and entire quantity of phosphorus and potassium was applied at the time of sowing. The *kharif* season crop was harvested during second fortnight of September, while spring season crop was harvested in first fortnight of June during both the years.

Data on plant height at harvest was recorded from the five plants tagged randomly in each plot. Two representative plants selected at random from each plot were sun dried and then dried in the oven at 70 °C to a constant weight for dry matter accumulation at harvest. The leaf area index was recorded at 30 days interval with the help of Sun Scan Canopy Analyzer. The canopy temperature measured with the help of Infrared thermometer (DT 520). The infrared thermometer was inclined at an angle of 45° above the canopy. The canopy temperature was recorded periodically at 14.30 p.m. Photosynthetically active radiation (PAR) interception was measured using Line quantum sensor (LI-COR photometer model LI-191-SA) which has quantum (photon) response through wavelength range of 400–700 nm. PAR interception was calculated by using the following formula:

Where,

$$\text{PAR interception (\%)} = \frac{\text{PAR (I)} - [\text{PAR (T)} + \text{PAR (R)}]}{\text{PAR (I)}} \times 100$$

PAR (I), (T) and (R) –PAR incident above the canopy, transmitted to the ground and reflected from the canopy.

## RESULTS AND DISCUSSION

**Photosynthetically active radiation (PAR) interception and leaf area index (LAI):** Maximum leaf area index and PAR interception in *kharif* maize was recorded at 60 DAS, while LAI and PAR interception was maximum at 90 DAS in spring maize. Tillage methods had significant influence on the LAI and PAR interception of both *kharif* and spring season maize crops. Minimum tillage resulted in significantly higher LAI and PAR interception as compared to conventional tillage method. Higher LAI under minimum tillage may be attributed to more root growth in deeper layer of soil and improved soil physical and chemical properties resulting in higher plant growth and LAI. Singh and Hadda (2015) reported that LAI was negatively affected by subsoil compaction. The higher PAR interception in minimum tillage may be due to more leaf area index. Application of 75 % RDF + 25 % N through FYM resulted in more leaf area index and PAR interception than 100% RDF. Leaf area index and PAR interception by crop was significantly higher with combined application of mulch and fertilizers as compared to crop raised with only respective fertilizer treatments. Sidhu et al (2007) and Li et al (2013) reported significantly higher leaf area and leaf area index with application of mulch as compared to no mulch treatment.

**Canopy temperature:** The crop grown with the minimum tillage provided a favorable micro-environment for the good crop stand and reduced canopy temperature. Minimum tillage resulted in 0.1 to 0.5 °C lower canopy temperature as compared to conventional tillage practices in *kharif* maize. In spring season crop, minimum tillage also resulted in lower canopy temperature (0.2 to 0.6 °C) as compared to conventional tillage. Canopy temperature difference under conventional and reduced tillage are attributable to the differences of some soil physical properties such as water holding capacity and surface penetrometer resistance (Ko and Piccinini 2009). Different fertilizer and mulch treatments did not have significant influence at 60 DAS in both season crops. However, application of 75% RDF + 25% N through FYM plus mulch resulted in significantly lower canopy temperature (39.6 and 38.8 °C) as compared to 100% RDF without mulch (40.3 and 34.4 °C) in spring maize at 90 DAS. Application of mulch along with fertilizers reduced the canopy temperature by 0.4–0.5 °C as compared to respective fertilizer treatments only. Application of mulch and organic manures resulted in better hydrothermal properties and better water availability which in turn decrease canopy temperature. Chakraborty et al (2008) reported variation in canopy air

temperature under different mulch and no mulch treatments in wheat.

**Biological parameters:** Spring maize resulted in higher plant height and dry matter accumulation as compared to *kharif* maize (Table 3). Spring maize took nearly 20 more days to maturity as compared to *kharif* maize resulted in

higher plant height and dry matter accumulation. Minimum tillage resulted in significantly taller plants (188.1 and 190.0 cm in *kharif* maize and 201.2 and 204.3 cm in spring maize) and higher dry matter accumulation per plant (204.3 & 207.8 g plant<sup>-1</sup> in *kharif* maize and 229.6 & 235.1 g plant<sup>-1</sup> in spring maize) as compared to conventional tillage. The higher

**Table 1.** Effect of tillage, cropping systems and fertilizer management practices on LAI, PAR interception and canopy temperature of *kharif* maize

Treatment	LAI				PAR interception (%)				Canopy temperature (°C)			
	60 DAS		At harvest		60 DAS		At harvest		60 DAS		At harvest	
	2014	2015	2014	2015	2014	2015	2014	2015	2014	2015	2014	2015
<b>Tillage</b>												
Minimum tillage	3.23	3.36	2.60	2.74	81.0	82.6	67.8	69.7	34.6	33.7	33.5	34.0
Conventional tillage	3.06	3.18	2.44	2.70	77.6	79.3	65.1	66.6	34.9	33.8	34.0	34.1
CD (p=0.05)	0.08	0.10	0.08	0.11	2.8	3.0	2.2	2.4	NS	NS	NS	NS
<b>Cropping Systems</b>												
Maize-Vegetable pea-Spring maize	3.20	3.33	2.54	2.70	80.0	81.4	67.6	69.1	34.6	33.7	33.7	34.1
Maize-Toria-Spring maize	3.11	3.22	2.51	2.63	78.3	80.3	65.8	67.5	34.8	33.9	34.0	34.1
Maize-Potato-Spring maize	3.13	3.27	2.51	2.68	79.6	81.1	66.0	67.9	34.8	33.6	33.6	33.9
CD (p=0.05)	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
<b>Fertilizer × mulch</b>												
100% RDF	3.04	3.15	2.42	2.57	77.3	78.4	64.8	66.0	35.0	34.0	34.1	34.2
75% RDF +25% N FYM	3.04	3.23	2.50	2.62	78.4	79.7	65.6	67.0	34.9	33.8	33.9	34.1
100% RDF + Mulch	3.20	3.33	2.56	2.73	80.2	82.4	67.4	69.2	34.6	33.6	33.6	33.9
75% RDF+25% N FYM+Mulch	3.30	3.38	2.60	2.77	81.2	83.2	68.2	70.5	34.5	33.5	33.4	33.8
CD (p=0.05)	0.12	0.14	0.12	0.11	2.7	3.3	2.5	2.7	NS	NS	NS	NS

**Table 2.** Effect of tillage, cropping systems and fertilizer management practices on LAI, PAR interception and canopy temperature of spring maize

Treatment	LAI				PAR interception (%)				Canopy temperature (°C)			
	60 DAS		90 DAS		60 DAS		90 DAS		60 DAS		90 DAS	
	2015	2016	2015	2016	2015	2016	2015	2016	2015	2016	2015	2016
<b>Tillage</b>												
Minimum tillage	3.22	3.25	3.43	3.50	77.8	79.4	84.4	85.1	35.5	36.0	39.8	39.4
Conventional tillage	2.95	3.03	3.17	3.21	72.5	75.2	78.7	80.5	35.7	36.6	40.1	39.9
CD (p=0.05)	0.16	0.15	0.17	0.12	3.4	2.3	2.7	3.0	NS	NS	NS	NS
<b>Cropping systems</b>												
Maize-Vegetable pea-Spring maize	3.15	3.23	3.41	3.43	76.1	78.2	82.6	83.6	35.4	36.2	39.7	38.9
Maize-Toria-Spring maize	3.00	3.06	3.21	3.31	74.6	76.0	80.7	82.0	35.7	36.5	40.1	39.3
Maize-Potato-Spring maize	3.11	3.12	3.28	3.34	74.9	77.6	81.3	82.6	35.6	36.1	40.0	39.1
CD (p=0.05)	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
<b>Fertilizer × mulch</b>												
100% RDF	2.90	3.03	3.12	3.22	73.0	74.7	78.5	80.0	35.9	36.5	40.3	39.4
75% RDF +25% N FYM	3.02	3.08	3.28	3.32	74.1	75.5	80.0	81.4	35.7	36.4	40.1	39.2
100% RDF + Mulch	3.15	3.19	3.32	3.38	76.2	78.7	83.2	84.3	35.4	36.1	39.7	39.0
75% RDF+25% N FYM+Mulch	3.25	3.25	3.47	3.50	77.4	80.0	84.4	85.4	35.3	36.1	39.6	38.8
CD (p=0.05)	0.20	0.15	0.18	0.15	2.9	8.4	3.0	3.1	NS	NS	0.5	0.5

growth parameters under minimum tillage might be due to better root development which helped in better soil and nutrient extraction and maintained plant vigour. Parihar et al (2015) also reported significantly higher growth parameters of maize under ZT flat planting than conventional till flat planting.

Fertilizer and mulch application produced significant variation in plant height and dry matter accumulation at harvest. Application of 75% RDF + 25% N through FYM resulted in higher plant height and dry matter accumulation as compared to 100% RDF, but at par with each other.

Mulching along with 100% RDF and 75% RDF + 25% N through FYM resulted in significantly higher dry matter accumulation and plant height as compared to respective fertilizer treatments *i.e.* 100% RDF and 75% RDF + 25% N through FYM, respectively. Integration of organic manures and chemical fertilizers along with mulch provide better environment for plant growth. Further it corrected the deficiency of both macro and micronutrients to attain more crop growth. Similar findings were reported by Khursid et al (2006) under mulch treatments.

Significantly higher grain yield was recorded under

**Table 3.** Effect of tillage, cropping systems and fertilizer management practices on plant height, dry matter accumulation and grain yield of *kharif* maize and spring maize

Treatment	<i>Kharif</i> maize						Spring maize					
	Plant height (cm)		Dry matter accumulation (g plant <sup>-1</sup> )		Grain yield (q ha <sup>-1</sup> )		Plant height (cm)		Dry matter accumulation (g plant <sup>-1</sup> )		Grain yield (q ha <sup>-1</sup> )	
	2014	2015	2014	2015	2014	2015	2015	2016	2015	2016	2015	2016
<b>Tillage</b>												
Minimum tillage	188.1	192.0	204.3	207.8	45.19	47.54	201.2	204.3	229.6	235.1	68.91	71.36
Conventional tillage	181.6	184.0	197.4	196.0	42.98	44.86	195.3	199.0	223.1	227.5	64.88	66.55
CD (p=0.05)	4.0	4.3	5.1	4.6	1.59	1.40	4.5	4.3	3.4	4.0	2.30	2.31
<b>Cropping systems</b>												
Maize-Vegetable pea-Spring maize	186.5	189.9	202.5	204.4	44.54	46.99	200.0	204.2	228.4	233.4	68.20	69.80
Maize-Toria-Spring maize	183.6	185.5	199.4	199.5	43.68	45.38	196.8	199.7	224.4	229.6	65.74	67.99
Maize-Potato-Spring maize	184.4	188.7	200.6	201.7	44.03	46.23	198.2	201.2	226.2	230.9	66.75	69.07
CD (p=0.05)	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
<b>Fertilizer × mulch</b>												
100% RDF	181.1	183.8	196.7	196.0	42.33	44.48	194.8	197.8	221.0	227.5	65.16	66.80
75% RDF +25% N FYM	182.9	186.0	198.1	198.3	43.19	45.26	196.5	200.4	224.1	229.6	66.34	67.53
100% RDF + Mulch	187.0	190.3	202.7	204.8	44.64	47.21	199.4	203.5	228.8	233.1	67.66	70.17
75% RDF+25% N FYM+Mulch	188.4	192.0	205.7	208.3	46.17	47.85	202.2	205.1	231.4	235.0	68.41	71.32
CD (p=0.05)	5.3	5.2	5.4	8.0	1.50	1.32	4.5	4.8	5.6	5.1	2.02	2.00

**Table 4.** Pearson Correlation coefficient for plant growth and grain yield of *kharif* and spring maize

Parameters	<i>Kharif</i> maize					Spring maize				
	Plant height at harvest	Dry matter per plant at harvest	Maximum LAI	PARI	Yield	Plant height at harvest	Dry matter per plant at harvest	Maximum LAI	PARI	Yield
Plant height at harvest	1.00					1.00				
Dry matter per plant at harvest	0.98**	1.00				0.98**	1.00			
LAI	0.96**	0.96**	1.00			0.94**	0.94**	1.00		
PARI	0.98**	0.98**	0.96**	1.00		0.96**	0.97**	0.92**	1.00	
Yield	0.97**	0.95**	0.92**	0.96**	1	0.96**	0.97**	0.96**	0.96**	1.00

\*\* Significant at 1 per cent level

minimum tillage than conventional tillage in both *kharif* and spring maize crops. The increase in grain yield under minimum tillage was 5.1 and 5.9 per cent in *kharif* maize during 2014 and 2015 and 6.2 and 7.2 per cent in spring maize during 2015 and 2016 than conventional tillage, respectively. Higher plant height, dry matter accumulation and leaf area index under minimum tillage resulted in more grain yield as compared to conventional tillage. Prasad et al (2016) also reported higher grain yield under zero tillage and minimum tillage as compared to conventional tillage. Application of 75% RDF + 25% N through FYM resulted in higher grain yield as compared to 100% RDF. Application of organic manures in combination with inorganic fertilizers not only enhanced the nutrient supply for higher grain yield, but also alters the soil physical and chemical properties which favour better crop growth and yield (Singh and Sekhon 2002). Application of 75% RDF + 25% N through FYM with mulch resulted in 9.0 and 7.0 per cent and 6.5 and 5.4 per cent higher yield in *Kharif* maize during 2014 and 2015 and 4.7 and 6.3 per cent and 3.0 and 5.3 per cent higher yield in spring maize during 2015 and 2016 as compared to 100% RDF and 75% RDF + 25% N through FYM without mulch, respectively. Mulching has favourable effects on crop productivity due to improvement in soil moisture, heat and air regimes, restriction on evaporation and weed suppression (Bu et al 2002). Choudhary and Kumar (2014) reported 18–35% higher productivity of sequential crops with mulch application

**Relationship between biophysical parameter in *kharif* and spring maize:** The *kharif* and spring maize grain yield showed significant positive correlation with plant height, dry matter accumulation per plant at harvest and leaf area index. Dry matter accumulation had significantly positive correlation with plant height, leaf area index and photosynthetically active radiation interception. Photosynthetically active radiation interception had significant correlation with LAI. Singh and Hadda (2015) reported higher grain yield with increased plant height, dry matter accumulation per plant and leaf area index in maize. The relationship between LAI and PARI of *kharif* maize was a linear function (Fig. 1) with  $R^2$  values ranging from 0.82 in first year to 0.89 in second year, the  $R^2$  for pooled data was 0.64. Similarly, the relation between LAI and PAR interception of spring maize was a linear function (Fig. 2) with  $R^2$  values ranging from 0.80 in first year to 0.81 in second year showing that LAI accounted for 80 and 81 per cent variation in PAR interception. The  $R^2$  for pooled data was 0.85. The multiple regression equations were developed between growth parameters and grain yield of *kharif* maize (Eq. 1) and spring maize (Eq. 2). These equations can be used to assess the grain yield of maize and

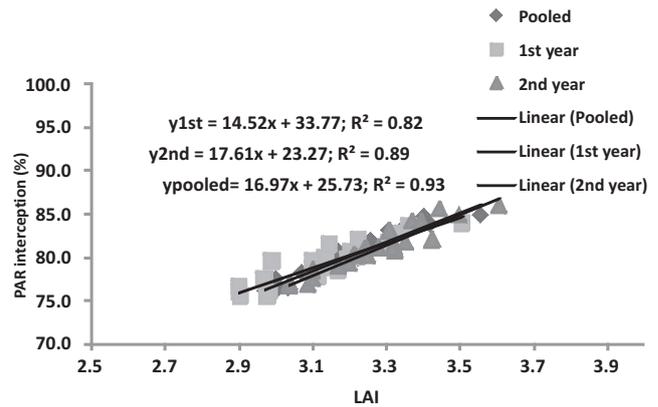


Fig. 1. Relation between maximum LAI and PAR interception of *kharif* maize

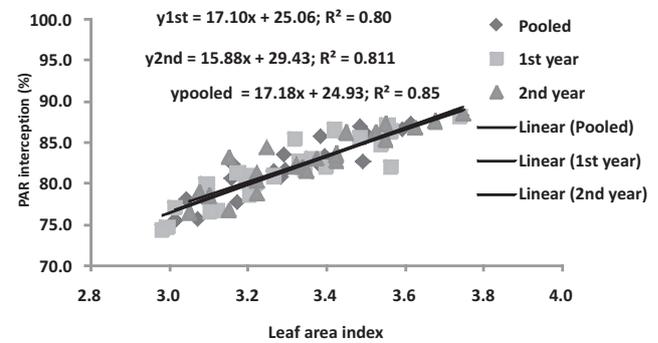


Fig. 2. Relation between maximum LAI and PAR interception of spring maize

spring maize without actually harvesting the crops.

$$Y = -27.83 + 0.318 X_1 - 0.302 X_2 - 2.533 X_3 \quad (R^2 = 0.948) \quad \text{Eq 1}$$

$$Y = -8.25 + 0.3075 X_1 + 0.0830 X_2 + 5.725 X_3 \quad (R^2 = 0.967) \quad \text{Eq 2}$$

Where, Y = Grain yield in  $q \text{ ha}^{-1}$ ,  $X_1$  = Plant height at harvest (cm),  $X_2$ =Dry matter accumulation per plant at harvest (g/plant),  $X_3$ = Maximum LAI

It was concluded from the two years study that grain yield of maize was under minimum tillage as compared to conventional tillage. Substitution of 25% nitrogen through organic manures and application of mulch further improved the growth and yield of both *kharif* and spring maize.

**ACKNOWLEDGEMENT**

The first author wish to acknowledge the Department of Science and Technology, Government of India, New Delhi for the providing fellowship in the form of INSPIRE Fellowship during Ph.D. programme.

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## Evaluation of Benzyl-butyl phthalate Induced Germination and Early Growth Vulnerability to Barley Seedlings (*Hordeum vulgare* L.)

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**Abstract:** Phthalates are dialkyl or alkyl/aryl esters of 1, 2 benzene dicarboxylic acid and well avowed for their widespread applications. In agricultural soil they were reported in considerable amount and through dietary route they enter into animals and human beings posing serious threat to their well being. The present study was designed to understand phthalates induced toxicity in cereal crops. The germination parameters such as germination percentage, speed of germination, peak value, mean daily germination, germination value, mean germination time, seed vigour index, germination rate index declined significantly. The increase in benzyl-butyl phthalate (BBP) concentration enhanced the seed mortality and phytotoxicity index in the barley seedlings. The effect of BBP on barley revealed that the roots were more vulnerable to toxicity than shoot of seedlings.

**Keywords:** Barley, Benzyl butyl phthalate, Growth, Germination vulnerability

Phthalates are also known as phthalate esters/phthalic esters/phthalate acid esters and chemically, these are the product of a chemical reaction between phthalic anhydride and alcohol which ranges from methanol to texanol (Sibali et al 2013). Phthalates play an important role in the plasticization of polyvinyl chloride (PVC) (Vats et al 2013). Phthalates are also used in cosmetic formulations, medical treatment tubings, plastic packing films, perfumes, personal hygiene products (Buckley et al 2012), herbicides, dyes, insect repellents and as an ingredient in aspirin coating etc. (McCarroll 2006). In these products, phthalates possess non-covalent bonding which is the contributing factor for the migration of phthalates to various environmental media. In environment, phthalates exert different noxious perturbations to the surrounding flora and fauna. Therefore, various international organizations like United State Environmental Protection Agency (USEPA) (Guo et al 2010) and China National Environmental Monitoring Centre (CNEMC) (Cai et al 2008) have declared phthalates as priority environmental pollutants. In environment, the most abundant phthalates are di-n-butyl phthalate (DBP), butyl benzyl phthalate (BBP), di-ethylhexyl phthalate (DEHP), diethyl phthalate (DEP), and di-n-octyl phthalate (DOP) (Hariklia et al 2003). Various studies have reported the degradation of phthalates by a wide range of bacteria and fungi under both aerobic and anaerobic conditions but in spite of this, they were reported in considerable amount in different ecosystems. From soil, phthalates may be

transferred to crops and from crops enter into different food chains. Thus, the occurrence of phthalates in soil raise a concern for the evaluation of phthalates induced stress among the plants and the monitoring of phthalates in different ecosystems. In the present study, BBP was selected as a test compound because it was listed among the most abundant phthalates and declared as priority environmental pollutants (Liao et al 2010) and its effects on cereal crops are less documented. *Hordeum vulgare* (L.) was used as experimental model because of its fast growth.

### MATERIAL AND METHODS

**BBP treatment:** The stock solution of BBP (1600 mg/L) was prepared using ethanol, tween-20 and distilled water in desired proportion. The different concentrations of BBP were prepared using the stock solution of BBP through serial dilution. The healthy seeds of *Hordeum vulgare* var. VLB-118 were purchased from Himachal Pradesh Agricultural University, Palampur, India. The surface sterilization of seeds was done using 0.01% mercuric chloride ( $HgCl_2$ ) for 1 min. and washed 8-10 times with distilled water to remove the traces of  $HgCl_2$ . The sterilized seed were dried in the folds of filter paper and pre-soaked for 6 h. For the prevention of phthalates background contamination, all the glassware was washed, oven dried (at 150°C for 25 min.) and autoclaved. The two layers of autoclaved filter paper (Whatman filter paper no. 1) was used for the lining of Petri plates and moistened with different concentrations (0, 25, 50, 100, 200,

400, 800 and 1600 mg/L) of BBP periodically. After treating seeds, Petri plates were kept in the seed germinator at  $25\pm 0.5^{\circ}\text{C}$  at photoperiod of 16 h for 7 days. The experimental set was observed daily for germination and morphological parameters.

**Studies on barley germination and early growth consequences:** The seeds were considered to be germinated when plumule and radical attained the length of 2 mm (Wang et al 2008). The germination percentage, speed of germination, peak value and germination value was estimated by method of Czabator et al (1962). The calculation of mean germination time is based on method of Ellis and Robertis (1981). Seedling vigour index, germination rate index and seedling mortality were recorded according to the method given by Orchard et al (1977), Mekki et al (2007) and Osman (2004) respectively. Thirty barley seedlings were randomly selected for the measurement of shoot and root length. The fresh and dry weight was calculated using the method of Lin et al (2012). The method of Rogers et al (1992) was used to calculate the root weight ratio, shoot weight ratio, shoot/root weight ratio and root/shoot weight ratio. The dry weight formation by plant was measured in terms of net primary productivity and was calculated as per the method given by Malik (2009).

**Statistical analysis:** The differences ( $p < 0.05$ ) among means were compared by critical difference (CD) value using Tukey's test (Grossen 1974).

## RESULTS AND DISCUSSION

**Effect of BBP on seed germination of barley:** The germination percentage, speed of germination and peak value declined with increase in concentration as compared to control. The decline in germination parameters was observed by Wu et al (2012) and Liu et al (2014) under phthalate exposure. The decrease in the speed of germination was observed in seedlings of barley and sorghum on treating with the effluent of ink industry (Zayneb et al 2015). The other parameters were also declined and the maximum percent decrease in mean daily germination (49.48%), germination value (71.87%), mean germination time (48.66%), germination rate index (45.05%) and seed vigour index (78.92%) was observed. The percent decrease was significantly higher in seed vigour index followed by germination value, mean daily germination, mean germination time and germination rate index. The remarkable decline in seed vigour index was observed which is actually not a single measurable index but is a concept that depends upon emergence potential, seed germination and growth under stressed conditions (Finch-Savage and Bassel 2016). It is also considered as the sum total of those seed

characteristics which determine the level of potential activities and performance of seeds during the process of seed germination. The seed mortality and phytotoxicity index (PI) increased significantly at higher concentration of BBP. According to Rusan et al (2015) the higher value of PI means toxic effects and lower value means stimulatory effects of any pollutants. The germination parameters are associated with the physiological aspects of barley seeds and the impairment in these during BBP exposure suggest its potential phytotoxicity to the seedlings. The seed germination is basically three step phenomenon which starts by the imbibition of water followed by the metabolic processes and radicle elongation (Chamorro et al 2016). The metabolic processes include the active mobilization of reserve food material (Nonogaki et al 2006). The seed germination is also controlled by both extrinsic and intrinsic factors. Among them, plant growth regulators and enzymes are the main intrinsic factors that regulate seed germination (Atici et al 2004). Therefore, in the barley seedlings, the exposure of phthalate might have hindered the mobilization of reserve food material and may have imbalanced the level of plant growth regulators which might have led to the reduction in germination and other associated parameters as compared to control.

**Effect of BBP on growth of barley seedlings:** All the growth parameters were adversely affected under the stress of BBP (Table 2). The growth parameters like shoot and root length, fresh weight of shoot and root, dry weight of shoot and root, root weight ratio, root shoot ratio and net primary productivity of treated barley seedlings significantly declined. The maximum percent decline in shoot length (59.61%), root length (56.86%), fresh weight of shoot (19.37%), fresh of weight of root (44.22%), dry weight of shoot (18.75%), dry weight of root (53.40%), shoot weight ratio (30.45%), root shoot ratio (48.12%) and net primary productivity (37.17%) was observed. All the growth parameters associated with root (except root length) were declined prominently as compared to shoot of barley seedling. The decline in root shoot ratio may be attributed to the impaired allocation of dry matter into the roots of seedling. The normal development of roots is required for the optimal growth, establishment and development of plant. Therefore, the possible reason for the retarded root growth indices under BBP exposure may be the direct contact of seedling roots to the pollutant (Biczak 2017). The increase in shoot weight and shoot root ratio was observed. This may be due to the hormone like acting property of phthalates (Gao et al 2016). Overall, BBP showed the inhibitory effects on the growth of barley seedling. Generally, the growth parameters are considered as the reflection of any plant's growth status (Qiu et al 2013) and

**Table 1.** Effect of BBP on seed germination of barley

Conc. (mg L <sup>-1</sup> )	GP	GS	PV	MDG	GV	MGT	GRI	SVI	SM	PI
0	80.83	12.01	11.55	1.73	20.25	28.07	80.08	1867.98	41.07	–
25	54.17	8.68	7.74	1.16	9.40	19.04	57.85 <sup>NS</sup>	1142.81	98.21	0.14
50	45.00	7.52	6.43	0.96	6.63	16.02	50.12	901.20	117.86	0.30
100	45.00	7.69	6.43	0.96	6.87	16.25	51.26 <sup>NS</sup>	886.10	117.86	0.14
200	45.83	7.77	6.55	0.98	6.99	16.52	51.83 <sup>NS</sup>	785.68	116.07	0.33
400	54.17	7.79	7.74	1.16	9.13	17.77	51.96	835.30	98.21	0.40
800	43.33	6.90	6.19	0.93	5.92	15.18	45.97	632.18	121.43	0.37
1600	40.83	6.60	5.83	0.88	5.70	14.41	44.00	393.74	126.79	0.56
CD (p=0.05)	19.42	3.12	3.31	0.42	6.22	6.78	28.83	87.39	41.60	0.13

Germination percentage: GP, Speed of germination: GS, Peak value: PV, Mean daily germination: MDG, Germination value: GV, Mean germination time: MGT, Seed vigour index: SVI, Germination rate index: GRI, Seed mortality: SM and Phytotoxicity index: PI. NS: Non significant at p 0.05 as compared to control.

**Table 2.** Effect of BBP on growth of barley seedlings

Conc. (mg L <sup>-1</sup> )	SL (cm)	RL (cm)	SFW (g)	RFW (g)	SDW (g)	RDW (g)	SWR	RWR	SRR	RSR	NPP (g plant <sup>-1</sup> day <sup>-1</sup> )
0	11.82	11.29	0.1336	0.0933 <sup>NS</sup>	0.0118	0.0134	0.471	0.529	0.913	1.152	0.0036
25	11.17 <sup>NS</sup>	9.49	0.1195 <sup>NS</sup>	0.1032 <sup>NS</sup>	0.0109 <sup>NS</sup>	0.0098	0.533 <sup>NS</sup>	0.467 <sup>NS</sup>	1.157 <sup>NS</sup>	0.883 <sup>NS</sup>	0.0030
50	10.51 <sup>NS</sup>	9.51	0.1236 <sup>NS</sup>	0.0708 <sup>NS</sup>	0.0120 <sup>NS</sup>	0.0078	0.601 <sup>NS</sup>	0.399 <sup>NS</sup>	1.531 <sup>NS</sup>	0.669 <sup>NS</sup>	0.0028
100	9.59	9.65	0.1033 <sup>NS</sup>	0.0796 <sup>NS</sup>	0.0107 <sup>NS</sup>	0.0060	0.632	0.368	1.783	0.597 <sup>NS</sup>	0.0024
200	9.58	7.56	0.1277 <sup>NS</sup>	0.0704 <sup>NS</sup>	0.0111 <sup>NS</sup>	0.0078	0.582 <sup>NS</sup>	0.418 <sup>NS</sup>	1.418 <sup>NS</sup>	0.729 <sup>NS</sup>	0.0027
400	8.74	6.68	0.1141 <sup>NS</sup>	0.0882 <sup>NS</sup>	0.0110 <sup>NS</sup>	0.0073	0.600 <sup>NS</sup>	0.400 <sup>NS</sup>	1.557 <sup>NS</sup>	0.683 <sup>NS</sup>	0.0026
800	7.48	7.11	0.0994 <sup>NS</sup>	0.0548 <sup>NS</sup>	0.0107 <sup>NS</sup>	0.0067	0.611	0.389	1.597	0.642 <sup>NS</sup>	0.0025
1600	4.77	4.87	0.1077 <sup>NS</sup>	0.0520 <sup>NS</sup>	0.0096 <sup>NS</sup>	0.0063	0.611	0.389	1.681	0.655 <sup>NS</sup>	0.0023
CD (p=0.05)	1.34		0.054		0.0051		0.13		0.68		0.0011

SL: Shoot length, RL: Root length, SFW: Shoot fresh weight, RFW: Root fresh weight, SDW: Shoot dry weight, RDW: Root dry weight, SWR: Shoot weight ratio, RWR: Root weight ratio, SRR: Shoot root ratio, RSR: Root shoot ratio, NPP: Net primary productivity.

also considered as the first visible sign of either biotic/abiotic stress. The inhibitory effects on the growth of wheat seedlings were reported by Gao et al (2016) under the exposure of DBP and DEHP for the treatment period of 7 and 14 days. The present results are also supported by the work of Liao et al (2009), Ma et al (2013), Ting-Ting et al (2014) and Zhang et al (2015) who studied the effect of phthalates on Chinese cabbage seedlings (*Brassica rapa* var. *chinensis*), rape seedlings (*Brassica chinensis* L.), mung bean seedlings and cucumber seedlings respectively.

### CONCLUSION

The exposure of BBP to the barley under controlled conditions led to the reduction in the seed germination and growth of seedlings. Further, the exposure of BBP resulted in the significant increase in phytotoxicity parameters like seed mortality and phytotoxicity index as compared to control. In the barley seedlings, roots were more vulnerable to BBP stress than shoots.

### ACKNOWLEDEMENTS

The authors are highly thankful to University Grants Commission, New Delhi (India) for financial assistance.

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# Estimation of Land Use Land Cover Change Relationship with Normalized Difference Vegetation Index (NDVI) Different Method and Land Surface Temperature (LST)

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**Abstract:** Accurate and continuous satellite images are being used for various global change studies like climate change, hydrological modeling, ecology studies and environmental modeling. Remote sensing and geographic information system helps to analyze satellite images to extract information about land use land cover estimation, runoff calculation and hydrological modeling. In present study satellite images were used for land cover classification using maximum likelihood classification to get land use land cover maps. Land use land cover maps of 2002 and 2015 were used for change detection analysis. Transition matrix was used for identifying the land cover change between 2002 and 2015. Highest increase in agriculture area with 9.14% and decrease of forest area with 6.18% was observed. These changes were analyzed using Normalized Difference Vegetation Index (NDVI) and Land Surface Temperature (LST) to study the vegetation impact on these two parameters. Analysis of NDVI shows different values for agriculture and forest cover with changing vegetation cover. Dense forest and sparse forest cover resulted in increasing LST temperatures. Results indicate that land cover change has significant influence on NDVI and LST for forest and agriculture classes.

**Keywords:** LULC, Land Surface Temperature, Normalized Vegetation Index, maximum likelihood classification, accuracy assessment

Global environmental changes like climate change and global warming are seriously causing problems as a result of rapid developmental activities, fossil fuel burning and urbanization. This results in enormous landscape modification. Urban areas are experiencing high temperatures than rural areas because of rapid land cover changes (Franco and Mandla 2012) and global warming. Deforestation and agriculture expansion causes altered soil moisture conditions thus influencing land surface temperatures (LST). Land cover change influence land surface temperature and climatic variables (Connors et al 2013). Different factors influence land surface temperature like weather, geographic location, soil properties, soil moisture conditions and vegetation cover. Anthropogenic activities like urban settlements and developmental projects change landscape from natural type, which influence local weather and climate. Remote sensing helps to gather information pertaining to earth surface. Satellite data collects information spatially and temporally with different sensors and resolutions. These images help to analyze and gather information about land use land cover change and land surface temperature at global, regional and local scales. To

study local climate variations, image resolution must be moderate to high with frequent temporal resolution to record monthly temperature anomalies and to delineate land use land cover using LST. Land sat series images support different applications such as land use land cover classification (Raj Kumar et al 2017), change analysis, urban related studies (Sainu Franco et al 2015). Landsat-8 images with two thermal infra-red bands (10 and 11) are being used for retrieving of land surface temperature.

This paper presents classification of land use land cover using satellite data and to correlate these changes with land surface temperature and normalized vegetation index to evaluate the vegetation changes in the study area. Some research studies explain the effect of land use land cover change on LST (Carlson and Arthur 2000, Sobrino et al 2001). Weng et al (2004) showed the relationship between the LST and vegetation like normalized vegetation index (Vani and Mandla 2017). The objective of the present study is a) to identify land use land cover change b) correlating these changes with normalized vegetation index and land surface temperature c) identifying relationship between NDVI and LST.

**MATERIAL AND METHODS**

**Study area:** Nallamalla forest watershed area is located in Andhra Pradesh, India. It is situated between 15.40°N longitude and 78.47°E latitude. Climate here is tropical wet and dry throughout the year. Maximum temperature is 32–41°C during summer season and 16–20°C during January. Annual rainfall recorded is 140 cm. This area is facing problems like water scarcity, ecological imbalance and socio-economic problems due to deforestation and agriculture expansion.

**Data and image-preprocessing:** Satellite data used in this study includes the Landsat series (TM,ETM+, Landsat 5 and Landsat 8). 30 meter spatial resolution Landsat images were collected for 2002 and 2015 years with same seasonal period (Table 1). The collected remote sensing data is geo-referenced with topo sheets.

**Table 1.** Satellite images and date of acquisition

Spatial resolution	Satellite image	Date
30 meter	Landsat 5	November 2002
	Landsat 8	October 2015

Land sat TIR sensors calculate top of the atmosphere radiance (TOA) to derive brightness temperature, which is calculated as total radiance emitted from earth surface and radiance reflected from atmosphere (upward and downward). Atmospheric effects must be corrected for images to obtain land surface brightness temperatures. Spectral emissivity values were corrected for soil thermal and moisture properties and vegetation.

**Image classification using maximum likelihood classifier:** Maximum likelihood classifier is used to classify Landsat images in this study. Land use classes were identified in the image with the help of visual interpretation and ground control points. Based on this knowledge training pixels were selected for each class. When classifying an unknown pixel, maximum likelihood classifier quantitatively evaluates both variance and co-variance of the spectral response pattern (Nagaveni and Mandla 2017). Each pixel is calculated for each band reflectance to calculate the overall probability to which specific class each pixel belongs to. Each pixel is allotted to the class that has the highest probability to belong. If the highest probability of any pixel is smaller than a threshold value to assign, the pixel remains unclassified (Richards et al 1990).

**Deriving land surface temperature (LST) from landsat images:** Land surface temperature is calculated from thermal infrared bands (band 10 and 11) of Landsat images 2002 and 2015. Observed temperature data was used to correlate calculated temperature from satellite images. Land

Surface Temperature is calculated using the below equations (Rajeshwari and Mani 2014).

Step (a):- Converting Digital number (DN) value to radiance value

$$L_{\lambda} = MLQ_{cal} + AL \tag{Eq.1}$$

Where– $L_{\lambda}$ = TOA spectral radiance, ML= Band-specific multiplicative rescaling factor, AL = Band-specific additive rescaling factor,

$Q_{cal}$  = Quantized and calibrated standard product pixel values

Step (b):-Brightness Temperature (K) from step (a)

$$T = \frac{K_2}{\ln \left( \frac{K_1}{L} + 1 \right)} \tag{Eq.2}$$

Where, $T$ = TOA brightness temperature,  $L_{\lambda}$ = TOA spectral radiance,  $K_1$ = Band-specific thermal conversion constant,  $K_2$  = Band-specific thermal conversion constant

Step(c):- Conversion of temperature from Kelvin to Degree Celsius

$$T(^{\circ}C) = T(K) - 273 \tag{Eq.3}$$

Band 10 and 11 values were obtained from metadata.

$K_1$  &  $K_2$  = Rescaling factors used in equations 1 & 2 (Rajeshwari and Mani 2014).

**Normalized Difference Vegetation Index (NDVI):** NDVI is a vegetation index calculated from satellite images to monitor and correlate temporal changes with land use land cover changes. Images were initially subjected to geo referencing and atmospheric corrections. NDVI is calculated using near infrared and red bands of Landsat images. NDVI maps helps to identify vegetation changes across the study area for 2002 to 2015. Healthy vegetation reflects more near infrared than red color as most of the visible radiation is absorbed during photosynthesis. Similarly unhealthy vegetation reflects more visible portion of light. Generally, change detection analysis is carried out with the help of land use land cover classification followed by normalized vegetation index (Jomaa and Kheir 2003).

$$NDVI = \frac{NIR - RED}{NIR + RED} \tag{Eq.4}$$

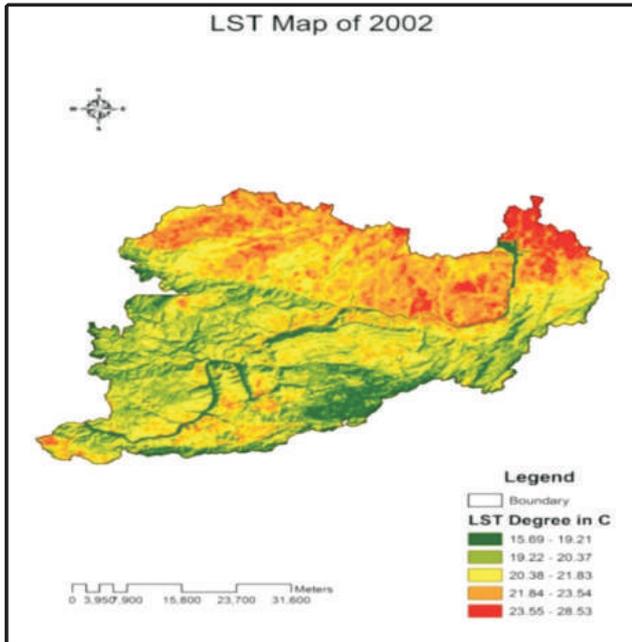
Where, NIR =Near infrared band reflectance, RED=Red band reflectance

**RESULTS AND DISCUSSION**

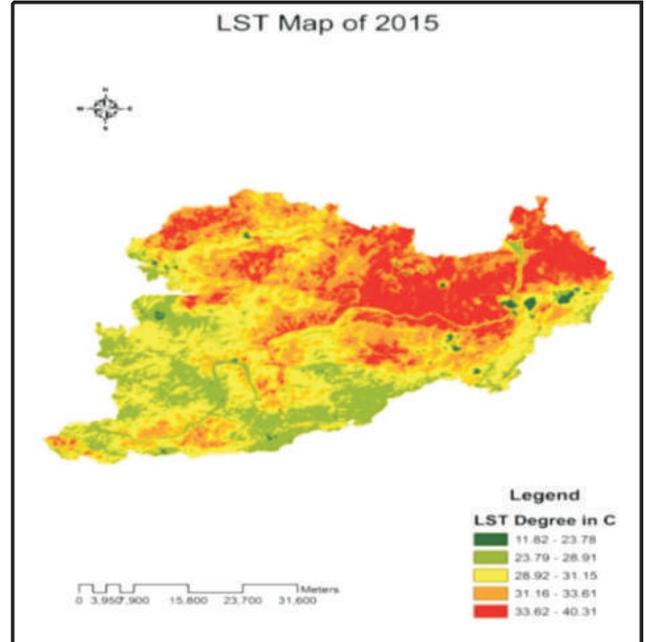
Image classification accuracy is shown in Table 2. Accuracy assessment gives the measurement of quality information from classified satellite images. Overall classification accuracy was improved with visual interpretation and ground control points. Producers accuracy

**Table 2.** Classification accuracy calculation

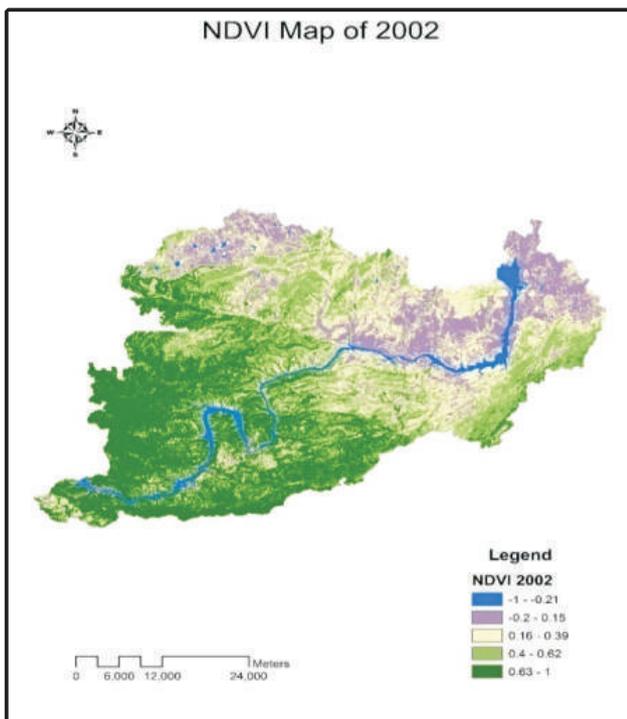
Class name	Reference totals	Classified totals	Number correct	Producers accuracy %	Users accuracy %
Water	15	15	9	60	60
Forest	76	102	74	97.37	72.55
Agriculture	115	94	86	74.78	91.49
Wasteland	50	43	40	80	93.02



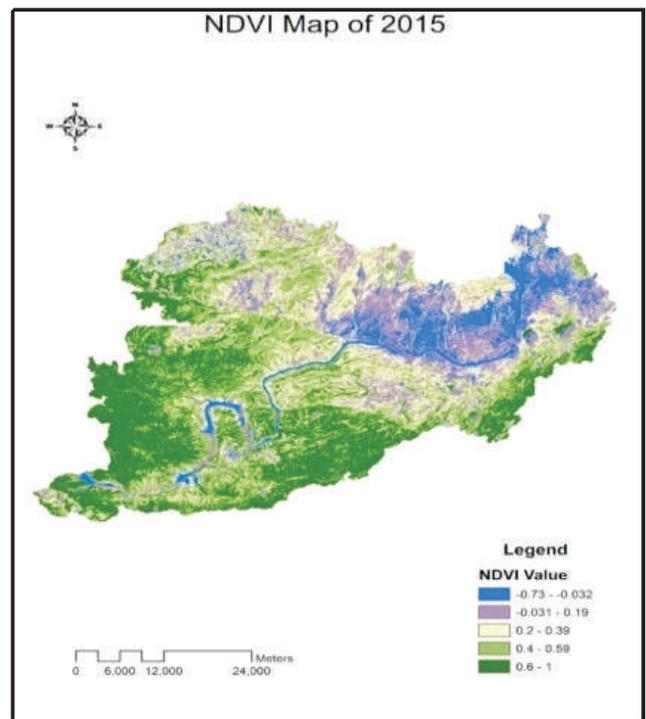
**Fig.1.** Land surface temperature map for 2002



**Fig. 2.** Land surface temperature map for 2015



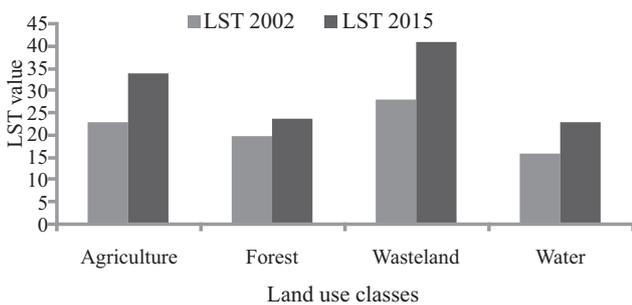
**Fig. 3.** NDVI map of the study area for 2002



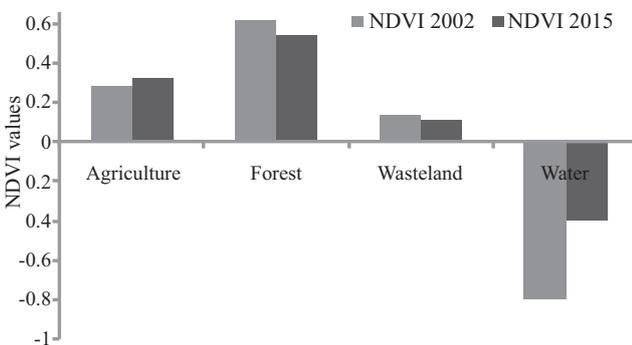
**Fig. 4.** NDVI map of the study area for 2015

**Table 3.** Comparison of area percentages of LULC changes for 2002-2015

LULC Type	2002 area %	2015 area %	Change % between 2002-2015
Agriculture	6.18	15.32	+9.14
Water	4.26	3.46	-0.8
Forest	80.25	74.07	-6.18
Wasteland	9.18	7.15	-2.03



**Fig. 5.** Temperature changes for land cover classes



**Fig. 6.** Different land use classes and NDVI values for 2002 and 2015 years

for forest is 97.37%, agriculture 74.78% and wasteland 80%. Users accuracy for forest 72.55%, agriculture 91.49% and wasteland with 93.02% were calculated.

Change analysis was carried out using transition matrix to identify the transformation of land cover classes between 2002 and 2015. The overall land use land cover change between 2002 and 2015 is given in (Table 3). Overall change in agriculture between 2002 and 2015 was calculated as 9.14% increase and forest decreased by 6.18% area.

Spatial distribution of forest, agriculture and wastelands were shown significant decrease or increase in respective class area. Sudden increase in agriculture land resulted in loss of forest area and increased wasteland is followed by deforestation. The change detection method used in present

study is post classification comparison. Transition matrix and zonal statistics for each class were prepared for 2002 and 2015 LULC maps. Results show that land surface temperature varies monthly and spatially due to vegetation cover abundance and density (Fig.1 and 2). Higher LST values were observed during March to May and lower NDVI values were observed for the same period. Here leaf falling season also influence soil reflectance values and lower NDVI values.

Land surface temperature in dense forest area was observed between 15-20°C, sparse vegetation 20-21°C and agriculture was 21-24°C in 2002, whereas, these values were increased to 22-24°C, 24-28°C and 28-31°C respectively by 2015. The Normalized Vegetation Index (NDVI) differencing method for different temporal images was used to correlate and interpret matrices of change detection analysis for land use land cover (Fig. 3 & 4). NDVI image of two different year's statistics shows that notable changes in forest and agriculture land classes. Overall analysis illustrate that LST and NDVI values mostly dependent on season of the year, type of plantation and properties of soil which influence back ground reflectance values. Atmospheric corrections like TOA improved overall accuracy and correlation between NDVI/LST values with classified land use land cover change analysis. The co-relation between land surface temperature(LST) and normalized difference vegetation index (NDVI) for different land use classes was observed in the study area. Classified images show 6-7% decrease of forest cover, which is correlated with LST (Fig. 5) and NDVI (Fig. 6). Reduction of forest cover in short time span can convert the watershed into drought prone in future if prevention and control of deforestation practices are not implemented. Wasteland increase is correlated with LST values and deforestation is also validated with NDVI values. Suitable site selection within the watershed can be identified to maintain water balance and hydrological cycle.

**CONCLUSIONS**

Dense forest vegetation and mixed vegetation show different radiation, thermal and soil moisture properties. Agriculture has significant impact on soil moisture and land surface temperature because of canopy density and shading conditions Direct relation for each land cover type with normalized vegetation index and land surface temperature is found. Overall negative or positive changes (atleast 15% decrease or increase) in land cover has shown significant influence on soil moisture and vegetation indices.

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## Development of Integrated Farming System Model for Marginal Farmers of Cauvery Delta Zone

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**Abstract:** Field experiments were conducted on development of IFS for marginal farmers in 0.8 ha area at Soil and Water management Research Institute, Thanjavur for a period of 4 years from 2012 to 2016 under irrigated condition in sandy loam soil to explore the productivity and profitability of Integrated Farming System. The IFS model with six components viz., crop + horticulture + dairy + fisheries + poultry + vermicompost in 0.8 ha area recorded higher gross return (Rs. 3,01,659) and net return (Rs. 1,37,349) with a B:C ratio of 1.83 against Rs. 1,22,650 and Rs. 42480 with the B:C ratio of 1.53 in conventional method of cropping alone of rice (*kharif*)-rice (*rabi*). Thus the developed IFS model could improve the productivity and profitability of marginal farmers.

**Keywords:** Integrated farming system, Components, Productivity, Gross and net income

The Cauvery delta zone is one of the seven agro climatic zones of Tamil Nadu forms one of the important river basins in the state. The Cauvery delta zone (CDZ) has a total geographical land area of 1.45 million ha which is equivalent to 11.13 per cent of the state area. The CDZ has the average annual rainfall of 930 mm out of which North East monsoon alone contributes 52.5 per cent followed by South-West monsoon with 30.5 per cent. Hot weather seasons account 11.4 per cent while the winter season has the least of 5.6 per cent only. The important cropping systems are rice – rice – fallow, rice – rice – pulses and single season rice – sesame. The crop failure is common due to drought and late release of irrigation water. The small and marginal farmers are not able to sustain their living standards due to low returns from conventional cropping method. Rice based cropping system derives low income due to its seasonal nature. Diversification of agriculture linking farm based enterprises would augment the income of rice farmers and provide additional employment. In the farming system approach even if the crop component fails the income from the allied enterprise will be highly helpful to the farmers. The end product from one enterprise can be effectively recycled as input for other enterprise. Mixed farming is the need of the hour to improve the economic status of rice farmers. Depending upon the climate and farmer situation suitable farming system models can be developed based on their resource availability. Hence field experiments were conducted, on development of integrated farming system model for marginal farmers of Cauvery Delta Zone with a objective to study the profitability

and productivity of IFS under irrigated condition.

### MATERIAL AND METHODS

Field experiments were conducted at Soil and Water Management Research Institute Thanjavur for four years from 2012 to 2016. The research station is situated in Cauvery Delta Zone of Tamil Nadu state at 10° 45' North latitude and 79° East longitude and 50 meters above the mean sea level. The soil was sandy loam with a pH of 6.3. The soil available N,P,K status was 224, 29.4 and 135 kg ha<sup>-1</sup> respectively. The integrated farming system model was established in June 2012 in 0.8 ha area. Six components were included viz., crop (0.61 ha) + horticulture (0.10 ha) + dairy (0.002) + fisheries (0.08) + poultry (0.002) + vermicompost (0.002) (Table 1).

In the cropping component, three cropping systems were included in a total area of 0.61 ha. Green fodder cumbu napier (CoCN4) was raised in 0.04 ha. Pulses, vegetables, desmanthus, agathi, coconut and curry leaf were planted in bunds of fishpond and boundaries of field. In horticultural components banana was raised in 0.10 ha. Dairy unit was started with one crossbred Jersey cow with one HF calf and animal multiplied with the strength of 2 cow + 2 calf at the end of fourth year. The green grass and dry fodder obtained from crop component were recycled and utilized as feed for animal. In the poultry unit 50 numbers of birds per batch of 12 weeks were reared. Three batches were reared in one year and sold on live weight basis. In the fisheries unit (800m<sup>2</sup>) composite fish culture of catla, rohu, mrigal and grass carp were released

and harvested from 9 to 11 months. Azolla, cumbu napier grass and rice bran from IFS model were recycled and utilized as feed for fisheries. This was compared with the conventional cropping alone in 0.8 ha area of farm. Pictorial presentation of IFS model given in Fig. 1.

## RESULTS AND DISCUSSION

**Productivity:** Higher rice grain equivalent yield of 10.938 t was obtained from the crop component. Crops applied with organic manures viz., farm yard manure, vermicompost, azolla by recycling might have contributed for better crop productivity. Similar results of high productivity was also reported by Jayanthi et al (2003). Among the allied components higher REY was achieved in fishery unit (3.295t) followed by dairy unit (3.097t). The fishery unit recorded more production and it is a viable component in Cauvery delta zone. Singh et al (2004) also reported higher fish productivity due to better plankton development by organic manure addition. The fish ponds also serve as water harvesting structures thus providing the irrigation input and nutritional food to the farm family. Higher level of fish productivity through recycling of poultry manure was reported by Kumar et al (2012) owing to better plankton development. Integrated Farming System recorded 20.83 t (REY) of production when compared to cropping alone in 0.8 ha with a production of 9.6t.

**Economics:** The four years mean data on economics of IFS model (Table 2) indicated that the crop alone contributed a gross income of Rs.1,55,780 ( 52% ) to the total income. This was followed by fisheries (15.2%) and dairy (14.2%). Gross income was less in dairy since the cow was dry for two years. Besides income the IFS model contributed food grain from crop component, fruits, vegetables, fodder, milk, fish and chicken. Next to fisheries, dairy unit contributed higher gross income (14.2%) and the cost of production was high due to the feed cost of concentrate and oilcakes. Labour involvement is also more in animal maintenance. If the animal is productive in all the years and feed preparation in the farm itself utilizing grain, Rice bran, Azolla, green fodder, dry fodder from the allied components, dairy unit could be economically viable. Kumar et al (2012) also reported increase in net income through integrated farming system due to use of recycled products within the system. Poultry unit also contributed 10% to gross income. Backyard poultry with desi birds is common in farm house holds and could be easily managed by farm women for broiler, egg production and able to meet the demand of the family. In large scale rearing of poultry birds proper hygienic conditions should be maintained and birds should be properly vaccinated (Solaippan et al 2007). Tripathi et al (2010) reported that the

**Table 1.** Details of crop and components

Cropping sequence		Area (m <sup>2</sup> )
CS – I : Rice – Rice – Blackgram		2000
CS – II : Maize – Rice – Gingelly		2000
CS – III : Bhendi – Rice – Sunflower		1600
Banana		1000
Fodder crop ( cumbu napier 4) CoCN4		400
Azolla		100
Total		7100
Live stock component (Dairy)		
Species	No.	Area (m <sup>2</sup> )
Milch cow	2	20
Poultry		
Desi Poultry bird	150 (50 in 3 cycle)	20
Vermicompost		20
Fisheries		
Catla	160	800
Border / bund crops	Pulse, Coconut, Curry leaf, Desmanthus, Glyricidia, Vegetables	40

integration of 7 different enterprises namely, crop + fish + goat + vermicompost + fruit production + spice production + agro forestry obtained the net return to the benefit cost ratio of 1.07:1 and maximum per cent contribution of enterprise is the fish production (68.53%) followed by vermicomposting (9.90%), spices and animal production. Ramasamy et al (2008) reported that the income from integrated crop + livestock + goat + poultry was Rs. 98,270 than Rs.28600 in the traditional farming system. The farm family could be employed throughout the year with Integrated Farming System. The conventional method of cropping alone of Rice (*kharif*) – Rice (*rabi*) in 0.8 ha area of the farm gross and net income was Rs.1,22,650 and 42,480. Similar results were reported by many earlier workers (Channabasavanna et al 2009, Singh et al 2009, Dey et al 2010 and Sachinkumar et al 2012).

**Organic manures and nutrient addition:** The organic manures collected per year on dry weight basis was 5738, 675 and 2490 kg from live stock, dairy and poultry (Table 3). Integrated farming system supplies good quality of organic manures and recycled into the field which reduced the external inputs. The nitrogen and phosphorus content was higher in poultry manure than farm yard manure (FYM) and vermicompost. The potassium content was higher in vermicompost than in poultry and farm yard manure. FYM supplied 41.3 kg N, 24.6 kg P<sub>2</sub>O<sub>5</sub> and 40.7 kg K<sub>2</sub>O. Poultry manure supplied 15.0 kg N, 11.1 kg P and 8.9 kg K. Vermicompost supplied 45.3 kg N, 28.4 kg P<sub>2</sub>O<sub>5</sub> and 36.1 kg

**Table 2.** Economics of IFS model with components (Mean of four years)

Crops + Components	REY	Gross income	Cost of production	Net income
Crops	10.938	155780 (52%)	83422	72358
Horti	0.902	16405 (5.4%)	9174	7231
Dairy	3.097	42877 (14.2)	29610	13267
Fishery	3.295	45915 (15.2%)	22022	23893
Poultry	2.221	31051 (10.0%)	16067	14984
Vermicompost	0.404	5739 (1.9%)	1455	4284
Boundary plants	0.26	3892 (1.3%)	2560	1332
Total	20.83	301659	164310	137349 (1.83)
Conventional (Rice – Rice) cropping alone	9.6	1,22,650	80170	42,480 (1.53)

**Table 3.** Organic manure and nutrients from components (Mean of 4 years)

organic manures	Quantity produced (dry weight) kg year <sup>-1</sup>	Nutrient content (%)			Quantity of nutrient kg year <sup>-1</sup>		
		N	P <sub>2</sub> O <sub>5</sub>	K <sub>2</sub> O	N	P <sub>2</sub> O <sub>5</sub>	K <sub>2</sub> O
Farm yard manure	5738	0.72	0.43	0.71	41.3	24.6	40.7
Poultry manure	675	2.23	1.65	1.33	15.0	11.1	8.9
Vermicompost	2490	1.82	1.14	1.42	45.3	28.4	36.1
Total	8903	4.77	3.22	3.49	101.6	64.1	85.7

K<sub>2</sub>O. In total 101.6 kg N, 64.1 kg P<sub>2</sub>O<sub>5</sub> and 85.7 kg K<sub>2</sub>O was added from livestock components into the crop component and sustain good soil health. Acharya and Mondal (2010) also reported similar benefits due to recycling from allied components and plant waste. The addition of nutrients through allied components were also confirmed by Baishya et al (2004) in lowland situation. Desai et al (2013) reported that integrated farming system provides excellent opportunity for organic recycling and reduces farmers dependency on external or market purchased inputs. It offers good scope for recycling of resources within the components.

**Livelihood security:** The average size of the farm family is six and two members fully employed in the Integrated Farming System activities. The members of the farm family meet their food requirements from farm produce and getting diversified food products from their own farm and it includes cereals, pulses, oilseeds, fruits, vegetables, milk, fish, chicken, fodder, vermicompost and others. So the farm family attains self-sufficiency in terms food, nutrition and employment through Integrated Farming System method. Livelihood of marginal farmers could be upgraded by the integration of crop and allied components (Kumar et al 2012). Sasikala et al (2015) reported that Integrated Farming System is a promising enterprise for the marginal and small farmers and IFS provide progressive economic growth, employment, family nutritional requirements and optimal utilization of resources. Integrated Farming System model developed for marginal farmers of Cauvery Delta

Zone with six components in 0.8 ha area achieved higher gross and net income and there by enhanced the productivity and profitability as compared to cropping alone of Rice (*kharif*) – rice (*Rabi*). The soil health is sustained through organic manure production and effective resource recycling within the components reduced the cost of production.

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## Physico-chemical Characteristics of Bottle Gourd and Strawberry Blended Toffee

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**Abstract:** The present study was designed to develop mixed toffee from bottle gourd and strawberry and to study the changes in chemical composition and acceptability of blended toffee during storage at ambient temperature. The physico-chemical analysis of toffee in ambient condition showed that toffees prepared from 100 per cent bottle gourd pulp recorded the highest mean L\* value of 55.67 and b\* value of 24.61 whereas, those prepared from 100 per cent strawberry pulp recorded the highest mean value for a\* (8.08). The highest mean moisture content (14.71%), fibre content (3.00%) and ash content (0.60%) were recorded in toffees exclusively prepared from strawberry whereas, the lowest mean value of 10.41 per cent, 1.85 per cent and 0.19 per cent were recorded in bottle gourd toffees, respectively. The maximum mean value of TSS, acidity and ascorbic acid were recorded in toffees containing whole strawberry pulp and minimum mean value were recorded in toffees having whole bottle gourd pulp. With the advancement in storage period, a decreasing trend was recorded in fibre, acidity and ascorbic acid contents. On the basis of sensory evaluation, the blended toffee prepared from the combination 30:70:: Bottle gourd : Strawberry was adjudged as the best. Therefore, bottle gourd can be blended with strawberry for preparation of high quality and nutritious fruit based toffee.

**Keywords:** Bottle gourd, Strawberry, Toffee, Evaluation, Storage

The fruits are highly perishable in nature and are available only for a very short duration. The spoilage of unmarketed surplus produce can be avoided by converting it into delicious and highly refreshing toffee. It is one of the most important confectionery products and is mostly preferred by children as well as adult and is affordable for all consumers. Due to their nutritious taste and flavour these toffee are widely accepted. The popularity is due utilization of 100 per cent fruits and vegetables pulp and enhanced amounts of protein, minerals and vitamins. The conventional toffee are prepared by using other ingredients like sugar, glucose, milk powder, fat and by using other synthetic colours and flavours. The added benefit of converting extra produce into value product is assurance of high income return to farmer and the processing industries thereby improving the economy of the country. People have less preference for bottle gourd due to its peculiar taste and flavour. However, blending of bottle gourd pulp with strawberry pulp can improve colour and appearance, taste, flavour, mouth feel, texture, nutrition and overall acceptability of their blended products. It is reported that pulpy fruits like mango, guava, papaya, fig, jackfruit, bottle gourd etc. can be utilized for preparation of toffee (Domale et al 2008) such fruit toffees naturally are very nutritious as

they contain most of the constituents of the fruit from which they are prepared. Value added products of bottle gourd and strawberry can also attract both national and international market because there is always a great demand from the consumers all over the world for the new food products, which are nutritious, therapeutic, delicious, appetizing and brilliant in colour and appearance. Only a few researchers have done some work on this valuable fruit, hence, there is a paucity of literature on processing technology of different bottle gourd and strawberry products. Also, very little work has been done on mixed fruit toffee. Keeping in view the health benefits of bottle gourd and strawberry in terms of nutritional as well as medicinal properties, a blend in the form of toffee was prepared and evaluated for its quality characteristics.

### MATERIAL AND METHODS

The present investigation was carried out at Sher-e-Kashmir University of Agricultural Sciences and Technology of Jammu during the year 2016-2017. The fully matured, healthy, uniform sized vegetable of bottle gourd (*Lagenariasi ceraria*) and strawberry fruit (*Fragaria × ananassa*) were selected for this study. The strawberry fruits selected were fully ripe, bright red in colour.

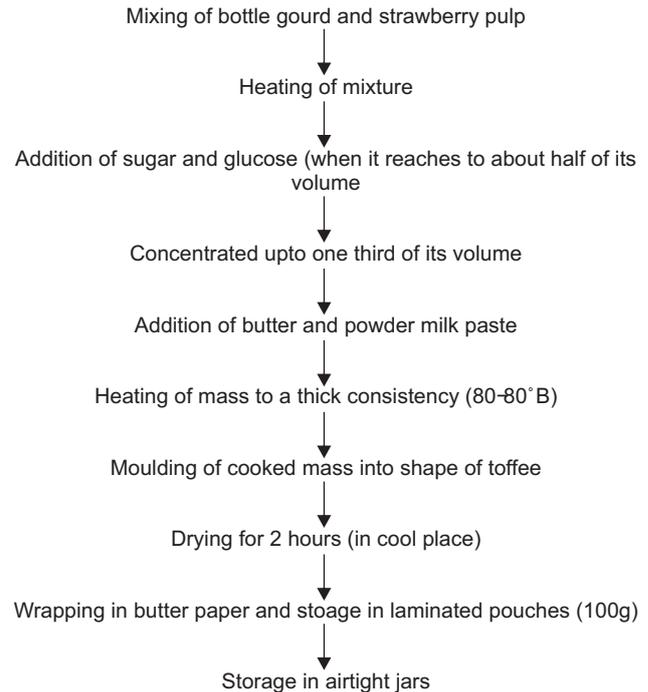
**Preparation of fruit for pulping:** The fruits and vegetables were washed under running tap water for removal of adhering dirt. After washing of fruits, preliminary trial was conducted to standardize the method of extraction of pulp. The standardized method was then used for the preparation of pulp for further studies. Bottle gourd fruit were peeled, sliced and blanched at 90° C for 2 minutes to inactivate polyphenol oxidase enzyme thereby preventing browning of the pulp. Sodium chloride @ 0.1% was added to enhance the flavour. Fully matured fresh strawberry fruit with firm texture were used for the experiment. The fruits were washed thoroughly under running water and cut into halves with stainless steel knife and crushed manually to pass through pulper to obtain a fine pulp. The pulp was pasteurized for 10–12 minutes to raise its temperature upto 78° C and cooled at room temperature. After cooling the prepared pulp was mixed with 0.01 % sodium benzoate and stored in glass jars for further use.

**Chemical and additives:** The prepared pulp was mixed with 0.01% sodium benzoate and stored in air tight glass jars for further use. Cane sugar, glucose, fat, milk powder were also procured from local market and used for preparation of bottle gourd and strawberry blended toffee.

**Preparation of blended toffee:** The toffee was prepared by taking various combination of bottle gourd : strawberry pulp viz. (100:0, 90:10, 80:20, 70:30, 60:40, 50:50, 40:60, 30:70, 20:80, 10:90 and 0:100). The toffee was prepared as per the procedure given by Revanwar and Sakhale (2003) with certain modifications as detailed in Fig 1. The prepared bottle gourd and strawberry pulp were mixed and heated till it remained one half of its original volume and other ingredients such as sugar (350g), glucose (50g) were mixed with the pulp and the contents were cooked again until the mass became concentrated upto one third of its original volume. Addition of edible fat (15g) and skim milk powder (75g) dissolved in little lukewarm water. After cooling it for 2 hours, the toffee was wrapped in butter paper followed by transparent plastic film and then packed in laminated pouches (100g) and stored in airtight tight jars. The detailed flow sheet for preparation of toffee is given in Fig 1.

**Physico-chemical analysis of toffee:** The pulp of bottle gourd and strawberry was evaluated for various physico-chemical properties like hunter colour value, moisture content, crude fibre, ash, TSS, titratable acidity, reducing sugars, total sugars and ascorbic acid using standard methods of AOAC (2012). Total sugars were estimated as per the method described by Rangana, (2006). The titrimetric method using 2,6–dichlorophenol indophenols dye was used to estimate ascorbic acid (AOAC 2012).

**Packaging and storage of toffee:** The prepared toffees



**Fig. 1.** Flow sheet for preparation of bottle gourd: strawberry blended toffee

were wrapped in butter paper followed by transparent plastic film and then packed in laminated pouches (100g) and stored in airtight jars for three months at ambient condition and periodically evaluated at 30 days interval for their physico-chemical composition, organoleptic properties and microbial quality of prepared toffee.

**Sensory evaluation of toffee:** Sensory evaluation was carried out on the basis of appearance, colour, taste, chewiness and over all acceptability by semi trained taste panel of 7-8 judges by using 9 point Hedonic Scale assigning score 9 (like extremely) to 1 (dislike extremely). A score of 5.5 and above was considered acceptable (Amerine et al 1965).

## RESULTS AND DISCUSSION

### Effect of blending and storage on colour value of toffee:

There was a significant decrease in L\* value of bottle gourd and strawberry blended toffee with the advancement in storage period (Table 1). The treatment T<sub>1</sub> (100:0:: Bottle gourd : Strawberry) recorded the highest L\* values of 57.81 at zero days of storage whereas, lowest L\* values of 31.08 was in T<sub>11</sub> (0:100:: Bottle gourd : Strawberry). However, after 90 days of storage treatment same trend was observed. In case of a\* colour values, the highest mean values 8.08 was recorded in T<sub>11</sub> and the minimum (2.90) in T<sub>1</sub>. As the storage period advanced, increase in a\* values was observed. A significant decrease in b\* values was noticed during storage

and the mean values decreased from 19.09 to 15.83 in bottle gourd and strawberry blended toffee. Parab et al (2014) and Jadhavar et al (2014) also reported decrease in L\* values and b\* values of papaya fruit bar and mango fruit during 90 days storage period. They also reported increase in a\* values with storage. The changes in b\* values for colour would be due browning reaction that proceeds oxidative and enzymatically controlled processes. Similar observations were also reported by Henriette et al (2005) in mango leather. Similarly Pineli et al (2015) reported decrease in L\* values in the later days of storage and increase in a\* values during storage of strawberry jam

**Effect of blending and storage on moisture, fibre and ash contents of toffee:** Moisture content of bottle gourd and strawberry toffee increased with increase in storage period and the initial mean value of 12.07 increased to 12.80 per cent after 90 days of storage (Table 2). The maximum mean moisture content of 14.71 was recorded in treatments T<sub>11</sub> whereas minimum mean moisture content of 10.41 was observed in T<sub>1</sub>. Similar trend was observed by Anisa et al (2016) in peach-soy fruit toffee and Parab et al (2014) in mango bar. The increase in moisture content might be due to high humidity in the external environment. The product might have absorbed the moisture from the external environment or due to chemical changes such as browning reaction. Kohinkar et al (2012) reported increase in the moisture content in fig and guava mixed fruit toffee during storage. The

mean fibre content of blended toffee declined significantly from the initial level of 2.71 per cent to 2.34 per cent. The treatment T<sub>11</sub> recorded the highest mean fibre content of 3.00 per cent and lowest fibre content of 1.85 per cent was in T<sub>1</sub>. Patel and Kushwaha (2013) also reported that fibre decrease more rapid in the initial stages but became very slow in the later stages with the increase in storage period. Attri et al (2014) observed that the fibre content in papaya toffee and leather decrease with increased in storage period. With the advancement of the storage period the mean ash content decreased from the initial level of 0.45 to 0.32 per cent during 90 days of storage. During storage T<sub>11</sub> recorded highest mean ash content of 0.60 per cent whereas the lowest mean ash content (0.19 %) was T<sub>1</sub>. Similar results have been reported by Pandita (2015) in aonlaladoo. Presence of high amount of ash is the indication of the presence of higher amounts of some of the essential elements like K, Na, P (Ting and Rouseff 1986)

**Effect of blending and storage on total soluble solids (TSS), acidity and ascorbic acid content of toffee:** The TSS content (Table 3) of fresh bottle gourd and strawberry mixed toffee ranged from 77.28 to 81.36° Brix. The T<sub>11</sub> had higher TSS content as compared to the rest of the treatments. The titrable acidity of bottle gourd and strawberry blended toffee ranged from 0.71 (T<sub>1</sub>) to 1.16 % (0:100: Bottle gourd: Strawberry). Similar results of decreased in acidity were documented by Sheoran et al (2007) in bael slab and

**Table 1.** Colour values (L\*, a\* and b\*) of bottle gourd and strawberry blended toffee as affected by different storage at ambient temperature

Treatment	L*					a*					b*				
	0*	30	60	90	Mean	0	30	60	90	Mean	0	30	60	90	Mean
T <sub>1</sub>	57.81	56.30	54.93	53.67	55.67	2.41	2.78	3.09	3.35	2.90	26.71	25.24	23.83	22.68	24.61
T <sub>2</sub>	48.03	46.23	44.61	43.46	45.58	2.44	2.82	3.14	3.38	2.94	25.79	24.34	22.88	21.78	23.69
T <sub>3</sub>	46.45	44.53	42.14	40.15	43.31	2.70	3.10	3.42	3.68	3.22	17.46	17.80	18.04	19.27	18.14
T <sub>4</sub>	44.83	42.20	40.79	39.54	41.84	2.33	3.60	3.93	4.20	3.51	21.96	20.47	19.13	17.88	19.86
T <sub>5</sub>	43.04	41.12	39.76	38.51	40.60	4.26	4.64	4.96	5.33	4.79	20.71	19.23	17.85	16.57	18.59
T <sub>6</sub>	41.40	39.82	38.33	36.91	39.11	5.68	5.89	6.14	6.50	6.05	19.50	18.02	16.63	15.36	17.37
T <sub>7</sub>	39.04	36.79	35.34	34.08	36.31	5.78	5.10	6.29	6.68	6.18	17.75	16.26	15.06	13.58	15.66
T <sub>8</sub>	35.96	34.40	33.01	31.65	33.75	5.95	6.35	6.72	7.01	6.50	16.58	15.09	14.62	13.41	14.92
T <sub>9</sub>	34.95	32.99	31.56	30.28	32.44	6.75	7.16	7.65	7.93	7.37	15.26	14.87	13.24	11.29	13.66
T <sub>10</sub>	33.65	31.95	30.52	29.10	31.40	7.14	7.50	7.88	8.27	7.69	14.89	13.02	12.57	11.21	12.92
T <sub>11</sub>	31.08	30.56	29.20	27.94	29.69	7.53	7.92	8.30	8.59	8.08	13.36	12.77	11.93	11.11	12.29
Mean	41.47	39.71	38.20	36.84		4.81	5.25	5.59	5.90		19.09	17.92	16.89	15.83	

\*storage period in days

CD (p 0.05)

Treatment	0.19	0.02	0.02
Storage	0.07	0.03	0.05
Treatment x Storage	0.02	0.08	0.10

toffees during storage. The decrease in acidity might be due to chemical interaction between organic constituents of the pulp induced by temperature and action of enzymes during storage. The decrease in acidity may also be attributed to the chemical degradation. Mewada et al (2013) reported that with the advancement of storage period acidity decreased in guava papaya mixed fruit toffee. These results are in conformation with results reported by Kumar et al (2017) in papaya and guava fruit bar. During storage period of 90 days, the ascorbic acid content of bottle gourd and strawberry blended toffee showed a decreasing trend at ambient temperature. The mean ascorbic acid content declined significantly from the initial value of 47.01 to 45.68 mg/100g during 90 days of storage. After 90 days of storage, the highest ascorbic acid content of 79.51 mg 100g<sup>-1</sup> were recorded by T<sub>11</sub>, whereas, in T<sub>1</sub> the lowest contents was observed (8.71 mg 100g<sup>-1</sup>). Chaurasiya et al (2014) and Kuchi et al (2014) also reported significant reduction in vitamin C content of guava jelly bar due to degradation of dehydro-ascorbic acid to furfural or hydro methyl furfural by ascorbic acid oxidase enzymes during storage. The findings are in conformity with those of Patel and Kushwaha (2013) in aonla murabba during 180 days of storage period.

**Effect of blending and storage on reducing sugar, total sugars and overall acceptability scores of toffee:** The mean reducing sugar content of bottle gourd and strawberry blended toffee ranged from 21.68 to 22.49 % (Table 4). The treatment T<sub>11</sub> contains minimum reducing sugars (20.94 %)

than other combination. The increase in reducing sugars during storage might be due to gradual loss of moisture, inversion of sucrose to glucose and fructose or due to breakdown of complex polysaccharides into simple sugars during storage. The results are in accordance with Rababah et al (2011) who also reported that reducing sugar increased with the advancement of storage period in strawberry jam. Similar observations were recorded by Khan et al (2012) and they attributed the increase in reducing sugars due to inversion of non-reducing into reducing sugars or hydrolysis of polysaccharides. Also Kaushal et al (2001) in apple pomace toffees and Domale et al (2008) in aonla toffees gave the similar findings. The storage period significantly affected the total sugars content of bottle gourd and strawberry blended toffee. During storage for 90 days there was a significant increase in total sugars content from initial mean values of 53.37 to final mean value of 54.17 per cent. After 90 days storage the highest total sugars content of 55.35 per cent was recorded in T<sub>1</sub> (100:0: Bottle gourd: Strawberry). The increase in total sugars with storage might be due to moisture loss from the products, inversion of sugars, and hydrolysis of starch and pectin into simple sugars. Kuchi et al (2014) also gave similar findings of increase in the total sugar content guava jelly bar and Sharma et al (2013) in apricot fruit bar, Chavan et al (2015) in guava and strawberry toffee.

A general decrease in overall acceptability scores was observed in all the treatments with the advancement of

**Table 2.** Moisture, fibre and ash content of bottle gourd and strawberry blended toffee during storage at ambient temperature

Treatment	Moisture (%)					Fibre (%)					Ash (%)				
	0*	30	60	90	Mean	0	30	60	90	Mean	0	30	60	90	Mean
T <sub>1</sub>	10.22	10.33	10.47	10.64	10.41	2.06	1.89	1.78	1.66	1.85	0.22	0.20	0.18	0.15	0.19
T <sub>2</sub>	10.55	10.66	10.82	10.96	10.74	2.22	1.99	1.89	1.72	1.96	0.26	0.23	0.21	0.18	0.22
T <sub>3</sub>	10.89	11.01	11.25	11.45	11.15	2.39	2.23	2.01	1.88	2.13	0.31	0.27	0.23	0.20	0.25
T <sub>4</sub>	11.02	11.35	11.60	11.81	11.45	2.51	2.39	2.27	2.13	2.33	0.35	0.31	0.28	0.23	0.29
T <sub>5</sub>	11.26	11.69	11.87	12.23	11.76	2.63	2.56	2.41	2.38	2.50	0.40	0.35	0.31	0.28	0.34
T <sub>6</sub>	11.83	12.26	12.44	12.65	12.28	2.74	2.66	2.52	2.47	2.60	0.45	0.41	0.36	0.30	0.38
T <sub>7</sub>	12.49	12.95	13.24	13.50	13.05	2.87	2.75	2.60	2.51	2.68	0.48	0.43	0.39	0.34	0.41
T <sub>8</sub>	12.95	13.09	13.48	13.71	13.31	2.95	2.84	2.71	2.56	2.77	0.54	0.49	0.44	0.39	0.47
T <sub>9</sub>	13.48	13.67	13.92	14.20	13.82	3.13	2.95	2.82	2.70	2.90	0.60	0.56	0.50	0.43	0.52
T <sub>10</sub>	13.76	13.91	14.20	14.45	14.08	3.10	2.99	2.89	2.77	2.94	0.65	0.61	0.56	0.49	0.58
T <sub>11</sub>	14.27	14.53	14.88	15.17	14.71	3.16	3.05	2.93	2.87	3.00	0.69	0.63	0.60	0.52	0.60
Mean	12.07	12.31	12.56	12.80		2.71	2.57	2.43	2.34		0.45	0.41	0.37	0.32	

\*storage period in days

CD (p 0.05)

Treatment 0.02 0.02 0.02

Storage 0.03 0.03 0.03

Treatment x Storage 0.04 0.06 NS

storage period. Initially, the maximum scores of 8.32 were in  $T_8$  (30:70:: Bottle gourd : Strawberry) whereas the minimum scores of 7.42 in  $T_1$ . After 90 days of storage, the highest score of 7.96 was in  $T_8$  whereas the lowest scores of 7.01 were observed in  $T_1$ . Mewada et al (2013) while carrying out storage studies on guava papaya mix toffee reported a

decrease in the sensory score of different parameters of bottle gourd and strawberry, irrespective of treatments during storage might be attributed to change in their objective characteristics like loss of colour pigments, breakdown of insoluble solids, change in sugar acid ratio and overall quality loss. Domale et al (2008) reported decrease in organoleptic

**Table 3.** TSS, acidity and ascorbic acid content of bottle gourd and strawberry blended toffee during storage at ambient temperature

Treatment	TSS (° Brix)					Acidity (%)					Ascorbic acid (mg 100g <sup>-1</sup> )				
	0*	30	60	90	Mean	0	30	60	90	Mean	0	30	60	90	Mean
$T_1$	76.78	77.10	77.51	77.74	77.28	0.77	0.74	0.70	0.65	0.71	9.90	9.55	9.10	8.71	9.31
$T_2$	77.21	77.60	77.95	78.28	77.76	0.81	0.78	0.73	0.68	0.74	17.77	17.35	16.90	16.41	17.10
$T_3$	78.74	77.17	78.63	78.89	78.61	0.86	0.82	0.79	0.75	0.80	24.72	24.30	23.84	23.44	24.07
$T_4$	77.25	78.62	79.02	79.46	78.84	0.90	0.85	0.82	0.77	0.83	32.96	32.56	32.11	31.62	32.30
$T_5$	78.55	78.90	79.26	79.78	79.12	0.96	0.93	0.88	0.82	0.89	40.65	40.23	39.78	39.29	39.98
$T_6$	79.10	79.46	79.81	80.12	79.62	1.01	0.98	0.92	0.85	0.93	47.91	47.50	47.05	46.56	47.25
$T_7$	79.30	79.88	80.22	80.53	79.98	1.07	1.02	0.99	0.95	1.01	55.20	54.80	54.37	53.92	54.56
$T_8$	79.78	80.17	80.52	80.84	80.33	1.12	1.09	1.04	1.00	1.05	61.43	61.01	60.56	59.98	60.74
$T_9$	80.01	80.40	80.73	81.04	80.55	1.16	1.12	1.08	1.03	1.09	69.57	69.14	68.70	68.25	68.74
$T_{10}$	80.21	80.60	80.94	81.25	80.75	1.21	1.17	1.12	1.06	1.13	76.25	75.83	75.38	74.90	75.58
$T_{11}$	80.88	81.23	81.51	81.82	81.36	1.25	1.18	1.14	1.11	1.16	80.88	80.46	79.10	79.51	80.20
Mean	78.98	79.28	79.65	79.98		1.00	0.96	0.93	0.87		47.01	46.60	46.159	45.68	

\*storage period in days

CD (p 0.05)

Treatment	0.02	0.02	0.02
Storage	0.03	0.03	0.03
Treatment x Storage	0.06	NS	0.09

**Table 4.** Reducing sugars, total sugar and overall acceptability scores of bottle gourd and strawberry blended toffee during storage at ambient temperature

Treatment	Reducing sugars (%)					Total sugars (%)					Overall acceptability scores				
	0*	30	60	90	Mean	0	30	60	90	Mean	0	30	60	90	Mean
$T_1$	23.47	23.67	23.89	24.14	23.79	54.38	54.88	55.23	55.35	54.95	7.42	7.31	7.16	7.01	7.22
$T_2$	22.79	22.94	22.25	23.63	23.15	54.26	54.45	54.85	55.05	54.65	7.52	7.41	7.29	7.14	7.33
$T_3$	22.34	22.58	22.80	23.04	22.69	53.69	53.99	54.42	54.69	54.19	7.63	7.51	7.36	7.19	7.41
$T_4$	22.17	22.40	22.66	22.98	22.55	53.60	53.91	54.16	54.45	54.03	7.73	7.61	7.45	7.25	7.50
$T_5$	21.82	22.04	22.27	22.62	22.19	53.57	53.74	54.00	54.32	53.79	7.96	7.85	7.70	7.53	7.75
$T_6$	21.67	21.89	22.17	22.47	22.05	53.45	53.62	53.87	54.09	53.76	8.17	8.05	7.90	7.71	7.95
$T_7$	20.85	21.16	21.60	21.84	21.36	53.17	53.48	53.76	53.97	53.59	8.25	8.16	8.01	7.79	8.06
$T_8$	21.33	21.56	21.81	22.02	21.68	53.01	53.36	53.59	53.81	53.43	8.32	8.21	8.06	7.96	8.13
$T_9$	20.99	21.33	21.69	21.88	21.47	52.84	53.18	53.43	53.63	53.26	8.25	8.14	7.99	7.74	8.03
$T_{10}$	20.64	20.86	21.11	21.37	20.10	52.64	52.87	53.16	53.39	53.01	8.22	8.10	7.96	7.72	8.01
$T_{11}$	20.40	20.85	21.12	21.38	20.94	52.46	52.66	53.02	53.22	52.83	8.18	8.07	7.93	7.51	7.98
Mean	21.68	21.93	22.21	22.49		53.37	53.66	53.95	54.17		7.96	7.85	7.70	7.51	

\*storage period in days

CD (p 0.05)

Treatment	0.07	0.02	0.01
Storage	0.03	0.03	0.02
Treatment x Storage	0.06	0.03	0.04

score in aonla toffees during storage. Similarly Verma and Chopra (2010) reported that organoleptic score of aonla-mango mixed fruit slab decreased during storage period and the product maintained its acceptability up to seven months at ambient storage.

Table 4 shows that the mean reducing sugar content of bottle gourd and strawberry blended toffee ranged from 21.68 to 22.49 %. The treatment T<sub>11</sub> (0:100:: Bottle gourd : Strawberry) contain minimum reducing sugars (20.94 %) than other combination. The increase in reducing sugars during storage might be due to gradual loss of moisture, inversion of sucrose to glucose and fructose or due to breakdown of complex polysaccharides into simple sugars during storage. The results are in accordance with Rababah et al (2011) who also reported that reducing sugar increased with the advancement of storage period in strawberry jam. Similar observations were recorded by Khan et al (2012) and they attributed the increase in reducing sugars due to inversion of non-reducing into reducing sugars or hydrolysis of polysaccharides. Also Kaushal et al (2001) in apple pomace toffees and Domale et al (2008) in aonla toffees gave the similar findings.

The storage period significantly affected the total sugars content of bottle gourd and strawberry blended toffee. During storage for 90 days there was a significant increase in total sugars content from initial mean values of 53.37 to final mean value of 54.17 per cent. After 90 days storage the highest total sugars content of 55.35 per cent was recorded in T<sub>1</sub> (100:0: Bottle gourd : Strawberry). The increase in total sugars with storage might be due to moisture loss from the products, inversion of sugars, and hydrolysis of starch and pectin into simple sugars. Kuchi et al (2014) also gave similar findings of increase in the total sugar content guava jelly bar and Sharma et al (2013) in apricot fruit bar, Chavan et al (2015) in guava and strawberry toffee.

A general decrease in overall acceptability scores was observed in all the treatments with the advancement of storage period. Initially, the maximum scores of 8.32 were recorded in T<sub>8</sub> (30:70:: Bottle gourd : Strawberry) whereas the minimum scores of 7.42 were observed in T<sub>1</sub> (100:0:: Bottle gourd : Strawberry). After 90 days of storage, the highest scores of 7.96 were recorded in T<sub>8</sub> (30:70:: Bottle gourd : Strawberry) whereas the lowest scores of 7.01 were observed in T<sub>1</sub> (100:0:: Bottle gourd : Strawberry). Mewada et al (2013) while carrying out storage studies on guava papaya mix toffee reported a decrease in the sensory score of different parameters of bottle gourd and strawberry, irrespective of treatments during storage might be attributed to change in their objective characteristics like loss of colour pigments, breakdown of insoluble solids, change in sugar

acid ratio and overall quality loss. Domale et al (2008) reported decrease in organoleptic score in aonla toffees during storage. Similarly Verma and Chopra (2010) reported that organoleptic score of aonla-mango mixed fruit slab decreased during storage period and the product maintained its acceptability up to seven months at ambient storage.

## CONCLUSION

The spoilage of unmarketed surplus produce of bottle gourd and strawberry can be utilized by converting it into delicious and highly refreshing products like toffee. The blended toffee remained acceptable upto three months at ambient condition. Based on sensory properties, bottle gourd can be blended with strawberry pulp in the ratio of 30:70 (Bottle gourd: Strawberry) for preparation of high quality nutritious fruit based toffee.

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# Development and Characterization of Natural Food Colorant from Microalgae *Chlorella* sp. (Abca-17) and its Use in Food Products

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**Abstract:** Present study was undertaken for development of stable natural food colorant from microalgae *Chlorella* sp. (Abca-17) and its characterization, techno-economic feasibility and use in the food products was studied. Stable natural colorant was developed from the chlorophyll extracted from microalgae *Chlorella* sp. (Abca-17) by making its metallo complex with copper to form copper chlorophyllin. Characterization of pigment revealed that it was free from heavy metals; having moisture content of 3.49 percent and total copper 4.16 percent. Pigment was fat soluble and insoluble in water and sugar solutions. Pigment was stable at low pH and high temperature. Pigment retention was 100 percent at pH range 2 to 9 whereas pigment retention ranged from 100 to 81.21 per cent from temperature range 30 °C to 100 °C and was 88.72 percent even at 90 °C. Copper chlorophyllin was used as natural colorant in sour cream dip and pan burfi and was suitable as natural colorant in pan burfi but was not a compatible food colorant for sour cream dip. Level of addition of 200 ppm of pigment in pan burfi was most desirable. Natural food colorant from microalgae *Chlorella* sp. (Abca-17) presented economical, environment friendly and sustainable approach.

**Keywords:** *Chlorella* sp., Microalgae, Natural food colorant, Sustainability

Food colours play an important role in food businesses as they tend to provide more acceptable product which is readily liked by the consumer and influence their purchase decision. Trend towards greener products and globalization resulted in exploration of natural additives. However, there are shortcomings associated with natural colourings due to their chemical structure and properties including lower tinctorial strength than artificial dyes and requiring higher levels of addition and resultant increased unit cost, lower stability against temperature, pH, light and preservatives, and having characteristic odour of the source. Traditional sources for natural food colorants predominantly include plants, plant extracts and to a lesser extent other sources such as insects, algae, fungi and bacteria (Solymosi et al 2015) and chlorophylls are the only natural green pigments biosynthesized in huge amounts. However, the use of chlorophyll as colorants presents challenge due to their instability in food systems. Several strategies for preservation must be applied in the form of chemical modification when they are used as colorants for food products, so that it does not modify the perception and quality of that foodstuff (Roca et al 2016).

A systematic study was undertaken for development of stable natural colorant from the chlorophyll extracted from microalgae *Chlorella* sp. (Abca-17) by making its metallo

complex with copper to form copper chlorophyllin and its characterization, techno-economic feasibility and use in the food products was studied and presented here in this communication.

## MATERIAL AND METHODS

**Microalgae strain:** The green microalgae *Chlorella* sp. (Abca-17) was used in the present investigation.

**Optimization of the growth conditions:** Optimization was carried out to find best conditions ensuring maximum growth of microalgae. Growth is optimized for variables viz. nitrogen concentration, pH and light (Table 1). Microalgae was cultivated in BG-11 media in 250 ml conical flasks. All flasks were inoculated uniformly at 1 ml inoculum in 100 ml media with incubation temperature of 30 °C and 16:8 hours light: dark cycle for 10 days; and optical density was noted at 600 nm after every 48 hours using spectrophotometer.

**Optimization of mass cultivation and harvesting:** Microalgae was mass cultivated using tap water and water treated by reverse osmosis. Microalgae was first mass cultivated in 10 bottles of 15 litres and later it was scaled up to pilot scale cultivation using photobioreactor giving yield of 750 g/3000 litres of media/day (Fig. 1). Algal biomass was harvested using different techniques to evaluate efficiency of the process in terms of efficacy of separation of cells from

**Table 1.** Optimization variables for growth of microalgae

Nitrogen concentration	Light	pH
0.25 g L <sup>-1</sup>	Indoor	6
0.50 g L <sup>-1</sup>	Single Tube light*	7
1.00 g L <sup>-1</sup>	Double Tube light*	8
1.50 g L <sup>-1</sup>	Outdoor	
2.00 g L <sup>-1</sup>		

\* Fluorescent illumination (40 Watt, 2325 Lumens)

growth media by noting the optical density of media left after separation of the cells. Algal biomass was harvested a) by filtration using filter cloth b) by employing electroflocculation technique using aluminium electrodes at voltage of 5 V for 30 min followed by washing of harvested mass with 0.1 percent hydrochloric acid solution for 2-3 times, following washing with R.O water c) by using clarifiers. Harvested mass was shade dried and evaluated for lead, arsenic, mercury and aluminium using Atomic Absorption Spectroscopy.

**Extraction of chlorophyll:** Based on the review of literature (Sartory and Grobbelaar 1984, Simon and Helliwell 1998) methanol was used for solvent extraction of chlorophyll. Chlorophyll was extracted from microalgae using Soxhlet Apparatus by refluxing at 60°C for 2 hours followed by siphoning the pigment containing extract and repeating the same procedure another three times with fresh solvent.

**Identification of pigments:** Identification of pigments was done by Thin Layer Chromatography (TLC). It was done by the procedure followed by McLaughlin and Masters (2004).

**Quantification of chlorophyll:** Extracted chlorophyll was diluted with methanol and measurement was carried out at wave length 652 nm and 665.2 nm. Chlorophyll-a, Chlorophyll-b and total chlorophyll was calculated as mg/g by using following equations given by Porra et al (1989).

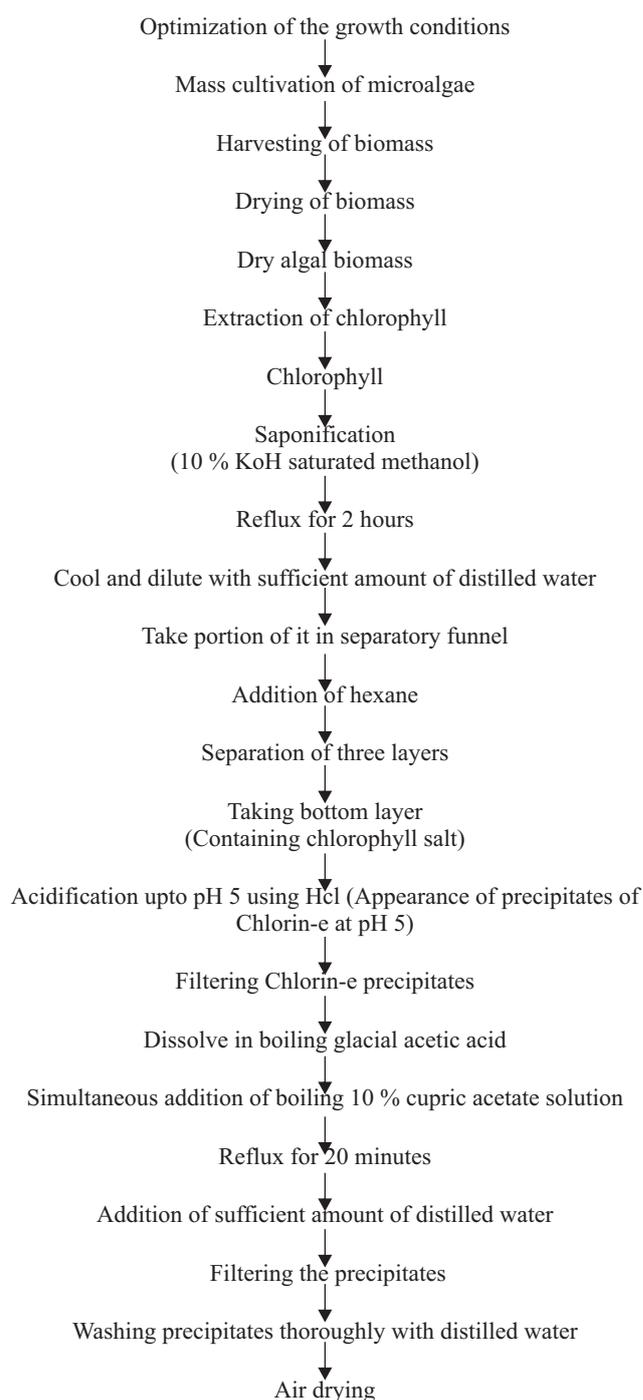
**Development of copper chlorophyllin:** Copper chlorophyllin was developed from chlorophyll by the method followed by Wall (1951) with slight modifications. Procedure for development of copper chlorophyllin from chlorophyll extracted from microalgae beginning from optimization of growth conditions to development of copper chlorophyllin is illustrated in Figure 2. Prepared copper chlorophyllin has been shown in Figure 3.

#### Characterization of copper chlorophyllin

**Moisture content:** Moisture content was evaluated by the method followed by Wall (1995).

**Total copper:** It was evaluated by the method followed by Wall (1995).

**Heavy metal residue:** Copper chlorophyllin was evaluated for heavy metal residue using Atomic Absorption Spectrometer (AAS). Measurements were made using a hollow electron discharge lamp (EDL) for lead, arsenic and

**Fig. 2.** Schematic of development of copper chlorophyllin from microalgae

mercury at wavelengths of 283.31, 193.70 and 253.7 nm respectively.

**Solubility:** Solubility of pigment was evaluated in vegetable oil, water, sugar solution, milk, light cream (25 % fat), sweetened condensed milk and khoa to determine its suitability as colorant in various food products.



Fig. 1. Algal biomass cultivation: (a) Laboratory Scale in plastic bottles; (b) Pilot scale in photobioreactor

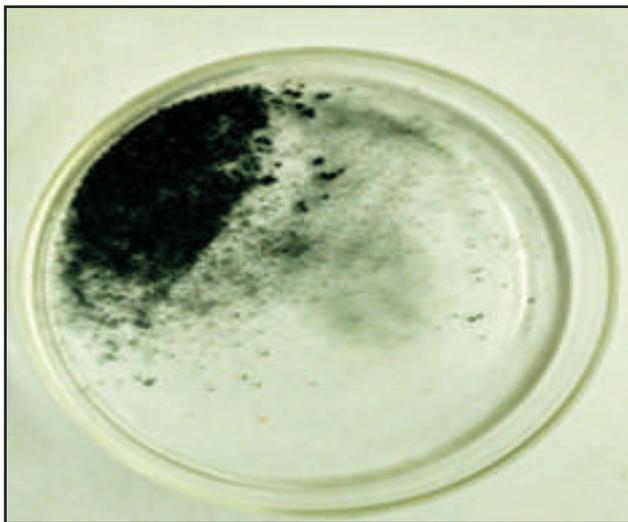


Fig. 3. Copper chlorophyllin

**pH and thermal stability:** pH stability of pigment was evaluated at pH range 2-9. Methanol extract of pigment was kept at aforesaid pH values for 30 min and its optical density was recorded to calculate degradation of pigment and it was expressed as percentage retention of the pigment at respective pH. Thermal stability of pigment was evaluated at 30, 40, 50, 60, 70, 80, 90 and 100°C for 30 min. Methanol extract of pigment was heated at aforesaid temperatures in water bath and its optical density was recorded to calculate degradation of pigment and it was expressed as percentage retention of the pigment at respective temperature.

**Standardization of level of addition of food colorant:** Standardization was done based on preliminary trials and maximum permissible limit prescribed by FSSAI; and following treatments were prepared. Copper chlorophyllin was added in pan burfi at 0, 100, 200, 300, 400, 500 ppm and

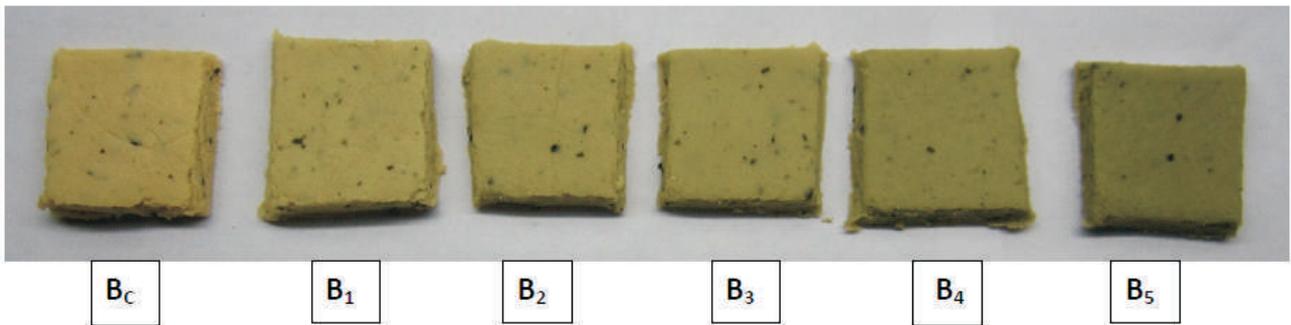


Fig. 4. Pan burfi with copper chlorophyllin as natural colorant

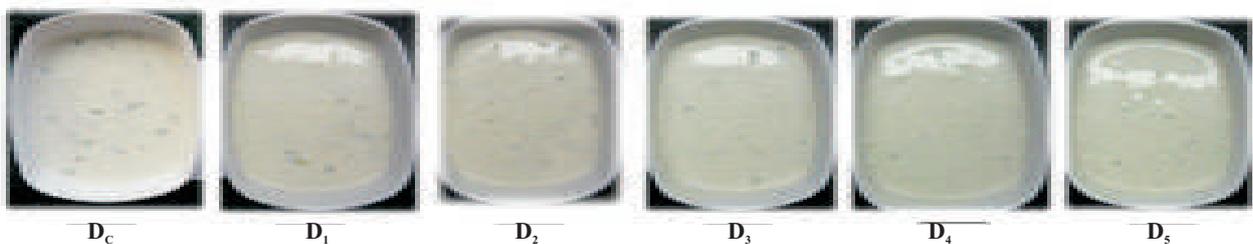


Fig. 5. Sour cream dip with copper chlorophyllin as natural colorant.

**Table 2.** Growth response of *Chlorella* sp. (Abca-17) at different nitrogen concentration

Days	Optical Density				
N (g l <sup>-1</sup> )	0.25	0.50	1.00	1.50	2.00
0	0.010 <sup>d</sup>	0.013 <sup>c</sup>	0.015 <sup>b</sup>	0.018 <sup>a</sup>	0.017 <sup>a</sup>
2	0.017 <sup>c</sup>	0.017 <sup>c</sup>	0.019 <sup>b</sup>	0.022 <sup>a</sup>	0.019 <sup>b</sup>
4	0.058 <sup>b</sup>	0.063 <sup>a</sup>	0.062 <sup>a</sup>	0.064 <sup>a</sup>	0.057 <sup>b</sup>
6	0.127 <sup>c</sup>	0.168 <sup>a</sup>	0.144 <sup>b</sup>	0.118 <sup>d</sup>	0.142 <sup>b</sup>
8	0.322 <sup>b</sup>	0.300 <sup>c</sup>	0.334 <sup>a</sup>	0.299 <sup>c</sup>	0.234 <sup>d</sup>
10	0.423 <sup>c</sup>	0.438 <sup>b</sup>	0.474 <sup>a</sup>	0.394 <sup>d</sup>	0.342 <sup>a</sup>

\*The means within a line followed by different superscripts are significantly different at  $p < 0.05$

**Table 3.** Growth response of *Chlorella* sp. (Abca-17) at different pH

Days	Optical Density		
pH	6	7	8
0	0.014 <sup>a</sup>	0.015 <sup>a</sup>	0.015 <sup>a</sup>
2	0.020 <sup>a</sup>	0.019 <sup>a</sup>	0.017 <sup>b</sup>
4	0.093 <sup>a</sup>	0.087 <sup>b</sup>	0.058 <sup>c</sup>
6	0.155 <sup>a</sup>	0.127 <sup>b</sup>	0.107 <sup>c</sup>
8	0.302 <sup>a</sup>	0.253 <sup>b</sup>	0.213 <sup>c</sup>
10	0.486 <sup>a</sup>	0.442 <sup>b</sup>	0.438 <sup>c</sup>

\*The means within a line followed by different superscripts are significantly different at  $p < 0.05$

**Table 4.** Growth response of *Chlorella* sp. (Abca-17) at different light conditions

Days	Optical Density			
Light conditions	Indoor	Single	Double	Outdoor
0	0.015 <sup>a</sup>	0.015 <sup>a</sup>	0.015 <sup>a</sup>	0.015 <sup>a</sup>
2	0.015 <sup>d</sup>	0.019 <sup>c</sup>	0.023 <sup>b</sup>	0.128 <sup>a</sup>
4	0.029 <sup>d</sup>	0.069 <sup>c</sup>	0.113 <sup>b</sup>	0.205 <sup>a</sup>
6	0.050 <sup>d</sup>	0.150 <sup>c</sup>	0.201 <sup>b</sup>	0.353 <sup>a</sup>
8	0.114 <sup>d</sup>	0.307 <sup>c</sup>	0.382 <sup>b</sup>	0.607 <sup>a</sup>
10	0.227 <sup>d</sup>	0.483 <sup>c</sup>	0.486 <sup>b</sup>	0.744 <sup>a</sup>

\*The means within a line followed by different superscripts are significantly different at  $p < 0.05$

\*\* Fluorescent illumination (40 Watt, 2325 Lumens)

in sour cream dip at 0, 20, 40, 60, 80, 100 ppm.

**Preparation of Pan Burfi:** Pan Burfi was prepared by following the traditional method of burfi preparation (Sachdeva and Rajorhia 1982) with some modification. Hot sugar syrup was prepared from 300 gm sugar by adding minimum quantity of water. Hot sugar syrup was added to 1 kg *khoa* and heated to 80°C. It was cooled down to 50°C and 10 g crushed betel leaves (previously blanched) were added to it. The mixture was kneaded properly and when desirable

flow characteristics were attained, it was poured in trays and allowed to set at room temperature.

**Preparation of sour cream dip:** Sour cream dip was prepared from sour cream (25 % fat content). 70 g coarsely crushed cucumber, 30 g finely chopped spring onions and 10 g salad seasoning were added to 890 gm of sour cream and thoroughly mixed.

**Sensory evaluation:** The sensory evaluation was carried for sensory attributes like colour and appearance, taste, flavour and overall acceptability using ten semi trained panellist using 9 point hedonic rating (Ranganna 2011).

## RESULTS AND DISCUSSION

**Optimization of growth conditions for cultivation of microalgae *Chlorella* sp. (Abca-17):** The highest growth was obtained corresponds to nitrogen concentration of 1g/l, pH 6 and outdoor conditions for light (Table 2, 3 and 4). Hence, these conditions were selected for mass cultivation of microalgae.

**Optimization of mass cultivation conditions and harvesting for microalgae *Chlorella* sp. (Abca-17):** Algal biomass which has to be used for food applications namely supplementation or production of food additives should be free from heavy metals. Tap water was not suitable for the cultivation of microalgae since it resulted in lead residue (0.78 mg 100g<sup>-1</sup>) in the algal biomass, however, treatment of tap water by reverse osmosis was successful in mitigating the problem of contamination of algal biomass with lead. Electroflocculation was not suitable for harvesting since it resulted in aluminium residue in the algal biomass. Filtration can be cost effective method for the harvesting of algal biomass, however, it was not effective in separation of algal biomass from the media. Clarifiers were found be most effective method for the harvesting of algal biomass.

**Identification and quantification of pigments in microalgae *Chlorella* sp. (Abca-17):** TLC of the lipid residue obtained after Soxhlet extraction revealed that it contains chlorophyll a, chlorophyll b, pheophytin a, pheophytin b and  $\beta$ - carotene. Chlorophyll a, Chlorophyll b and total chlorophyll content of the extracted pigment was 16.20, 22.65 and 38.85 mg g<sup>-1</sup>, respectively.

### Characterization of copper chlorophyllin

**Moisture content, total copper, heavy metal residue and solubility:** Moisture content in copper chlorophyllin should not be more than 5 percent, total copper should be between 4-6 percent and heavy metals viz. lead, arsenic and mercury should be in range 10, 3 and 0.5 ppm respectively as per FDA. It can be observed that prepared copper chlorophyllin was complying with legal standards (Table 5). Solubility is an important parameter in the characterization of pigment, since

**Table 6.** pH and thermal stability of copper chlorophyllin

pH	2	3	4	5	6	7	8	9
Retention of Pigment (%)	100	100	100	100	100	100	100	100
Temperature (°C)	30	40	50	60	70	80	90	100
Retention of Pigment (%)	100	100	100	96.81	93.63	90.68	88.72	81.21

it dictates the congeniality of utilization of that particular pigment in food products. It can be observed that pigment is fat soluble and is soluble in vegetable oil, light cream, sweetened condensed milk and khoa; however, it is insoluble in water and also in sugar solutions (20-80 percent) and was sparingly soluble in milk. From these observations it can be inferred that this pigment is suitable for application in fat rich foods like frozen desserts, dairy based confectionery and ethnic khoa based sweets.

**pH and thermal stability:** pH and thermal stability of a pigment are two very important characteristics of a pigment governing its efficacy for use in the food products. Food products usually range from medium acid to low acid and every food product has peculiar pH and food products encounter high temperature during its processing, thus it is very essential for a pigment to be tolerant to pH and temperature and should not undergo degradation. There is 100 percent retention of pigment from pH 2-9 and thus prepared copper chlorophyllin is suitable as colour additive since it can be used in wide range of pH without undergoing degradation (Table 6). Pigment retention is attributed to prevention of removal of copper ion from porphyrin ring in contrast to chlorophyll where magnesium ion excludes from porphyrin ring and results in formation of pheophytin.

The pigment endured high temperature and pigment retention ranged from 100 to 81.21 percent from temperature range 30°C to 100°C and 88.72 percent retention was even upto 90°C, thus it is suitable for usage in food products undergoing thermal processing. The reduction in the percentage retention of copper chlorophyllin was not due to degradation of pigment but it was rather due to formation of precipitates of pigment which rendered it less dispersible in the solution. Copper chlorophyllin takes longer time to disperse in food formulations and also has greater tendency to foam in high speed filling operations (Kendrick 2012).

**Sensory quality of food products with copper chlorophyllin as natural food colorant:** Pan burfi and sour cream dip with different levels of copper chlorophyllin i.e. 0 to 500 ppm and 0 to 100 ppm is shown in Figure 4 and 5 respectively. The addition of copper chlorophyllin had no effect on the taste and flavour of the pan burfi and sour cream dip (Table 7 and 8). An ideal food colorant should not impart any characteristic taste or flavour to the food, however, there is a

drawback associated with natural colourings that they impart characteristic odour of the source to the food they are added. The scores for colour and appearance attribute for pan burfi increased linearly with the addition of colorant from 0 to 200 ppm (B<sub>c</sub>-B<sub>2</sub>) followed by decrease in colour attribute on further addition of the colorant (B<sub>3</sub>-B<sub>5</sub>). Sample having 200 ppm copper chlorophyllin (B<sub>2</sub>) was best. The colour of the pan burfi was more natural. However, contrary results were observed for the colour and appearance attribute of sour cream dip with

**Table 5.** Moisture content, total copper, heavy metal content and solubility of copper chlorophyllin

Moisture content (%)	3.49 ± 0.12*
Total copper (%)	4.16 ± 0.23*
<b>Heavy Metals (ppm)</b>	
Lead	Below detection limit
Arsenic	Below detection limit
Mercury	Below detection limit
<b>Solubility</b>	
Vegetable oil	Soluble
Water	Insoluble
Sugar solution (20, 40, 60, 80 %)	Insoluble
Milk	Sparingly soluble
Light cream (25 % fat)	Soluble
Sweetened condensed milk	Soluble
Khoa	Soluble

\*Mean and standard deviation

**Table 7.** Sensory evaluation of pan burfi with copper chlorophyllin (CC) as natural food colorant

Sample	Colour and appearance	Taste	Flavour	Overall acceptability
B <sub>c</sub>	6.8 <sup>c</sup>	7.4 <sup>a</sup>	7.2 <sup>a</sup>	6.7 <sup>c</sup>
B <sub>1</sub>	7.6 <sup>b</sup>	7.4 <sup>a</sup>	7.2 <sup>a</sup>	7.4 <sup>b</sup>
B <sub>2</sub>	7.8 <sup>a</sup>	7.4 <sup>a</sup>	7.2 <sup>a</sup>	7.8 <sup>a</sup>
B <sub>3</sub>	7.6 <sup>b</sup>	7.4 <sup>a</sup>	7.2 <sup>a</sup>	7.3 <sup>b</sup>
B <sub>4</sub>	6.4 <sup>d</sup>	7.4 <sup>a</sup>	7.2 <sup>a</sup>	6.9 <sup>c</sup>
B <sub>5</sub>	5.8 <sup>e</sup>	7.4 <sup>a</sup>	7.2 <sup>a</sup>	6.3 <sup>d</sup>

\* B<sub>c</sub>-0 ppm CC; B<sub>1</sub>-100 ppm CC; B<sub>2</sub>-200 ppm CC; B<sub>3</sub>-300 ppm CC; B<sub>4</sub>-400 ppm CC; B<sub>5</sub>-500 ppm CC

\*The means within a line followed by different superscripts are significantly different at p < 0.05

Table 8. Sensory evaluation of sour cream dip with copper chlorophyllin (CC) as natural food colorant

Sample	Colour and appearance	Taste	Flavour	Overall acceptability
D <sub>c</sub>	7.8 <sup>a</sup>	7.4 <sup>a</sup>	6.4 <sup>a</sup>	7.2 <sup>a</sup>
D <sub>1</sub>	6.8 <sup>c</sup>	7.4 <sup>a</sup>	6.4 <sup>a</sup>	6.4 <sup>b</sup>
D <sub>2</sub>	6.4 <sup>d</sup>	7.4 <sup>a</sup>	6.4 <sup>a</sup>	6.1 <sup>c</sup>
D <sub>3</sub>	7.2 <sup>b</sup>	7.4 <sup>a</sup>	6.4 <sup>a</sup>	6.5 <sup>b</sup>
D <sub>4</sub>	6.8 <sup>c</sup>	7.4 <sup>a</sup>	6.4 <sup>a</sup>	6.4 <sup>b</sup>
D <sub>5</sub>	6.4 <sup>d</sup>	7.4 <sup>a</sup>	6.4 <sup>a</sup>	6.2 <sup>c</sup>

\* D<sub>c</sub>-0 ppm CC; D<sub>1</sub>-20 ppm CC; D<sub>2</sub>-40 ppm CC; D<sub>3</sub>-60 ppm CC; D<sub>4</sub>-80 ppm CC; D<sub>5</sub>-100 ppm CC

\*The means within a line followed by different superscripts are significantly different at  $p < 0.05$

Table 9. Techno-economic feasibility of production of copper chlorophyllin from microalgae *Chlorella* sp. (Abca-17) and broccoli leaves

Parameters	Microalgae <i>Chlorella</i> sp. (Abca-17)	Broccoli leaves
Cultivation/day	750 g / 3000 L	6 Month
Operation cost	100 Rs/day	50-100
% Chlorophyll*	4-5 %	0.8-1.0 %
Chlorophyll extraction rate	70-80 %	100 %
Land foot print	3 % in comparison to broccoli	-
Extraction cost	50 Rs	50 Rs

\*On dry weight basis

copper chlorophyllin as colorant. Sample with no colorant (D<sub>c</sub>) was most desirable. Hence, copper chlorophyllin is not a compatible food colorant for sour cream dip.

#### Techno-economic feasibility of production of copper chlorophyllin from microalgae *Chlorella* sp. (Abca-17):

The comparison between the production of copper chlorophyllin from microalgae *Chlorella* sp. (Abca-17) and broccoli leaves indicate that dehydrated alfalfa meal and broccoli leaf meal contains 0.2-0.4 and 0.8-1.0 percent chlorophyll respectively (Table 9) and are most commonly used sources for commercial production of copper chlorophyllin (Panda 2003). Microalgae have advantage of high production rate in lesser amount of time as compared to broccoli which is a 6 month crop. Moreover microalgae can be grown regardless of soil and climatic conditions. Operation cost and extraction cost is nearly same in case of microalgae and broccoli. The chlorophyll content of *Chlorella* sp. (Abca-17) is markedly high as compared to broccoli leaves (4-5 percent as compared to 0.8-1.0 percent). The extraction rate of chlorophyll is higher in case of broccoli leaves in comparison to *Chlorella*; however, somewhat less extraction rate from *Chlorella* can be overlooked for the high

amount of chlorophyll present in the *Chlorella*. The land requirement (land foot print) for cultivation of microalgae is 3 percent in comparison to the broccoli. Thus, microalgal biomass has more productivity and is economically advantageous for production of copper chlorophyllin as compared to broccoli leaves.

#### CONCLUSION

Nitrogen concentration of 1g/l, pH 6 and outdoor conditions for light were most suitable for the growth of microalgae *Chlorella* sp. (Abca-17). Water treated with reverse osmosis was suitable for cultivation of *Chlorella* sp. (Abca-17) and harvesting by using clarifiers was found to be most effective. Developed pigment was stable at low pH and high temperature and thus suitable for various food applications. Copper chlorophyllin was fat soluble and insoluble in water and sugar solutions and thus it was suitable for application in fat rich foods and suitable as natural colorant in pan burfi but not a compatible food colorant for sour cream dip. Level of addition of 200 ppm of copper chlorophyllin in pan burfi was most desirable. It is techno-economically feasible to develop copper chlorophyllin from microalgae *Chlorella* sp. (Abca-17) and is more economical as compared to broccoli leaves. Thus, microalgae present more economical, environment friendly and sustainable approach for making copper chlorophyllin for use as natural colorant in food products, which can be explored for commercialization to meet the present need of natural colour additives in food products.

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Received 16 November, 2017; Accepted 31 January, 2018



## Interactive Effect of GA<sub>3</sub> and Proline on Nutrients Status and Growth Parameters of Pea (*Pisum sativum* L.)

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**Abstract:** The present study was carried out to investigate the possibility of using gibberellic acid GA<sub>3</sub> (50, 100) mg L<sup>-1</sup> and proline (25, 50) mg.L<sup>-1</sup> applied exogenously as foliar spray which will have beneficial effects on some growth parameters of pea plant (*Pisum sativum* L.). The experiment was conducted during the growing season 2016–2017 in pots at Department of Biology/College of Education for Pure Science–Ibn-AL Haitham / Baghdad University. The experiment was laid out in a completely Randomized Design (C.R.D.) with three replicates. The main parameters were (plant height, nitrogen, phosphorus, calcium and proline concentration of plant shoot, nitrogen, phosphorus and calcium content of plant seeds, yield components: seeds number per pod, seeds weight per pod, 100 seeds weight and harvest index). Looking at the results, it was noticed that, growth parameters studied showed increment with foliar spray with both gibberellic acid and proline, and may be concluded that foliar application of GA<sub>3</sub> at 100 mg.L<sup>-1</sup> and proline at 25 mg.L<sup>-1</sup> can be recommended to pea plant obtaining better growth and yield.

**Keywords:** Gibberellic acid, Proline, Nutrient status, Pea plant

Pea plant (*Pisum sativum* L.) belongs to Fabaceae family, it is a cool season grain legume crops with life cycle of one year, grown in many parts of the world. To face the increased demand for grain of growing population, many supporting techniques to enhance agronomic yield with high quality, application of growth regulators is promising management because it improves nutrient uptake and transport to the edible parts of plant (Aghtape et al 2010). Gibberellic acid (GA<sub>3</sub>) is a plant growth hormone, in higher plants it is considered the most important biologically active regulating plant stem, it stimulates both cell division and elongation and increases cell wall extensibility and promotes bolting and flowering (Verma and Verma 2010). The application of GA<sub>3</sub> can be recommended to pea plant and gave better growth, it was noticed that some morphological, physiological and quality parameters showed a significant increase as compared to control (Singh et al 2015). Throughout their plant cycle, plants are subjected to various abiotic environmental stresses that limit their growth and productivity (Roychoudhury and Basu 2012). Plant accumulate metabolites such as amino acids, they are fundamental ingredients in the process of protein synthesis and play a vital role in plant metabolism and development. Proline is an amino acid accumulates in cytoplasm of plants, it covers a

wide range of protective roles, it is acting as an excellent osmolytes, defense and signalling molecules, antioxidative and metal chelator (Hayat et al 2012). and act as protein stabilizer, an inhibitor of lipid membrane peroxidation, ROS scavenger and osmotic adjustment (Trovato et al 2008).

The objective of this experiment is to screen out the best gibberellic acid and proline concentration applied as foliar spray for better growth, yield and quality of pea plant.

### MATERIAL AND METHODS

The experiment was conducted at green garden of Department of Biology, College of Education for Pure Science–Ibn–AL Haitham during the growth season 2016–2017, to find out the role of gibberellic acid (0, 50, 100) mg L<sup>-1</sup> and proline (0, 25, 50) mg L<sup>-1</sup> foliar application on field pea plant (*Pisum sativum* L.). The experiment was laid out in a completely randomized design with three replicates. Seeds were sown in the pots filled with equal quantity of soil (10kg) on November 26, 2016, thinning of plants was done 15 days after germination. During the growth season the pots were kept free from weeds, Gibberellic acid and proline were applied twice as foliar spraying at 37 and 51 days from the date of sowing, control plants were sprayed with distilled water. Plants height were measured by January 28, 2017. The plants were sampled on February 18, 2017 for chemical

analysis. Shoot samples were oven dried at 65 C°, crushed and digested according (Agiza et al 1960). chemical analysis of nitrogen (Chapman and Pratt 1961), phosphorus (Matt 1970) calcium (Wimberly 1968) and protein (Thachuk 1977) was done by standard methods. Seeds number and seeds weight per pod, 100 seeds weight, harvest index was measured on April 7, 2017 when crop was harvested. Seeds were crushed, digested and prepared for mineral measuring (nitrogen, phosphorus and calcium) using the same methods for shoot measurement.

## RESULTS AND DISCUSSION

The results of the present experiment indicates that foliar application of GA<sub>3</sub> and proline increased the growth and yield of pea plant. The data in (Table 1) clearly indicated that spraying with different concentrations of GA<sub>3</sub> (0, 50, 100) mg.L<sup>-1</sup> and proline (0, 25, 50) mg L<sup>-1</sup> increased plant height mean by (130.09, 41.12)% respectively. The superiority in plant height recorded at the interaction between GA<sub>3</sub> 100 mg L<sup>-1</sup> and proline 50 mg.L<sup>-1</sup>, it was 61.00 cm over the control 22.00 cm. Data in (Table 2) showed that application of GA<sub>3</sub> from 0 to 100 mg L<sup>-1</sup> gave an increase in means of nitrogen, phosphorus and protein concentrations in plant shoot by about (10.85, 20.00 and 10.73)% respectively and there was no effect on calcium concentration, in contrast proline foliar spraying (0, 25, 50) mg.L<sup>-1</sup> caused also increase means of nutrient and protein concentrations by about (12.07, 28.57, 15.91 and 11.79) % for nitrogen, phosphorus ,calcium and protein concentration respectively. The treatment GA<sub>3</sub> at 50 mg.L<sup>-1</sup> and proline at 25 mg L<sup>-1</sup> maintained best value for nitrogen concentration that recorded 3.40 comparing with control 2.60, while the treatment GA<sub>3</sub> 100 mg L<sup>-1</sup> and proline 25 mg.L<sup>-1</sup> gave the best values for phosphorus ,calcium and protein that recorded 0.20, 3.18 and 20.81 in comparison with their control values 0.13, 2.37 and 16.25 .

The results in (Table 3) showed that GA<sub>3</sub> foliar spraying had a pronounced effect on nutrients content in plant seeds, thus increasing concentration of GA<sub>3</sub> from 0 to 100 mg.L<sup>-1</sup> gave positive increase by about (40.16, 64.81 and 35.99%) for nitrogen, phosphorus and calcium means respectively and also increasing concentrations of proline from 0 to 50 mg.L<sup>-1</sup> gave a significant increase in term of percentage were (43.70, 63.20 and 48.84%) respectively for the nutrients means. The results also showed a significant variation in the treatment values from the control due to effect of both GA<sub>3</sub> and proline, for nitrogen content the treatment GA<sub>3</sub> at 100 mg.L<sup>-1</sup> and proline at 25 mg.L<sup>-1</sup> recorded the best value 163.15 when compared to the control 76.88, for phosphorus content both of 25 and 50 mg.L<sup>-1</sup> proline gave the best values

with GA<sub>3</sub> at 100 mg.L<sup>-1</sup> that was 22.25 in comparison with the control 7.48, for the calcium content the best value was with the GA<sub>3</sub> at 100 mg.L<sup>-1</sup> and proline at 50 mg.L<sup>-1</sup> and recorded 140.08 comparing with it's control 63.98 .

The results in (Table 4) indicated that spraying with GA<sub>3</sub> from 0 to 100 mg.L<sup>-1</sup> gave an increase in means of seeds number per pod ,seeds weight per pod, and harvest index by (22.93, 9.43 and 8.05%) respectively while the concentration of 50 mg.L<sup>-1</sup> gave an increase in means of 100 seeds weight about 13.91%. Foliar spray with proline gave an increase in means of seeds number per pod, weight number per pod, 100 seeds weight by about (10.84, 15.69 and 7.06%) respectively and there was no effect on harvest index, the interaction between both of GA<sub>3</sub> and proline gave the best values at the treatment 100 mg.L<sup>-1</sup> GA<sub>3</sub> and 25mg.L<sup>-1</sup> proline for seeds number per pod ,the treatment 50 mg.L<sup>-1</sup> GA<sub>3</sub> and 25 mg.L<sup>-1</sup> proline for seeds weight per pod and 100 seed weight, while the treatment 100mg.L<sup>-1</sup> GA<sub>3</sub> and 50mg.L<sup>-1</sup> proline gave the best value for harvest index, and gave the values 3.98, 0.64, 26.25 and 40.79, respectively over their controls.

GA<sub>3</sub> is growth promoter which has the ability to increase mitosis in the subapical regions of apical meristems, stimulating cell divisions in the intercalary meristems and causing elongation of cell, due to elongation and cell division and increasing the length of internode (Thomson et al 2015). GA<sub>3</sub> induced the activity of the enzyme xyloglucan transglycosylase (XET), which hydrolyses xyloglucans in cell wall, causes rearrangement in cell wall matrix, so it promotes extension of cell wall and facilitates penetration of proteins called (expansions) into cell wall causing the lessening of it (Jain 2011). Application of GA<sub>3</sub> may function in sucrose assimilation, increase in photosynthetic activity, better food accumulation leading to increase growth parameters (Singh et al 2015).

Proline application results in its rapid uptake and coupled with its synthesis in plant, thereby increasing the endogenous level of proline ,it plays an important role for osmotic adjustment against various stresses (Ahmed et al 2011). In addition to the role of osmo-protection, proline protects the enzymes, protein structure, cell organelles and membranes by checking lipid peroxidation and facilitates the energy supply for plant growth, and effective quencher of ROS formed through life cycle of plant and enhanced the activity of antioxidant enzymes, therefor proline increases resistance to unfavorable climatic conditions (Ashraf and Foolad 2007)

From the present investigation provides the important role of GA<sub>3</sub> and proline when given as foliar spraying on pea

**Table 1.** Effect of gibberillic acid and proline acid on pea plant height (cm)

Gibberillic acid (mg L <sup>-1</sup> )	Nitrogen			Mean of gibberillic acid
	Proline acid (mg L <sup>-1</sup> )			
	0	25	50	
0	22.00	24.50	25.00	23.83
50	32.00	51.00	53.00	45.33
100	44.50	59.00	61.00	54.83
Mean of proline acid	32.83	44.83	46.33	
LSD (0.05)	Gibberillic acid =2.00 Proline acid =2.00 Interaction= 3.46			

**Table 2.** Effect of gibberillic acid and proline acid on nitrogen concentration (%) of pea plant shoot

Gibberillic acid (mg L <sup>-1</sup> )	Nitrogen			Mean of gibberillic acid
	Proline acid (mg L <sup>-1</sup> )			
	0	25	50	
0	2.60	3.07	3.19	2.95
50	2.93	3.40	3.25	3.19
100	2.18	3.33	3.30	3.27
Mean of proline acid	2.90	3.27	3.25	
LSD (0.05)	Gibberillic acid =0.09 Proline acid = 0.09 Interaction= 0.16			

**Table 3.** Effect of gibberillic acid and proline acid on phosphorus concentration (%) of pea plant shoot

Gibberillic acid (mg L <sup>-1</sup> )	Phosphorus			Mean of gibberillic acid
	Proline acid (mg L <sup>-1</sup> )			
	0	25	50	
0	0.13	0.15	0.17	0.15
50	0.14	0.18	0.18	0.17
100	0.16	0.20	0.19	0.18
Mean of proline acid	0.14	0.18	0.18	
LSD (0.05)	Gibberillic acid =0.026 Proline acid = 0.026 Interaction= 0.044			

**Table 4.** Effect of gibberillic acid and proline acid on calcium concentration (%) of pea plant shoot

Gibberillic acid (mg L <sup>-1</sup> )	Calcium			Mean of gibberillic acid
	Proline acid (mg L <sup>-1</sup> )			
	0	25	50	
0	2.37	4.18	2.88	3.14
50	2.63	3.16	3.14	2.98
100	2.92	3.18	3.17	3.09
Mean of proline acid	2.64	3.51	3.06	
LSD (0.05)	Gibberillic acid =0.87 Proline acid = 0.87 Interaction= 1.51			

plant, both of them enhance nutrient uptake and improve plant growth, and it was concluded that application of GA<sub>3</sub> at

**Table 5.** Effect of gibberillic acid and proline acid on protein concentration (%) of pea plant shoot

Gibberillic acid (mg L <sup>-1</sup> )	Protein			Mean of gibberillic acid
	Proline acid (mg L <sup>-1</sup> )			
	0	25	50	
0	16.25	19.19	19.94	18.46
50	18.31	21.25	20.31	19.96
100	19.88	20.81	20.63	20.44
Mean of proline acid	18.15	20.42	20.29	
LSD (0.05)	Gibberillic acid =0.14 Proline acid = 0.14 Interaction= 0.24			

**Table 6.** Effect of gibberillic acid and proline acid on nitrogen content of pea plant seeds

Gibberillic acid (mg L <sup>-1</sup> )	Nitrogen			Mean of gibberillic acid
	Proline acid (mg L <sup>-1</sup> )			
	0	25	50	
0	76.88	104.94	134.46	105.43
50	101.99	155.45	151.70	136.38
100	126.91	163.15	153.26	142.77
Mean of proline acid	101.93	141.18	146.47	
LSD (0.05)	Gibberillic acid =0.09 Proline acid = 0.09 Interaction= 0.16			

**Table 7.** Effect of gibberillic acid and proline acid on phosphorus content of pea plant seeds

Gibberillic acid (mg L <sup>-1</sup> )	Nitrogen			Mean of gibberillic acid
	Proline acid (mg L <sup>-1</sup> )			
	0	25	50	
0	7.48	11.88	18.42	12.59
50	12.50	18.62	20.91	17.34
100	17.76	22.25	22.25	20.75
Mean of proline acid	12.58	17.58	20.53	
LSD (0.05)	Gibberillic acid =0.13 Proline acid = 0.13 Interaction= 0.22			

**Table 8.** Effect of gibberillic acid and proline acid on phosphorus content of pea plant seeds

Gibberillic acid (mg L <sup>-1</sup> )	Phosphorus			Mean of gibberillic acid
	Proline acid (mg L <sup>-1</sup> )			
	0	25	50	
0	63.98	99.00	122.70	95.23
50	92.12	138.13	132.02	120.76
100	109.15	139.26	140.08	129.50
Mean of proline acid	88.42	125.46	131.60	
LSD (0.05)	Gibberillic acid =0.62 Proline acid = 0.62 Interaction= 1.08			

100 mg L<sup>-1</sup> and proline at 25 mg L<sup>-1</sup> showed a significant effect on growth parameters studied.

**Table 9.** Effect of gibberillic acid and proline acid on seed number per pod of pea plant

Gibberillic acid (mg L <sup>-1</sup> )	Seed number pod <sup>-1</sup>			Mean of gibberillic acid
	Proline acid (mg L <sup>-1</sup> )			
	0	25	50	
0	2.80	3.15	3.48	3.14
50	3.28	3.92	3.77	3.66
100	3.89	3.98	3.72	3.86
Mean of proline acid	3.32	3.68	3.66	
LSD (0.05)	Gibberillic acid =0.09 Proline acid = 0.09 Interaction= 0.15			

**Table 10.** Effect of gibberillic acid and proline acid on seed weight per pod of pea plant

Gibberillic acid (mg L <sup>-1</sup> )	Seed weight pod <sup>-1</sup>			Mean of gibberillic acid
	Proline acid (mg L <sup>-1</sup> )			
	0	25	50	
0	0.47	0.54	0.57	0.53
50	0.50	0.64	0.60	0.58
100	0.53	0.59	0.61	0.58
Mean of proline acid	0.51	0.59	0.59	
LSD (0.05)	Gibberillic acid =0.05 Proline acid = 0.05 Interaction= 0.08			

**Table 11.** Effect of gibberillic acid and proline acid on 100 seed weight of pea plant

Gibberillic acid (mg L <sup>-1</sup> )	100 seed weight			Mean of gibberillic acid
	Proline acid (mg L <sup>-1</sup> )			
	0	25	50	
0	18.90	21.70	23.65	21.42
50	22.95	26.25	24.00	24.40
100	25.25	23.90	23.65	24.27
Mean of proline acid	22.37	23.95	23.77	
LSD (0.05)	Gibberillic acid =0.20 Proline acid = 0.20 Interaction= 0.35			

**Table 12.** Effect of gibberillic acid and proline acid on harvest index of pea plant

Gibberillic acid (mg L <sup>-1</sup> )	Harvest index			Mean of gibberillic acid
	Proline acid (mg L <sup>-1</sup> )			
	0	25	50	
0	38.62	36.59	41.13	38.78
50	45.57	36.48	39.81	40.62
100	45.85	39.05	40.79	41.90
Mean of proline acid	43.35	37.37	40.58	
LSD (0.05)	Gibberillic acid =0.23 Proline acid = 0.23 Interaction= 0.40			

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## Optimization of Machine Parameters for Grading of Sapota through Trommel Screen Grader

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**Abstract:** The present work was conducted to determine physical properties of sapota (*Achras Sapota*) and to evaluate the performance parameters of a multifruit grader for the grading of sapota. The performance was evaluated in terms of separation efficiencies for each grader and overall grading efficiency at feed trough angles 3.8°, 7° and 9.5° and speed of 14, 17 and 22 RPM for power operated grader and manually operated grader. The optimization of machine parameter was done using design expert 7.0 software. The maximum value of actual capacity and grading efficiency at optimized condition was obtained as 269.4 kg ha<sup>-1</sup> and 93.58 % respectively for power operated grader. Results of cost analysis shows lesser cost of grading (Rs 12.84 qt<sup>-1</sup>) by power operated grader as compared to manually operated grader (Rs 19.51 qt<sup>-1</sup>).

**Keywords:** Optimization, Trommel screen, Grading, Efficiency

Sapota (*Achras Sapota*) is a very popular fruit and is native to tropical America. In India it covers an area of 1,21,000 ha with a production of 14,57,000 tonnes (Horticulture Statistics Division, DAC&FW 2014-15). It is mostly grown in south India with Karnataka as the leading producer which accounts for 27.79 percent of total national production of sapota (National Horticultural Board 2014-15). Cleaning, sorting and grading are the three important post-harvest operations for fruit processing and packaging industry. It provides basics for buying and selling. In market, size of a fruit is generally considered as the main criteria for selling of fruits followed by its maturity (Balakrishnan 2003). Grading is one of the important operations done at the farmer level. Grading on the basis of size and quality is essential requirement for the marketing of fruit and vegetable grown in commercial farms. Proper grading can reduce handling losses during transportation (Londhe et al 2013). Generally, Sapota fruits are separated by hand with the help of labour. It results in uneven grading, time consuming, labour intensive, slow, non-consistent and costly operation. Therefore farmers are looking forward to have an appropriate sapota grading machine in order to cope with the labour shortage problem and to obtain a better quality of agricultural products. Mechanical grading of fruits is efficient and provides uniform grading of fruits. In mechanical fruit graders, divergence roller type, oscillating screens, rotary screen, weight graders (Ali et al 2010) are used in our country. Some graders are less

efficient and some are costly. The divergence roller type fruit grader is commonly used in Maharashtra for grading of onions, potatoes, sapota and oranges etc. In some countries pattern classification is used for multipurpose sorting but it is costly. In this research work, a trommel screen type grader is used for grading sapota fruits. The machine has both manual (handle) and motor operated arrangement for grading of the fruits on the basis of three size grades. The three trommel screens with different mesh size helps to separate fruits on the basis of their size. In the present work the performance of the machine was evaluated for sapota fruit and the machine parameters (trough angle and RPM) was optimized for the maximum overall grading efficiency.

### MATERIAL AND METHODS

Local variety of sapota fruits was procured from local market, Parbhani (Maharashtra, India). Random samples were drawn from a freshly harvested lot in each three size grades: first (large), second (medium) and third (small) were taken as (measurement of physical and frictional properties) study samples. Physical and frictional characteristics linear dimension, mass, bulk density, sphericity, rolling angle, static co-efficient of friction were determined.

**Physical characteristics of sapota:** Equatorial diameter ( $D_e$ ), polar diameter ( $D_p$ ) and thickness ( $T$ ) of each of twenty fruits were measured for each grade using vernier caliper. The bulk density of sample was computed by the mass of fruit

(g) and volume of fruit ( $\text{cm}^3$ ) (Mohsenin 1986). The fruit shape was expressed in terms of its sphericity index was calculated based on recommendation of Mohsenin et al (1978).

$$\text{Sphericity (\%)} = \frac{(D_p D_e T)^{1/3}}{D_p} \times 100$$

Where,  $D_p$  = Polar diameter (cm),  $D_e$  = Equatorial diameter (cm),  $T$  = Thickness of sapota (cm)

**Frictional characteristics of sapota:** To determine the rolling angle, the sapota was kept at the centre of the working surface, (horizontal platform) in the most stable position (on their base) to prevent toppling over top upwards. The platform was inclined until the sapota begins to roll. When the rolling started, the position of platform was noted by protractor. In this equipment, the rolling angle was measured in three different platforms such as plywood, aluminum and mild steel. Rolling angle was measured with mild steel platform was considered in the design of sapota grader. The co-efficient of static friction is the tangent of the slope angle of the table measured with protractor (Oje and Ugbor 1991). It was determined on three surfaces that is plywood, aluminum and mild steel for sapota fruits a frame made with a rectangular wooden were placed on the surface. The frame was filled with fruits and the table was tilted slowly manually until movement of the whole fruit mass. The co-efficient of dynamic friction was the ratio of the force required to slide the fruit over a surface divided by the normal force pressing fruit against the surface, (Oje and Ugbor 1991). It was measured for the same material that is plywood aluminum and mild steel for sapota fruits. The force required to pull that frame was noted in term of weight.

#### Performance evaluation of grader for sapota:

Performance evaluation of mutifruit grader for sapota was done by calculating actual capacity, separation efficiency for each grade, overall grading efficiency (Borkar et al 2004) and loss percentage (Mangaraj et al 2009). The actual capacity of the grader was evaluated by using the equation given by Patel et al (2009).

#### Actual capacity:

$$Q = \frac{\text{Total weight of fruit (kg)}}{\text{Time (hr)}}$$

#### Separation efficiency:

$$G_s = \frac{N_t - N_u - N_o}{N_t} \times 100$$

Where,  $G_s$  = separation efficiency of a particular grade in percent,  $N_t$  = Total number of fruits in the sample,  $N_u$  = Total number of undersize fruits in the sample,  $N_o$  = Total number of oversize fruits in the sample.

#### Overall grading efficiency:

$$E = \frac{N_t - N_{tm}}{N_t} \times 100$$

Where,  $E$  = Overall grading efficiency of grader for sapota,  $N_{tm}$  = Total number of misclassified fruits in all sample

#### Losses:

$$L = \frac{N_b}{N_t} \times 100$$

Where,  $L$  = Losses (%),  $N_b$  = Number of bounced fruit out from inlet during grading and  $N_t$  = Total number of fruits in the sample.

The various combinations were tested in random order to estimate the effect of independent variable on actual capacity, separation efficiency and overall grading efficiency of grader for sapota. Data was also analyzed statically by using analysis of variance (ANOVA). Actual capacity; separation efficiency and overall grading efficiency were measured experimentally. The independent variables for the machine was optimized by using Design Expert 7.0 software.

**Cost analysis of grader for sapota:** Based on the 25 years' service life of grader for sapota and 1200 h of annual use of sapota grader, the total cost of grading per hour as well as total cost per quintal of sapota grading was calculated.

## RESULTS AND DISCUSSION

**Physical properties of sapota:** The polar diameter of sapota was in the range of 3.88 to 4.90 cm .The maximum thickness was in the range of 3.06 cm to 3.84 cm and the equatorial diameter 3.25 to 4.29 cm. The weight varies between 25 to 50 g. The bulk density was in the range of 606 to 626  $\text{kg/m}^3$  and the sphericity varied between 83.96 to 87.68 percent (Table 2). Similar values for these properties were observed by Athmaselvi et al (2014). The results of frictional properties shows that the sapota fruit has maximum rolling angle, coefficient of static friction and coefficient of dynamic

**Table 1.** Experimental plan for performance evaluation of grader for sapota

Treatment	Speed (rpm)	*Feed through angle (degree)
S <sub>1</sub> F <sub>1</sub>	14	3.8
S <sub>1</sub> F <sub>2</sub>	14	7.0
S <sub>1</sub> F <sub>3</sub>	14	9.5
S <sub>2</sub> F <sub>1</sub>	17	3.8
S <sub>2</sub> F <sub>2</sub>	17	7.0
S <sub>2</sub> F <sub>3</sub>	17	9.5
S <sub>3</sub> F <sub>1</sub>	22	3.8
S <sub>3</sub> F <sub>2</sub>	22	7.0
S <sub>3</sub> F <sub>3</sub>	22	9.5

\*Feed through angle is determined by using trigonometric relationship  
Where, S<sub>1</sub>, S<sub>2</sub>, S<sub>3</sub> - Three different levels of speed of grading unit. F<sub>1</sub>, F<sub>2</sub>, F<sub>3</sub> - Three different levels of feed through angle. The grade standards of sapota are 1. Grade - I -above 4 cm, 2. Grade -II -between 3.5 cm and 4 cm, 3. Grade -III -below 3.5 cm

**Table 2.** Physical properties of sapota fruit

Particular	Large (G1)	Medium (G2)	Small (G3)
Polar diameter (cm)	4.90 ± 0.55	4.54 ± 0.47	3.88 ± 0.50
Equatorial diameter (cm)	4.29 ± 0.30	3.56 ± 0.30	3.25 ± 0.37
Thickness (cm)	3.84 ± 0.55	3.37 ± 0.23	3.06 ± 0.28
Weight (gm)	49.80 ± 8.56	40.70 ± 5.68	25.80 ± 3.50
Bulk density (Kg/m <sup>3</sup> )	606.70 ± 44.09	614.73 ± 31.79	626.10 ± 44.09
Sphericity (%)	86.60 ± 6.29	83.96 ± 6.64	87.68 ± 7.13

friction for wooden surface. It has maximum coefficient of static friction. Davies and Zibokere (2011) also observed maximum coefficient of static friction (0.63) for plywood surface followed by galvanised steel sheet and glass for gbafilo fruit.

**Effect of independent variables on performance of power operated grader for sapota and their optimization for maximum grading efficiency:**

The measured values for the actual capacity with different combination of independent variables ranged between 236 to 295 kg hr<sup>-1</sup> (Table 4). Thus with the increase of speed the capacity increases to some extent. The capacity at a particular speed increases as the feed trough angle increase from 3.8 to 7 ° but it decrease as the angle increase further to 9.5°. The value similar to average capacity was obtained at the feed trough angle 7° and 17 rpm. The separation efficiency was obtained in the range of 75.56 to 90.33 per cent which also seems to have maximum value for the feed trough angle 7° and 17 rpm. This shows that as the rpm increases from 14 to 17 rpm there is a significant increase in the separation efficiency for all the

**Table 3.** Frictional properties of sapota fruit

Particular	Wooden surface	Mild steel	Aluminium
Rolling angle (degree)	6.2 ± 0.95	5.05 ± 0.82	5.1 ± 0.91
Coefficient of static friction	0.308 ± 0.0043	0.218 ± 0.0033	0.259 ± 0.0035
Coefficient of dynamic friction	0.218 ± 0.0048	0.118 ± 0.0041	0.160 ± 0.0034

**Table 5.** Effect of variables on performance of manually operated grader for sapota

Treatment	Actual capacity (kg hr <sup>-1</sup> )	Separation efficiency (%)			Overall grading efficiency (%)	Loss (%)
		GI	GII	GIII		
S <sub>1</sub> F <sub>1</sub>	211	83	80	70	81	5
S <sub>1</sub> F <sub>2</sub>	240	88	82	78	85	3.75
S <sub>1</sub> F <sub>3</sub>	220	83	78	71	80	6.25
Average	223.6	84.66	80	73	82	5
CD (p=0.05)	4.98	3.56	2.91	3.61	2.42	0.42

Feed Trough Angle (Degree): F<sub>1</sub>-3.8, F<sub>2</sub>-7, F<sub>3</sub>-9.5, S<sub>i</sub>: Speed of manual operation

three grades but it again decrease as the speed increase beyond 17 rpm. This is because at high speed and higher feed trough angle the sapota roll down with high speed from the trough towards the inlet of grading cylinder resulting in the chocking of cylinder and improper grading. Similar results were obtained for the overall efficiency of the grader which was in the range of 85 to 94 per cent, the maximum being obtained at feed trough angle 7° and 17 rpm. Maximum loss occurred at the highest feed trough angle and highest rpm due to more bouncing of sapota at higher angle and speed. The independent variables were optimized using the Design

**Table 4.** Effect of variables on performance of power operated grader for sapota

Treatments	Actual capacity (kg hr <sup>-1</sup> )	Separation efficiency (%)			Overall grading efficiency (%)	Loss (%)
		G I	G II	G III		
S <sub>1</sub> F <sub>1</sub>	236	87	88	77	87	1.55
S <sub>1</sub> F <sub>2</sub>	254	91	92	75	90	0.75
S <sub>1</sub> F <sub>3</sub>	241	87	82	63	84	2.3
S <sub>2</sub> F <sub>1</sub>	247	91	90	78	90	2.32
S <sub>2</sub> F <sub>2</sub>	257	96	92	86	94	1.56
S <sub>2</sub> F <sub>3</sub>	223	88	85	73	85	1.53
S <sub>3</sub> F <sub>1</sub>	272	93	86	80	89	1.76
S <sub>3</sub> F <sub>2</sub>	295	92	89	78	91	1.57
S <sub>3</sub> F <sub>3</sub>	285	88	84	70	85	2.50
Average	256.67	90.33	87.55	75.56	88.33	1.76
CD (p=0.05)	4.97	3.56	2.91	3.61	2.42	0.41

Speed (RPM): S<sub>1</sub>-14, S<sub>2</sub>-17 & S<sub>3</sub>-22, Feed Trough Angle (Degree): F<sub>1</sub>-3.8, F<sub>2</sub>-7, F<sub>3</sub>-9.5

Expert 7.0 software. The optimization was done to maximize capacity, separation efficiencies and overall grading efficiency and to minimize loss percentage. The optimized RPM was obtained as 20.04 and the optimized trough angle was obtained as 5.95°. The maximum value of actual capacity at optimized condition was obtained as 269.4 kg h<sup>-1</sup>. The maximum value of separation efficiencies for Grader 1 (G I) was 95.36 percent, for Grader 2 (G II) 92.02 percent, for Grader 3 (G III) 84.92 percent. The maximum overall grading efficiency obtained at optimized condition was 93.58 percent. The minimum loss at optimized condition was 1.76 percent which is very less. So, from the analysis it can be observed that the machine is working well for separation of sapota into its respective grades.

**Effect of independent variables on performance of manually operated grader for sapota:** The experiment was conducted with 10 kg of sapota. The capacity was obtained in terms of kg hr<sup>-1</sup> and it was in the range of 211 to 240 for the manual grading. The overall grading efficiency varied between 80 and 85 percent with the maximum value at 7° trough angle. The loss percentage was obtained maximum at 9.5° trough angle due to more bouncing of sapota at higher angle. Thus in both graders (i.e. power operated and manual

operated) the best results obtained at 17 rpm and 7° trough angle. There were no significant bruising or mechanical injury to the fruit was observed but there were some losses observed due to bouncing of fruits at some higher feed trough angle and rpm. The comparative cost analysis of the three grading systems was done as per given by Ukey and Unde (2010). The highest capacity with maximum overall grading efficiency is selected for cost analysis. total cost per quintal of graded sapota is less for power operated grader (Rs 12.38) as compared to the manual operated grader (Rs 19.51) and manual picking (traditional method) (Rs 50). The cost analysis shows that the cost incurred in manual grader is about 65 percent more than the power operator grader while the cost of manual picking is about 4 times more than power operated grader. Though the power operated grader requires more one time investment but the low operating cost makes it more suitable for use and it is easy to operate and ergonomically suitable.

In power operated grader the maximum overall efficiency of 94 percent with actual capacity of 257 kg hr<sup>-1</sup> and 1.57 percent loss was observed at 17 rpm and 7° trough angle. In manual operated grader the maximum overall efficiency of 85 percent with actual capacity 240 kg hr<sup>-1</sup> and 3.75 per cent loss

**Table 6.** Operating cost of the power operated grader, manually operated grader and manual sorting

Particulars	Power operated grader	Manually operated grader
Assumed service life(Years)	25	25
Annual use (hr.)	1200	1200
Initial cost (Rs.)	45000	45000
Salvage value (%)	10	10
Interest (%)	14.5	14.5
Taxes and shelter (%)	2	2
Repair and maintenance (%)	2	2
Labour charges	Rs 20 hr <sup>-1</sup> (one labour)	Rs 40 hr <sup>-1</sup> (two labour)
Electricity	Rs 6/hr	NA
Capacity (kg/hr)	257	240
Annual overhead charges		
a. Depreciation (Rs hr <sup>-1</sup> )	1.35	1.35
b. Interest (Rs hr <sup>-1</sup> )	2.99	2.99
c. Taxes, Shelter (Rs hr <sup>-1</sup> )	0.75	0.75
Total Overhead charges (Rs hr <sup>-1</sup> )	5.09	5.09
Repair and maintenance (Rs hr <sup>-1</sup> )	0.75	0.75
Electricity (Rs hr <sup>-1</sup> )	6	NA
Labour charges (Rs hr <sup>-1</sup> )	20	40
Total cost (Rs hr <sup>-1</sup> )	31.84	46.84
Total cost per quintal of graded sapota (Rs qt <sup>-1</sup> )	12.38	19.51

was observed at the average manual speed and feed trough angle  $7^\circ$ . The maximum value of actual capacity at optimized condition was obtained as 269.4 kg/h. The maximum value of separation efficiencies for Grader 1, 2 and 3 were 95.36, 92.02 and 84.92 per cent respectively. The maximum overall grading efficiency obtained at optimized condition was 93.58 per cent. The minimum loss at optimized condition was 1.76 per cent. The total cost of grading reduced to Rs 12.38 qt<sup>-1</sup> for power operated grader as compared to the grading cost of Rs 19.51 and Rs 50 qt<sup>-1</sup> for manual operated grading and manual sorting respectively. In both graders, damages like bruising or any mechanical injury to the fruit was not observed during grading only the minor losses due to bouncing back of sapota occurred.

### CONCLUSION

The power operated Multi fruit grader is suitable for grading of sapota with 94 percent grading efficiency with Rs 12.38 qt<sup>-1</sup> cost of grading and in the absence of electricity, manually operated grader is also suitable for marginal farmers with 85 percent grading efficiency and Rs 19.51 qt<sup>-1</sup> cost of grading.

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## Potential of Entomopathogens in Managing Potato Whitegrubs in Himachal Pradesh

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**Abstract:** *Brahmina coriacea* (Hope) is the most widespread and destructive species of whitegrubs having potential to inflict 40 to 50 per cent yield losses to potato in Himachal Pradesh. The entomopathogens constitute a potential group of biocontrol agents against whitegrubs, therefore *Beauveria bassiana* Vuill., *Metarhizium anisopliae* (Metchnikoff), *Heterorhabditis indica* Poinar and *Bacillus cereus* Frankland & Frankland were evaluated in potato at Kheradhar. *H. indica* @ 10 kg ha<sup>-1</sup> was highly effective with tuber damage ranging from 12.5 to 12.7 per cent in treated plots. Mixed application of *H. indica* + *B. bassiana* or *M. anisopliae* showed additive or synergistic effect. There was 11.4 to 12.2 per cent tuber damage in *H. indica*+ *B. bassiana* or *M. anisopliae* treatments. Maximum reduction in tuber damage was observed in *H. indica* + *B. bassiana*, followed by *H. indica* + *M. anisopliae* treatment. There was 48.75 to 55.38 per cent reduction in tuber damage when *Galleria mellonella* cadavers infected with *H. indica* were applied in soil. Direct application of *G. mellonella* cadavers infected with *H. indica* showed higher efficacy which may be attributed to greater activity of infective juveniles in soil.

**Keywords:** Whitegrubs, *Brahmina coriacea*, *Beauveria bassiana*, *Heterorhabditis indica*, *Metarhizium anisopliae*

The problem of whitegrubs is quite serious in hilly states where potatoes are grown during summer season as rain-fed crop under long day conditions (Chandel et al 2015). In most parts of the north western Himalaya, potato cultivation is done on sloppy lands with light and loose textured soil and high rainfall. The potato fields are normally situated in the vicinity of fruit orchards in Himachal Pradesh and other hilly parts of India. These conditions are conducive for the development and multiplication of whitegrubs. In India, 24 species of whitegrubs damage potato, and *B. coriacea* is most widespread and destructive species in Himachal Pradesh (Pathania and Chandel 2017). The life cycle of *B. coriacea* is annual with three larval stages (Chandel et al 2003), and damage is caused by second and third instar grubs. The economic importance of chafers is primarily due to the feeding activity of third instar grubs. There exists a highly positive correlation between the population of the third instar grubs and tuber damage (Anonymous 2004). Chandel et al (2008) reported that with unit increase in population of third instar grubs of *B. coriacea*, the tuber damage increases by 12.17 per cent. It is very difficult to control whitegrubs by applying conventional insecticides owing to their poor efficacy, high cost and associated environmental pollution. Biological control is an important component of IPM which implies the utilization of ecologically safe and effective methods for the management of whitegrubs. Different entomopathogens such as *Metarhizium anisopliae*, *Beauveria bassiana* and *Heterorhabditis indica* are of

paramount importance in managing whitegrubs, as they sustain themselves in soil, after proper establishment and are commercially labeled for whitegrubs in India. In the present investigation, the field efficacy of entomopathogenic fungi, bacteria and nematodes for the control of *B. coriacea* grubs in potato was studied.

### MATERIAL AND METHODS

**Field evaluation of talc based formulations of different entomopathogens against whitegrubs in potato:** *M. anisopliae*, *B. bassiana* and *Bacillus cereus* formulated as dusts and *H. indica* as semi solid formulation were evaluated against grubs of *B. coriacea* in potato. The experiment was conducted in summer planted potatoes grown in whitegrub endemic area at PDS Kheradhar on variety Kufri Jyoti. All recommended package of practices were adopted except for whitegrub's management. There were seven treatments which were replicated thrice in RBD with plot size of 12 m<sup>2</sup> (Table 1). The formulations of *M. anisopliae*, *B. bassiana* and *H. indica* were obtained from NBAIR, Bangalore, and the dust formulation of *B. cereus* was supplied from Vivekananda Parvatiya Krishi Anusandhan Sansthan (VPKAS), Almora. Each formulated product was mixed thoroughly with FYM in plastic trough, and added into the furrows near the base of plants. After addition of FYM+ biopesticide mixture, it was gently mixed in the soil using hand hoe. All the treatments were applied at the time of earthing up in first week of July.

**Field evaluation of *Galleria mellonella* cadavers infected with *H. indica*:**

The cadavers of *G. mellonella* infected with *H. indica* were supplied by Foundation for Agricultural Resources Management and Environmental Remediation (FARMER), Ghaziabad, and was evaluated in summer planted potato cv. Kufri Jyoti was done in Shimla and Sirmaur districts of Himachal Pradesh. The plot size was 12 m<sup>2</sup> each consisting of five rows of 20 tubers each. Total 14 cadavers were used per plot, distributed uniformly in a plot as shown in Fig. 1. The treatment was imposed in row I, III and V near to plants 1,5, 10, 15 and 20 in rows I and V, whereas in row III, the cadavers were imposed near to plants 3, 8, 12 and 17. The cadaver to plant ratio was 1:7. To apply a cadaver, 3-4 cm deep hole was dug near to the base of plant and one cadaver/hole was gently placed and covered with soil. Total 15 continuous plots were inundated with cadavers of *G. melonella* infected with *H. indica*, and equal numbers of untreated plots were maintained as control for comparison.

**Data recording and statistical analysis:** The crop was harvested towards mid-October in both the experiments. At the time of harvesting, healthy and whitegrub infested tubers were separated and percentage of whitegrub infested tubers was calculated on number and weight basis. Data on number of grubs/ft<sup>3</sup> were recorded. The data were analyzed through RBD using CPCS software in experiment 1, whereas in second experiment, the data were compared using paired 't' test.

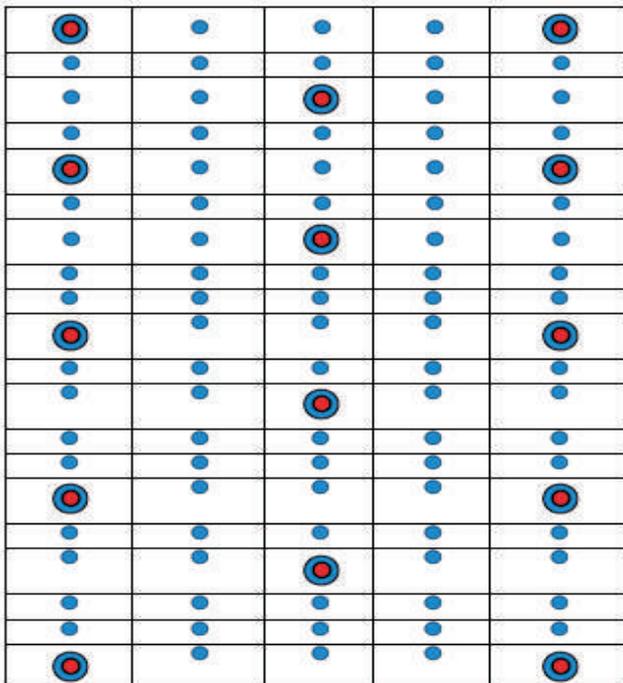


Fig. 1. Distribution of cadavers in a plot (● indicates the location of treated plants in a plot where *G. mellonella* cadavers were applied)

**RESULTS AND DISCUSSION**

**Field efficacy of talc based formulations of different entomopathogens against potato whitegrubs:**

At the time of harvesting in mid-October, the differences in treatments were significant (Table 1). When different entomopathogens were applied singly, *H. indica* @ 10 kg ha<sup>-1</sup> was found highly effective with tuber infestation ranging from 12.5 to 12.7 per cent. This was followed by *B. bassiana* @ 10 kg ha<sup>-1</sup> showing 14.5 and 15.0 per cent tuber infestation on weight and number basis, respectively. In *M. anisopliae* treated plots, 15.7 and 15.8 per cent tuber infestation was observed, respectively. Chandel et al (2005) evaluated *B. bassiana* (2 x 10<sup>9</sup> c.f.u./g) @ 0.42 g/ m<sup>2</sup> and *M. anisopliae* (5 x 10<sup>8</sup> conidia/g) @ 2.78 g/ m<sup>2</sup> in Shimla hills, and reported 25.70 and 21.75 per cent whitegrub damage in potato tubers. Chandel and Mehta (2005) didn't find satisfactory control of *B. coriacea* grubs in potato with the application of a Jaipur culture of *B. bassiana* and *M. anisopliae* @ 5 x 10<sup>13</sup> conidia/ha. *B. cereus* was found least effective having 15.3 to 16.2 per cent tuber damage. The tuber damage in *M. anisopliae* and *B. bassiana* treated plots was statistically at par with each other.

Mixed application of *H. indica* + *B. bassiana* or *M. anisopliae* showed comparatively better results suggesting additive or synergistic effect. The control was slightly better when *H. indica* was applied in combination with *B. bassiana* (11.4-11.8% tuber damage). In control plots, the corresponding tuber damage averaged 19.4 and 20.5 per cent. Tuber damage in *B. bassiana* and *H. indica* was statistically at par with *H. indica* + *B. bassiana* or *M. anisopliae*; however, *M. anisopliae* treatment showed significantly higher damage as compared to *H. indica* + *B. bassiana* or *M. anisopliae*. Maximum reduction in tuber damage (41.24 – 42.44 %) was observed in *H. indica* + *B. bassiana*, followed by 37.11 to 41.46 per cent in *H. indica* + *M. anisopliae* treatment. Wu et al (2014) have also observed additive or synergistic interactions between *Heterorhabditis megidis* and *B. bassiana* and between *H. bacteriophora* and *M. anisopliae* or *B. bassiana* against third instar grubs of *Cylocephalalurida* which corroborates our findings. In *H. indica* treated plots, 35.57 to 38.0 per cent reduction in tuber damage occurred (Table 1). *B. bassiana* revealed 25.26 and 26.83 per cent reduction in tuber damage. Low soil temperature around 20°C in Shimla hills appears to be responsible for the erratic performance of inundative application of fungi mixed in soil for the control of potato whitegrubs. The grub population was recorded per cubic feet of soil, and maximum grubs (4.7/ft<sup>3</sup>) were recorded in untreated fields. In *B. bassiana* and *B. cereus* 3.0 grubs/ft<sup>3</sup> were recorded, and in *M. anisopliae* treated plots 3.7 grubs/ft<sup>3</sup>

were observed in the soil. In *H. indica*, *H. indica* + *M. anisopliae* and *H. indica* + *B. bassiana* treatments, 2.0 to 2.3 grubs/ ft<sup>3</sup> were recorded. Reduction in grub population was higher in *H. indica* + *M. anisopliae* (57.45 %) and *H. indica* + *B. bassiana* treatments (55.32 %). In the current study, there was 36.17 per cent reduction in the population of grubs in *B. bassiana* and *B. cereus* treated plots, whereas in *M. anisopliae* treatment, 21.27 per cent reduction in grub population. According to Sharma et al (2009) *Steinernema carpocapsae* and *H. indica* were effective in checking tuber damage.

**Field efficacy of *H. indica* applied as infected cadavers of *G. mellonella* in potato:** During 2015, the tuber damage averaged 7.22 and 7.17 per cent on number and weight basis in treated plots as compared to 16.18 and 15.63 per cent in untreated plots. Similarly, during 2016, the tuber damage was recorded to be 9.95 and 9.85 per cent in treated plots against 19.56 and 19.22 per cent in control plots, respectively (Table 2). The calculated 't' values ranged from 11.21 to 15.76 per cent, and the data were highly significant (p=0.05). The grub population in treated plots was recorded to be 1.46 and 1.13 per cent during 2015 and 2016 as compared to 2.49 and 2.64 in untreated plots, and the differences were statistically significant. The reduction in tuber damage on number basis was 55.38 and 49.13, whereas on weight basis, 54.13 and 48.75 per cent tuber damage was observed in treated plots as compared to control plots (Fig. 2). The reduction in grub population was to the tune of 41.37 and 57.1 per cent during

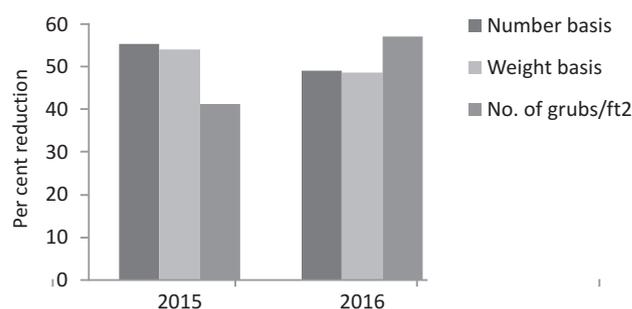


Fig. 2. Reduction in tuber damage in plots inoculated with *H. indica*

2015 and 2016, respectively. Lozano-Gutierrez and Espana-Luna (2008) investigated the virulence of two strains (BbZ3 and BbZ4) of *B. bassiana* by introducing infected cadavers of *G. mellonella* through the orifices on the stem pads of nopal plant. Both these strains caused 100 per cent mortality in the larvae of *Laniiferacyclades*.

The results clearly suggest that EPNs have greater potential to control infestation of whitegrubs as compared to entomopathogenic fungi and bacteria. The combination of *B. bassiana* + *H. indica* has proven to be more effective method for decimating whitegrub population. The technology involving direct use of *G. mellonella* cadavers infected with nematodes has shown better efficacy as compared to its powder formulation. When cadavers are used, the infective juveniles show greater activity dispersing uniformly in all directions to seek their host. Ganguly et al (2011) also

Table 1. Field efficacy of different bio control agents against whitegrubs

Treatments	Dose (kg ha <sup>-1</sup> )	Per cent tuber infestation		No. of grubs/feet <sup>3</sup>
		Wt. basis	No. basis	
<i>M. anisopliae</i> (1x10 <sup>9</sup> cfu/g)	10 kg ha <sup>-1</sup>	15.7 (23.57)	15.8 (22.93)	3.7 (21.27)
<i>B. bassiana</i> (1x10 <sup>9</sup> cfu/g)	10 kg ha <sup>-1</sup>	14.5 (25.26)	15.0 (26.83)	3.0 (36.17)
<i>B. cereus</i> (1x10 <sup>10</sup> spores/g)	10 kg ha <sup>-1</sup>	16.2 (19.75)	15.3 (25.37)	3.0 (36.17)
<i>H. indica</i> (1 lakh IJs/g)	10 kg ha <sup>-1</sup>	12.5 (35.57)	12.7 (38.05)	2.3 (51.06)
<i>H. indica</i> + <i>M. anisopliae</i>	50 % + 50 %	12.2 (37.11)	12.0 (41.46)	2.0 (57.45)
<i>H. indica</i> + <i>B. bassiana</i>	50 % + 50 %	11.4 (41.24)	11.8 ( 42.44)	2.1 (55.32)
Untreated check	-	19.4	20.5	4.7
CD (p=0.05)		3.29	4.06	

Figures in parentheses indicate per cent reduction over control

Table 2. Field evaluation of *H.indica* against potato white grubs in HP during 2015-16

Treatment	Per cent infestation of white grubs				Number of grubs/feet <sup>3</sup>	
	Number basis		Weight basis		2015	2016
	2015	2016	2015	2016		
Treated plots (n=15)	7.22	9.95	7.17	9.85	1.46	1.13
Untreated plots (n=15)	16.18	19.56	15.63	19.22	2.49	2.64
CD (p=0.05)	15.38*	15.76*	14.91*	11.21*	11.38*	9.83*

reported that entomopathogenic nematodes can recycle themselves in environment and they have a good host searching ability which make their application successful against various soil insect-pests. New nematode isolates having specificity to scarab larvae can give good control of *B. coriacea* grubs in potato in higher hills of north western Himalaya. The combination of nematodes and fungi may achieve an effect comparable or superior to insecticides for curative control of whitegrubs. The knowledge about ecology of entomopathogens can contribute to better understanding of the factors affecting survival and virulence of entomopathogens in soil.

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# Manuscripts Preserved at the Al-Hussein Holy Shrine: Isolation and Diagnosis of Fungi Causing Potential Damage

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**Abstract:** A total of 110 samples were collected, 60 samples of manuscripts preserved in the Al-Hussein Holy shrine, and 50 samples of the internal and external air of the fortified (the place where the manuscripts are kept). Fungal species were isolated and identified. The results showed dominance *Aspergillus* spp. on the other genus and ranked first in terms of occurrence, frequency and distribution density coefficient followed by *Penicillium* spp. in the second rank in terms of occurrence, frequency and distribution intensity, while the other genus *Mucor*, *Rhizopus*, Yeast and white mycelium recorded the lowest rank. The degradation of cellulose, protein, starch and fat because the activity of fungi on the manuscripts were detected for the purpose of identifying the effects of fungi and their damage to manuscripts. The fungi were isolated from the internal and external air of the fortified and showed the results of the fungus *Aspergillus* spp. with different types on the rest of the fungal species and dominated in terms of occurrence and frequency and density of distribution followed by Yeast second rank, while *Penicillium* spp. was the third and the remaining fungi *Mucor*, white mycelium and *Rhizopus* recorded the lowest rank. The existence of some fungal species on the manuscripts may be the main cause of damage, as well as there were similarity and relationship between fungi isolated from the manuscripts and fungi isolated from the internal and external air of the fortified, where the manuscripts kept in, which confirms the contamination and the need to address for the purpose of conservation and preservation of the legacy of civilization.

**Keywords:** Opportunistic fungi, Manuscripts fungi, Air fungi, Fungal enzymes

Manuscripts and books are of raw materials of organic origin (plant or animal) such as paper, skin, papyrus, cloth and sometimes wood. These materials have a characteristic hygroscopic nature that the internal water content changes with the changing ambient humidity. As the relative humidity increases in the surrounding environment, organic matter absorbs water, thus increasing the water content of the materials, making the manuscripts and books susceptible to decomposing fungi and also facilitating the adhesion of dust and other suspensions into the air. The dust and pendants found in the air have the role in the injury of manuscripts and the benefits of fungus because it carries the fungi that grow very quickly, especially if the availability of moisture and heat where the fungus plays the role of sovereignty in the destruction of manuscripts compared to bacteria and actinomycetes, because of its ability to withstand the wide range of temperatures and lack of moisture. It has been documented that fungi can grow down to 0°C (cold fungus) and can tolerate more than 60°C (thermophilic fungus), while the fungi grows well at a relative humidity of more than 60%, saprophytic fungi are characterized by introduction of fungi in many buildings used by humans (Youssef 2012). Because of lack of studies on the fungus of manuscripts, this study is targeted to isolate and diagnose the fungus associated with

the manuscripts and causes the damage, and study the effectiveness of enzymatic analysis of the components of the manuscripts, as well as study the relationship of fungi associated with the internal and external air surrounding them in places saved.

## MATERIAL AND METHODS

### Agricultural media were used

**Sabouraud's dextrose agar medium:** This medium, as reported in Kwon-Chung and Bennett (1992), melted 65 g of Sabouraud's dextrose agar powder with liter of distilled water and pH was adjusted at 6.5.

**Czapex agar (CA):** It was given by Ramirz (1982), which included the following composition: 1 g K<sub>2</sub>HPO<sub>4</sub>, 0.5 g KCl, 2 g NaNO<sub>3</sub>, 0.5 g MgSO<sub>4</sub>·7H<sub>2</sub>O, 0.05 g FeSO<sub>4</sub>·7H<sub>2</sub>O, 20 g Sucrose, 18 g Agar then added to a liter of distilled water

**Potato dextrose agar (PDA):** Prepare the PDA by Collee and his group (1996) by pouring 39 g of medium powder per litre of distilled water.

**Cellulose agar medium:** Baath and Sodarstrow (1980) method which included the following materials: 2 g NaNO<sub>3</sub>, 1 g NH<sub>4</sub>(2SO<sub>4</sub>), 1 g KH<sub>2</sub>PO<sub>4</sub>, 0.5 g MgSO<sub>4</sub>·7H<sub>2</sub>O, 0.5 g KCl, 0.05 CaCl<sub>2</sub>, 0.01 g FeSO<sub>4</sub>·7H<sub>2</sub>O, 0.01 g CaSO<sub>4</sub>·5H<sub>2</sub>O, 0.005 g MnSO<sub>4</sub>·4H<sub>2</sub>O, 0.001 g ZnSO<sub>4</sub>·7H<sub>2</sub>O, 15 g Agar. Dissolved in

a litre of distilled water and added to the 5 g of pure cellulosic acid 85% (Tansey 1971). The medium was used to detect the susceptibility of fungi to the production of cellulose enzyme.

**Milk skimmed medium:** Five grams of skimmed milk was poured in the 50 ml distilled water. Dissolved 10 g of sugar in 450 ml distilled water in another flask. Equilibrate the pH to 7. Sterilize the two solutions separately and then cool to 45°C. Then mixed together (Aaronson 1973). This medium was used to detect the susceptibility of fungi to protease production.

**Starch agar medium:** A fifteen gram of starch, 1 g  $K_2HPO_4$ , 0.5 g of  $MgSO_4 \cdot 7H_2O$  and 15 g of sugar in a litre of distilled water (Sarhan 2012) modified (delete the yeast extract).

**Tween 80 agar medium:** This medium was prepared from the following ingredients, 10 g peptone, 5 g NaCl and 0.1 g  $CaCl_2$ , per litre of distilled water, 5 ml of Tween 80 was added and the pH was adjusted at 6.8. This medium was used to investigate the susceptibility of fungi and yeasts to production of lipase enzymes (Slifkin 2000).

To all of the above mentioned Media, 250 mg/L of Chloramphenicol antibiotic was added before sterilization, and then sterilized by autoclave at 121°C under 1.5 pressure for 20 min. After cooling, the sterile medium was poured into plastic Petri dishes.

**Collection of samples:** The study included the collection of 110 samples; 60 samples of manuscripts and 50 samples of the internal and external air of the fortified (25 samples each). The samples were taken from the manuscripts by smear and planted on special media, and then transferred to the laboratory. Samples were also taken from the inner and outer air of the fortified, using an open dish technique to isolate air fungus.

**Manuscripts at the center for the maintenance and restoration of manuscripts of the Al-Hussein holy shrine:** Some of the fungi were isolated from ancient manuscripts and preserved in the centre for the maintenance and restoration of manuscripts, taking isolates by sterile cotton swabs from three locations of the manuscript, represented by the beginning, middle and end of the manuscript. The inoculations were planted in Sabouraud's Dextrose Agar medium (SDA). Direct isolation was done in the Streaking method. They were placed in the incubator for growth at 28°C and for 5–7 days. The dishes were examined first for the purpose of counting the growing colonies on the growing media. The fungal species were purified onto the SDA and incubated at 28°C for 5–7 days to obtain pure colonies. The fungus was also re-grown on Czapek Dox Agar and Potato Dextrose Agar medium. The fungi were identified according to their morphological and colony colours. The following sources were used in diagnosis (Ellis 1971, Barnett

and Barry 1972, Pitt and Hocking 1997, Moubasher et al 1982).

The total number of isolates and fungal species isolated from each manuscript and percentage of occurrence calculated from the following equation:

$$\text{Occurrence\%} = \frac{\text{Number of specimens that appeared genus or species}}{\text{The total number of samples during the study}} \times 100$$

The percentage of frequency calculated from the following equation:

$$\text{Frequency\%} = \frac{\text{Number of single isolates}}{\text{Total number of isolates}} \times 100$$

Distribution Intensity Index (DII) according to the distribution density coefficient of all fungi isolated from the following equation Booth et al 1988:

$$\text{DII} = \% \text{ occurrence} \times \sqrt{\% \text{ Frequency}}$$

**Detection of analyzing fungi:** In order to investigate the activity of fungi and at their damage to the manuscripts, fungi were studied. Analyzing enzymes of cellulose, protein, starch and lipids were examined. Each experiment included two replicates for each fungal species and each enzyme type in addition to the control (without inoculation). The center of selective media was inoculated with 6 mm tablet of pure fungus that have been developed on PDA medium, three days age, at 28°C for 72 hours.

**Cellulose:** Use the medium agar-cellulose media. Cellulose decomposition was detected by using the HCl-Iodine reagent. Add the detector to the dish and leave for 5 minutes, then pour the solution and leave the dish for 10 minutes. The appearance of a translucent circle around the fungal colonies showed that cellulose was transformed into simple sugars by the enzyme cellulase. The diameter of the circle, means the higher activity of the fungus in the production of the enzyme (Yeoh et al 1985).

**Protein:** Use the medium Skimmed milk-agar media. Protein breakdown (casein in milk) was detected when a translucent circle appeared around the colonies. The higher diameter of circle means higher activity of the fungus in the production of the enzyme (Aaronson 1973).

**Starch:** Use the medium starch agar. Detection of starch decomposition using reagent. Add the detector to the dish and left for 5 minutes and then poured the solution and left the dishes for 5 minutes. The appearance of a transparent circle around the fungal colonies indicates the production of the enzyme amylase and the greater the diameter of the circle

whenever evidence of fungal activity in the production of the enzyme (Pandey et al 2006).

**Lipase enzyme:** Use the medium Tween 80-supported peptide. The results were recorded by observation of white sediments around the colonies or by the appearance of a transparent circle around the colony of fungi (Narasimhan and Valentin 2015).

**Isolation of fungi from the air:** The air samples were collected from inside and outside the fortified, where the 50 samples of air were stored, 25 samples of the inside of the fortified and 25 samples of the outside of the fortified by exposing the SDA into the air for three minutes. Closed the dishes tightly and transferred to the laboratory. Incubator at 28°C for a period of 3-5 days and then previewed the colonies and calculate them. The method of work was completed as mentioned in the isolating fungi from the above manuscripts.

## RESULTS AND DISCUSSION

Isolation and diagnosis of fungi isolated from manuscripts. Ten species of fungus belonging to six genera were isolated from three sites of the manuscript representing the beginning, middle and end of the manuscript, as well as the isolation of the sterile white fungus (Table 1). *Aspergillus* was 76.7%, followed by *Penicillium*, *Mucor*, and *Rhizopus*. The *Aspergillus* spp. recorded the highest percentage of appearance of the five types and *A. niger*, accounted for 80% followed by a *A. flavus* with 70%, followed by *A. fumigatus* with 61%. The highest per cent frequency value was for *A. niger* (19.97) followed by *A. flavus* (17.62), *A. fumigates* and *A. terreus* 13.45, *A. versicolor* (10.26), *Penicillium* (8.74), *Mucor* (5.13) and *Rhizopuse* (4.44), while the lowest frequency was of Yeast and White sterile mycelium (2.77 and 2.22%, respectively). Species *A. fumigatus*, *A. terreus*, *A. flavus*, *niger*, *A.*, *Penicillium* spp., *A. versicolor* were the most intense in distribution, while the less dense species were *Mucor*, *Rhizopuse*, and Yeast, as well as sterile white mycelium (Table 2). The current study showed that *Aspergillus* spp., which was the most visible and recombinant, and the distribution density coefficient are 80%, 70%, 61%, 53% and 41% for *A. niger*, *A. flavus*, *A. fumigatus*, *A. terreus* and *A. versicolor*, respectively.

The reason for *Aspergillus* spp. occurs in all samples is to suit the different environmental conditions for its growth and reproduction. The fungus also has the ability to form large numbers of asexual reproduction in addition of sexual and sclerotia are more resistant to adverse environmental conditions and most species have high enzymatic ability to use different organic matter and protein as food sources. As well as growth in broad ranges of heat and humidity.

**Table 1.** Number of isolates and fungal species isolated from the three sites of the manuscript during the study period

isolates of fungal	Manuscripts			Number of species
	Beginning	Center	End	
<i>A. niger</i>	48	54	42	144
<i>A. flavus</i>	42	48	37	127
<i>A. fumigatus</i>	36	43	32	111
<i>A. terreus</i>	31	38	28	97
<i>A. versicolor</i>	23	30	21	74
<i>Penicillium</i>	20	25	18	63
<i>Mucor</i>	15	10	12	37
<i>Rhizopus</i>	12	10	10	32
Yeast	8	7	5	20
White sterile mycelium	6	5	5	16
Total	241	270	210	721

**Table 2.** Percentage of total occurrence, percentage of frequency and distribution density coefficient of fungi isolated from manuscripts

isolates of fungal	Percentage of occurrence	Percentage of frequency	Distribution intensity coefficient
<i>A. niger</i>	%80	19.97	357.5
<i>A. flavus</i>	%70	17.62	293.8
<i>A. fumigatus</i>	61 %	15.40	239.4
<i>A. terreus</i>	%53	13.45	194.4
<i>A. versicolor</i>	%41	10.26	131.3
<i>Penicillium</i>	%35	8.74	103.5
<i>Mucor</i>	%20	5.13	45.3
<i>Rhizopuse</i>	%17	4.44	35.8
Yeast	%11	2.77	18.3

*Aspergillus* species are characterized by growing in temperatures ranging from 45-5°C or higher. These fungi also have the ability to grow at low moisture levels and with moisture content ranging between 18-15% (Rustum 1997). Some species also have the ability to compete and inhibit the growth of other species by producing effective bioactive toxins such as Aflatoxin. The second rank of fungus is listed after *Aspergillus* spp. is *Penicillium* spp. (35%), and it is present in all places and is an opportunistic fungi and has the potential to grow on many materials under different conditions (Pitt and Hocking 1997).

The *Aspergillus* species were the densest in the manuscript samples followed by *Penicillium*. These fungi have special life strategies that enable them to tolerate environmental conditions, making them more viable than other genus and species. The rest of the fungal species

appeared in one or two species and differed in their appearance and frequency between the beginning, center and end of the manuscript, as well as differences in appearance and frequency of the site during the study months. This may be due to variations in environmental conditions of temperature, humidity, etc. or the nature of the manuscript and its components.

**Detection of Fungi Analyzed**

**Cellulose:** The five fungal isolates of *Aspergillus* spp. had the ability to produce cellulose degradation enzyme at different efficiencies (Table 3). *A. versicolor* and *A. terreus* were very effective, with a transparent halo diameter greater than 15 mm, and *A. fumigatus*, *A. flavus* were moderately effective, with a transparent halo diameter of 10–15 mm (Fig. 1).

The rest of the fungal species tested were not effective. This result is consistent with the fact that most of the true fungi have the ability to analyze natural cellulose for the purpose of growth and durability of life through the production of cellulose degradation enzymes. In nature, fungi are effective in the analysis of crystalline cellulose, mainly *Trichoderma viride*, *T. lignorum*, *T. koningii*, *penicillium verrucosum*, *P. funiculosum*, *Chrysosporium lignorum*, and *Chaetomium*. Sharif (2012) reported that many fungi possess cellulose degradation enzymes, which can attack cellulose industrial products such as paper, cardboard, cotton products, and wood products. Differences were also observed between isolates of the genus *Aspergillus* spp. from weak to good. The weakness of some isolates can be explained by the secretion of cellulose for several reasons, including insufficient incubation duration to stimulate secretion and difference in the ability to exploit the plant medium or the inappropriate pH of these isolates (Abdel-Hadi 2011, Luiza 2000). The results of the study suggest that the presence of these fungi on the manuscripts may be due to their ability to secrete the cellulose enzyme on the tissue paper, which is the fiber of cellulose, its constituent component.

**Protein:** *A. flavus*, *A. fumigatus*, *Penicillium* spp. were highly

effective, where the diameter of the transparent halo was greater than 15 mm (Table 4, Fig. 2).

*A. niger* was the medium effective, the diameter of the transparent halo was between 10–15 mm. The results were similar to those of Al-Amiri (2013), where the fungi *A. niger*, *A. flavus*, *A. terreus*, and other fungi were not able to produce protease. Protease enzymes have been widely produced in the industry using *Aspergillus* spp. and bacteria such as some species of *Bacillus*. Valentin (2003) confirmed that fungi attacked skins because leather is an organic substance that contains fats, carbohydrates and proteins in their composition, this confirms our results caused by the presence of fungi on the covers of manuscripts. This is due to the use of leather in the packaging of printed books and the manuscript and the chemical composition of the skin is the same as the installation of paper and parchment, as the parchment and parchment protein materials extracted from the skin and the majority of fungi specialized in the analysis of skins and parchment attributed to the genotypes *Penicillium*, *Aspergillus*, *Alternaria* and *Helminthosporium*. These races play a role in the analysis of cellulosic materials.

**Starch:** *A. fumigatus*, *Penicillium* spp. were highly effective where the diameter of the transparent halo was greater than 15 mm (Table 5, Figure 3), while *A. niger*, *A. flavus* and *Mucor* was less effective, the diameter of the transparent halo was lower than 10 mm either the rest of the fungal species were not analyzed, and this confirms that the presence of these fungi on the manuscripts may be due to the presence of starch, which is a material included in the installation of manuscripts, leaflets, lattice, and the heels of manuscript books. This may also be used in various restoration processes inside the manuscript, as the starch is a complex compound of glucose there are some fungus specializing in the analysis and feeding on its components through the secretion of secretory enzymes.

**Fat:** The results of the lysis test for the fungus isolates isolated from the manuscripts were found in the center of the lipase (Table 6). The test results showed that most fungal isolate species have the ability to secrete the lipase enzyme.

**Table 3.** Degradation of cellulose by fungus on the cellulose agar at 28° C and for a period of 3 days incubation

isolates of fungal	Diameter of analysis zone (mm)	Cellulose activity
<i>A. niger</i>	>15	+++
<i>A. terreus</i>	>15	+++
<i>A. versicolor</i>	>15	+++
<i>A. flavus</i>	15 – 10	++
<i>A. fumigatus</i>	15 – 10	++

+++ Highly effective, ++ Medium effective

**Table 4.** Protein degradation by fungus on skimmed milk at 28° C and for a period of 3 days

Isolates of fungal	Diameter of analysis zone (mm)	Effectiveness of casein degradation
<i>Penicillium</i>	>15	+++
<i>A. fumigatus</i>	>15	+++
<i>A. terreus</i>	>15	+++
<i>A. flavus</i>	>15	+++
<i>A. niger</i>	10-15	++

+++ Highly effective, ++ Medium effective



**Table 5.** Starch degradation by fungus on starch at 28° C for 3 days incubation

isolates of fungal	Diameter of analysis zone (mm)	Effectiveness of starch degradation
<i>Penicillium</i>	>15	+++
<i>A.fumigatus</i>	>15	+++
<i>A.terreus</i>	>15	+++
<i>A.niger</i>	10>	+
<i>A. flavus</i>	10>	+
<i>Mucor</i>	10>	+

+++ Highly effective, + week effective

*A. flavus*, *A. fumigatus*, *A. niger*, *A. versicolor*, *A. terreus*, *Mucor* spp., *Rhizopus* spp., and White sterile mycelium. Sumathy and his group (2012) reported that *Aspergillus*, *Fusarium*, *Geotrichum* and *Penicillium* had the ability to produce Lipase enzyme. The results were in accordance with that found by Bramono and his co-workers (2006) studying the susceptibility of some fungi to the secretion of lipase. The rest of the fungal species, i.e. *Penicillium* and Yeast which they had not any activity of analyzing (Fig. 4).

**Isolation and diagnosis of fungi isolated from the air inside and outside the fortified:** The results showed that there are differences in the occurrence of fungal species during the study at different locations (Table 6). Concerning the air inside the fortified, *Aspergillus* spp. were dominant. The percentages of occurrence were *A. flavus* (92) followed by *A. niger* (84), *A. fumigatus* (80), *A. nidulans* (40), As for the other sites, an air outside the fortified the results showed, the highest recorded percentage of occurrence was of *A. flavus* (100), followed by *A. fumigatus*, (88), *A. niger* (72) and *A. nidulans* (60) (Table 6). Six of isolates and fungal species isolated from the sites inside and outside the fortified during the study period. The results of the fungal percentage of frequency showed a clear variance for both sites (Table 7). The frequency of fungal species of the internal air of the fortified, the highest value of the frequency was *Aspergillus* spp. followed by Yeast. *A. flavus* recorded the highest frequency of 19.33 percent followed by *A. niger*, *A. fumigatus*, *A. nidulans*, *A. oryzae*, Yeast and *Penicillium*, while the *Mucor* and *Rhizopus* were 3.36 and 2.53 per cent, respectively. Concerning outside the fortified *Aspergillus* spp. the highest percent frequency was *A. flavus*, (17.36) followed by *A. fumigatus*, *A. niger* *A. nidulans* and by *A. oryzae*. Yeast ranked second with a frequency of 12.5, followed by *Penicillium* with a frequency of 9.72. The fungi of white mycelium, *Mucor* and *Rhizopus* were the last and lowest frequencies giving 6.25, 4.17 and 3.47 per cent, respectively. The results of the determination of the density

**Table 6.** Number of isolates and fungal species isolated from the sites inside and outside the fortified during the period of study

Number of total isolates external and internal air fungal species	Indoor air	Outdoor air	Total isolates
<i>A. flavus</i>	23	25	48
<i>A. niger</i>	21	22	43
<i>A. fumigatus</i>	20	18	38
<i>A. nidulans</i>	10	15	25
<i>A. oryzae</i>	7	12	19
<i>Penicillium</i>	11	14	25
Yeast	13	18	31
White sterile mycelium	7	9	16
<i>Mucor</i>	4	6	10
<i>Rhizopus</i>	3	5	8
Total	119	144	263

coefficient of the isolated fungi from the air and both the inside and outside of the fortification showed that there is a difference between the distribution density coefficient (Table 7). The results of the site within the fortification showed that *A. fumigatus*, *A. flavus*, *A. niger*, *Penicillium* spp, *A. nidulans*, Yeast were the most intense in distribution, while the less dense species were *Mucor*, *A. oryzae*, *Rhizopus*, and white sterile mycelium. The results of the outside the fortified species showed that *A. fumigatus*, *flavus*. *A. niger*, *Penicillium* spp, *A. nidulans*, Yeast and *A.oryzae* were the most densely distributed while the less intense species were *Mucor*, *Rhizopus*, and white sterial mycelium. The *Aspergillus* spp. in air samples, ranked first in terms of occurrence, frequency and distribution intensity coefficient for both sites inside and outside the fortified, and this result is similar to what were mentioned by Mohammad and Mohammed (2007) on the dominance of *Aspergillus* spp. in the air. The reason is that this fungus is an aerobic fungus. The speed of the wind has led to the transmission of this fungus from the areas of its propagation and propagation by means of plant and soil residues and carried into the buildings (Latge 1999). The fungus also has the ability to form large numbers of asexual breeding units, some of which are sexually active and sclerotia that are more resistant to adverse environmental conditions. Most of these species have high enzymatic potential to help them use various organic substances and protein as food sources .These reasons made *Aspergillus* spp. this superiority is similar to that having of Menezes et al (2004). In the same fungus role in the air, the number of isolates of *A. fumigatus* was observed in the outer air than in the internal air, while the increase of *A. niger* isolates was observed in the indoor air

**Table 7.** Percentage of total appearance, percentage of frequency and distribution density coefficient of fungi isolated from indoor and outdoor air the fortified

Fungal isolates	Percentage of total occurrence		Percentage of frequency		Distribution density coefficient of fungi isolated	
	Outdoor air	Indoor air	Outdoor air	Indoor air	Outdoor air	Indoor air
<i>A.flavus</i>	100	92	17.36	19.33	416.7	404.5
<i>A.fumigatus</i>	88	80	15.28	16.81	343.1	328.0
<i>A.niger</i>	72	84	12.5	17.65	254.6	352.9
Yeast	72	52	12.5	10.92	254.6	171.8
<i>A.nidulanse</i>	60	40	10.42	9.24	193.7	115.9
<i>Penicillium</i>	56	44	9.72	8.40	174.6	133.7
<i>A.oryzae</i>	48	28	8.33	5.88	138.5	67.9
White sterile mycelium	36	28	6.25	5.88	90.0	67.9
<i>Mucor</i>	24	16	4.17	3.36	49.0	29.3
<i>Rhizopus</i>	20	12	3.47	2.53	37.3	19.1

than in the outside air. This may be due to the possibility of various fungal species each other as appropriate conditions (Mohammad and Mohammed 2007).

The species *A.flavus*, *A. fumigatus*, and *A. niger* had the highest rate of occurrence compared to other fungi, as well as the highest frequency ratio and the most distributed factor between the internal and external air of the fortified. This result is in consistent with several studies of air inside and outside buildings (Shelton et al 2002, Macura and Gniadek 2000). The Yeast was the second rank beyond the *Aspergillus* spp. both in terms of percentage of occurrence, frequency, and distribution density coefficient. Su et al (2001) reported that yeasts fall within the dominant group of indoor air samples. Ismail et al (1999) noted that yeast is predominant in air samples inside and outside buildings. *Penicillium* spp. was ranked as the third common source of occurrence, frequency and distribution density. The reason for this widespread is its ability to produce large numbers of breeding units that are unsuitable for adverse environmental conditions (Faris et al 2010). Semenov et al (2003) shows that *Penicillium* is present in the air and in the internal dust of homes and buildings and is supported by Faris et al (2010). The air fungus recorded in the study is mostly due to the saprophytic and this sovereignty has already been recorded in the Al-Bader (1995) study of external air fungus in the city of Basra as shown in Al-Ani and Al-Hamdani 2000. Many studies around the world have shown that saprophytic fungi predominate in the air fungal community (Abdulrahman et al 1999, Valeria and Airaudi 2001). This is due to the nature of the fungus feeding, its presence in the soil, on plant surfaces and animal skins, and mostly for large, open, dry, easy to volatilize units and spread as dominant plankton in the microbial community.

There are no global or local standards to assess atmospheric pollution in indoor or outdoor air. However, most studies on air pollution tend to compare the innate content of the air inside the buildings with the outside air. If there are indoor types not found in the outside air, this may give an indication that the source of contamination was inside the building rather than outside air (Kuske et al 2005).

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## Present Status and Future Prospects of Fisheries In Manipur

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**Abstract:** Manipur State shares a part of the Indo-Burma biodiversity hotspots and harbours more than 280 fish species. The State is home to the largest freshwater lake of the North east India and the only "Floating National Park" in the world. Fisheries play a very important role in the socio-economic sector of the State. There are around 56,461 ha of water bodies suitable for fish culture. However, only around 32.9% has been used and developed for fish production. The current fish production of the State is 30,500 mt against requirements of 40,000 mt. If the resources are prudently utilised, the State has potential not only to attain self-sufficiency in fish production but can also supply surplus to the neighbouring states. New and better technologies along with better plan and policy would help to enhance the production. Understanding the various problems and issues faced by the farmers/fishers and improvising strategies to address them will contribute to augment production and productivity. Analysing the present status and the potentiality, the future prospects of fisheries in the State have been projected along with strategies to improvement and development.

**Keywords:** Biodiversity hotspots, Fish, Indigenous flora and fauna, Loktak lake

Manipur state is nestled in the eastern-most corner of Northeast India covering a total area of 22,347 sq km. The state lies at latitude 23° 83'N – 25° 68'N and longitude 93° 03'E – 94° 78'E, bounded by Nagaland to the north, Mizoram to the south, Assam to the west, and Burma to the east and a part of south (Eshuo and Chaturvedi 2011). The oval shaped valley (Imphal) occupies the heart of the state surrounded by green verdant hills all around. The hilly region inhabited by tribal community covers about 90 percent of the total land area of the state with 41 percent of the total population living in it. The state has a population of 2,721,756 with male-female ratio of 987:1000 and the literacy rate is 79.85 per cent as per 2011 census, Government of India. With suitable climate and soil condition for crop farming, agriculture forms the back bone of state's economy contributing 50-60% to the state GDP and engaging about 80% of the state total populations. The climatic condition is widely influenced by the topography of the hilly regions and hence ranged from tropical to sub-alpine with an average annual rainfall of 1467mm. Around 80% of the total state populations are non-vegetarian and the food items includes chicken, fish, beefs, muttons, pork etc. with pork and fish as the most preferred. Fish is however, the only animal protein sources widely accepted and consumed by almost all the

people including the vegetarian sect of the people.

**Water resources:** Manipur has diversified water bodies with 56,461.05 ha suitable for fish farming of which only 18,600ha or 32.94% of the total potential water areas are so far developed and used for fishery purposes. If these resources are judiciously explored and utilized, the state has potential to produce around 53,000-64,000 metric tons of fish per annum as reported by Khongbantabam (2015). With Barak River as the biggest river basin, the State has more than 15 meandering rivers covering a length of 2,000 km (Gurumayum et al 2006, Devi & Singh 2015). Each of the river systems has characteristic ecological conditions and diverse fish population. The water logged marshy and swampy areas, canals, bheels and wetlands of the state covered around 22,632.73ha while ponds and tanks around 5,000 ha (Economic Survey of Manipur, 2008-09). The state is also home to the largest fresh water lake of the North east India, the Loktak Lake covering an area of 24,672 ha. It is the most important inland water resources of the state with floating mat vegetation (locally called *phum*). Fishing and other fishery activities carried out in and around the lakes accounts for about 50% of the total fish production of the state. The state has around 153 floodplain wetlands (locally called *pats*) accounting for 28.34% of the total

valley area (Gurumayum et al 2006). The Loktak lake and the pats supports a huge fisher folk's livelihood. Being an agrarian state, Manipur has huge area covered by paddy fields especially in the hill districts. Keeping fish along with the paddy has been in practice since ages ago. Though there is no systematic method followed, integration of fish-cum-paddy with fish as the secondary crop has been considered as one of the best alternatives for ensuring the diversity of food basket without compromising on the sociological and environmental functions of the fields.

**Fishery resources:** Manipur shares a part of the Indo-Burma biodiversity hotspot and is immensely endowed with diverse biological resources. The state fish faunal diversity has been seen to be influenced by the Burmese fish faunal which has been clearly highlighted by the presence of many indigenous fish species in Manipur and Myanmar (Burma) water but not found in any parts of India. The number of fish species found in Manipur was reported to be 125 in 2005 (Suresh et al 2005). However, in 2012, which is around 7 years from the previous report, Goswami et al (2012) listed 281 species. *Osteobrama belangeri* (pengba) which is also the State fish of Manipur was found abundantly in the water bodies of Manipur especially in the Loktak lake and Nambul river. However, with the construction of Ithai barrage across Manipur river for the operation of Loktak hydro-electric project, the fish population was reported drastic reduction in the wild. Various authors had documented the economic importance, conservation and availability status of fish in the State in details (CAMP 1998, Viswanath et al 1998, Sarkar & Ponniah 2000, Munilkumar & Nandeesh 2007, Khomdram et al 2014). Some of the important indigenous fish species found in Manipur are *Aspidoparia ukhrulensis*, *Barilius lairokensis*, *Chela khujairokensis*, *Garra abhoyai*, *Sisor barakensis*, *Glyptothorax manipurensis*, *Glyptothorax senapatiensis*, *Botia berdmorei*, *Pseudecheneis ukhrulensis*, *Schistura fasciata*, *S. manipurensis*, *S. kangjupkhulensis*, *S. prashadi*, *S. sikmaiensis*, *S. tigrinum*, *S. reticulata*, *S. khugae* and *S. minutus* etc. Most of these species are identified recently and are also used for ornamental purposes.

**Aquatic plant resources:** The water bodies of Manipur are diverse and harbour various aquatic grasses comprising of *Eichornia crassipes*, *Phragmites karka*, *Oryza sativa*, *Zizania latifolia*, *Cynodon spp.*, *Limnophila spp.*, *Sagittaria spp.*, *Saccharum latifolium*, *Erianthus pucerus*, *Erianthus ravennae*, *Lersi hexandra*, *Carex*

*spp.*; *Phragmites karka*, *Nelumbo nucifera*, *Trapa natans*, *Euryale ferox*, *Nymphaea alba*, *N. nouchali*, *N. Stellata*, *Nymphoides indica* etc. Hence, grass carp and common carp are the mainstay carp species in the extensive aquaculture systems. The fox-fruit *Euryale ferox* (locally called thangjing), which is a delicacy in the state is widely culture by many farmers in homestead ponds. Most of the aquatic plants are highly marketable for their flowers, roots, rhizome and stems, fruits and seeds for various purposes including medicinal use.

**Ornamental fisheries resources:** Manipur shares the Indo-Burma global diversity hotspot with remarkable endemism in the freshwater fish diversity. Khomdram et al (2014) documented 139 ornamental fishes found in Manipur while Goswami et al (2012) listed 185 species (including exotics) wherein 45 are consumed as food fish too. The Loktak lake and various rivers especially the Barak river, Iril river and Chakpi river harbors varying fish species having ornamental values. Biswas et al (2015) also reported that many hill stream fishes have aesthetic appearance and served as good aquarium species due to their varying coloration and bizarre shape. Some of the highly prized ornamental fish species found in Manipur are Khabak (*Bangna devdevi*), Belun Paibi (*Devario acuticephalus*), Ching ngakra (*Pterocryptis barakensis*), Ngakha meingangbi (*Puntius manipurensis*), Ngatup (*Schistura kangjupkhulensis*), Sarengkhoibi (*botia berdmorei*), Ngarang (*Devario aequipinnatus*), Ngapemma (*Trichogaster labiosa*), Phabounga (*Puntius chola*), Ngakijou (*Lepidocephalichthys berdmori*) etc.

**Role of fisheries in the socio-economic sector:** Fisheries has been playing an integral role in the Manipuri society as fish forms a part and parcel of every Manipuri dish served on the table. Fish has thus, been termed to be the most widely accepted food items in the state. It is consumed by almost all people irrespective of age, culture, religion and food habits including the vegetarian sect of people. Fishes of all sizes and varieties are found in the market in the form of live and fresh, frozen, dried, smoked, canned and fermented and consumed as curry, boiled, fried or chutney. Fish plays a major role in many customary and religious rituals of the Manipuris such as traditional use of fresh Nganap (*Acanthopthalmus pangia*) and Catfish (*Wallago attu* and *Clarias batrachus*) in the marriage rituals, Ngamu (*Channa orientalis*) in healing rites (Ushilshinba), Ngamu and Phabounga (*Puntius spp.*) in rituals conducted for newly borne child (Epaan thaba) etc (Gurumayum et al 2006). Being one of

the most commonly accepted food items, fish is generally used to serve in most of the common feast. The pool barb (*Puntius sophore*) has been widely consumed by the Manipuris in fermented form (locally called Ngari). Due to its flavor and the nutritive value, Ngari has become an irreplaceable and inseparable ingredient of almost all Manipuri dishes such as Kangsoi, Iromba, Ametpa, Singju etc. As the state fish production could not meet the consumer demand, Manipur imports various forms of fish (frozen, dried, smoked, canned) from other states like Assam, West Bengal, Andhra Pradesh etc. Canned or tinned fish widely consumed in the state are imported from Myanmar. The price of fish and fishery products in the state are thus very high. Carps fetches around Rs. 150–250 per kilogram while the fresh live locally produced catfish could reach Rs. 800–1000/kg, Ngaton (*Ompok* spp.) and Pengba (*Osteobrama belangeri*) of Rs. 600–650/kg. A kilogram of dried Ngaprum (eels) could be as high as Rs. 1000–1200 or dried prawns of Rs. 400–500/kg. The best quality grade of ngari (fermented fish) could fetch around Rs. 500–600/kg.

Unlike many other states of India, women in Manipur enjoy equal status and participation in almost all aspects of life with no social stigmas or social taboos against women. The Women Piscicultural Organization Plan scheme called 'Nupi Ngayok Marup' which was launched during 1980s to popularize fish farming among the women in the state remains the backbone of women in fisheries today. There are around 696 numbers of Nupi Ngayok Marup with 7–10 members under each cooperative society (Khangabam & Singh 2002, Gurumayum et al 2006). Manipur State has been rated to have the highest women participation in India in fishery activities which includes fishing, aquaculture and related activities, harvesting, processing and value addition upto marketing (Gurumayum et al 2006). Marketing of fish of various forms are mostly done by the womenfolk's in the State (Devi & Singh 2015).

**Fishery activities** : Fish culture in Manipur was believed to have started since paddy culture began as '*fish-cum paddy culture*' in the paddy field traditionally with the fish as the secondary crop. With the increase of the demand of fish for food, slowly fish culture in separate ponds began and later improves with better culture practices and technologies. Fish farming practices in the state is more or less pond-based with several species stocked in the same pond (polyculture) or integrated with agro/animal husbandry taking advantage of the rich aquatic

microorganism and the aquatic floras of the water. Monoculture practices are rarely seen or reported. Aquaculture methods in the state are mostly traditional especially in the hilly regions though few semi intensive and intensive systems are being taken up in the valleys. Integration of fish with horticulture, agricultural crops and livestock has been a traditional practice in Manipur over centuries. Pen and cage culture has been taken up in the large water bodies such as Loktak lake, Thoubal Dam and Khoupum Dam Reservoir. Indian major carps (catla, rohu, mrigal), exotic carps (common carp, grass carp, silver carp), catfishes (magur, pangasius, singhi) and other species such as big head carp, tilapia, mola, pengba, eels, snakeheads, perches etc are cultured in the state. The State has 19 fish seed hatchery which are producing fish seed for IMC, grass carp, pabda and pengba. Grass Carp and Common Carp remain the most preferred cultured species. The present estimated per hectare production is 700–1800 kg/ha/yr. Most of the small fish farms followed single cropping system. The larger farms adopt double harvesting system or continuous harvesting system based on demand and requirements. There are 123 fishing villages in the state with 34,064 fishermen, out of which 8,395 are full time fishers (Khangabam and Kohli 2002). The fisherman or the fishers of the state are mostly concentrated in and around the Loktak Lake in Moirang. Around 55 rural and urban hamlets encircled the water bodies and the lake, thus has a population of about 1,00,000 people harboring the majority of the state total fishermen in and around it.

**Market and marketing of fish and fishery products:**

Marketing of fish is one of the biggest business in the state because the state consumes a huge amount of fish. A large section of Ema Keithel (Women Market) is meant for selling various forms and types of fishes. Kwakeithel is one of the main markets for exclusive cured fish products (fermented, smoked and dried fish). Other important fish markets are Moirang Bazaar, Bishnupur Bazaar, Porompat, Lamphelpat super market, Senapati Bazaar, Sinjamei Bazaar, Nagamapal etc. Fish are sold in almost all general markets including the roadside mini stalls and sales. Imphal is the main area where major fish selling and buying takes place. Fishes are brought from various terminal markets which are mainly sold by the producers themselves or women fish dealers as whole-sales. There is price bargaining and negotiation on buying. Modern Wholesale Fish Market and Patlou Modern Fish Market were recently constructed at Moirang in Bishnupur

district. The marketing hours vary from market to market and seasons. The women in Ema market on an average sell around 15-25kg/day for about Rs. 3000-4000/day.

**Constraints and issues faced by the state farmers and fishers**

**Technical constraints:** Lack of awareness of best culture methods and species, technical-know-how, trained managerial manpower, breeding knowledge and the consequences of inbreeding depression, irregular electricity and power supply, poor transportation infrastructure and lack of inputs (seed, feed, fertilizers).

**Financial constraints:** Lack of awareness and access to loans, schemes, projects and subsidies, necessary capital and incapability to purchase inputs and long process and documentation to avail financial supports

**Social Constraints:** Frequent bandh and road blockades crippling transportation, poor access to markets especially those from far off villages, poor information infrastructure and extension services, lack of awareness, competition and encouragement, poisoning and poaching and poor governing policies, administration and legal policies

**Environmental problems and other issues:** Drying up of lakes and wetlands due to siltation, daming, urbanization and other anthropogenic activities, inbreeding depression, pollution and habitat loss, over-exploitation, uncheck entry of exotic species and invasion threatening the local species, indiscriminate fishing methods (fish poisons, dynamites, electrocution etc.) and natural calamities such as excessive rain, floods, landslides etc.

**Future prospects and strategies for further improvement and development:** The water resources of the state have a potential of producing around 64,000 mt of fish annually with multiple water bodies not utilized/poorly utilized or sparsely stocked. Long term state action plan and policy for exploring and utilization of the potential resources would greatly enhance the production level. Culture of small indigenous freshwater fish species (SIFFS) should be promoted for polyculture with carps as it will increase the yields from the system without any extra effort or inputs. Polyculture of catfish with other species especially carps and compatible high value SIFFS could yield high production and profit as catfish fetches high price and demand. Integrated fish culture with paddy, piggery, poultry, horticulture, apiculture etc should be encouraged to enhance the crop yield. Awareness on use and value of ornamental fishes is

required to reduce reckless exploitation and habitat destructions. Popularizing ornamental fish culture and marketing in the state can promote employment creation and income generation. Taking fish culture as full fledged entrepreneurship should be encouraged. As fishery in the State is still traditional, adopting new and better technology in both culture and capture system would contribute to increase crop yield. New technologies and better management practices can be disseminated to farmers through farm demonstration, awareness programs, workshops and training programs. Timely consultancy supports of experts and fishery institutions will promote better fishery practices. Establishment of robust cold chain and marketing facilities reduce spoilage and wastage. The state need to critically look into conservations, restorations and enhancement programs to conserve the habitats and species biodiversity. Biswas et al (2015) rightly pointed out the need to prepare database of the fish species, develop rearing and captive breeding protocol for threatened and vulnerable species of the regions for conservation of genetic diversity.

**CONCLUSION**

To make Manipur a self-sufficient State in fish production, the various underutilized water bodies needs to be judiciously explored and utilized sustainably. Proper stocking strategy with diverse fast growing fish species, upgradation of quality fish seed productions and better policy for natural water bodies management and development will enhance the fish basket of the state. The State should take vehement steps in conserving the native fish species which are threatened in their natural system. Standardization of protocols for captive rearing and breeding of high value indigenous fish species is essential. Promotion and adoption of robust and modern aquaculture system with improve and integrated infrastructure facilities such as hatchery, feed mills, cold storage and transport facilities can be implemented through various governmental schemes and assistance. Judiciously harnessing the untapped and potential resources using modern technologies can not only bridge the demand-supply gap of the State but also produce surplus that can be supplied to the neighboring states too. Upgrading the fishery sector of the State will directly or indirectly uplift the livelihood of many resource dependent fishers, enhance employment and income generation and elevate the nutritional security of the people.

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# Assessment of Contamination Levels and Ecological Risk Indices of Environmentally Hazardous Metals for Granite Mining Waste

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**Abstract:** The heavy metals (HMs) present in the granite mining waste soils were identified, assessed the contamination levels and ecological risks posed by potentially hazardous HMs. Twenty soil samples were collected from mineral bench, dump yard and stockyard, including agricultural land at mining area in Chimakurthy, Andhra Pradesh, India. Six heavy metals (*Cr, Co, Ni, Cu, Zn* and *Mn*) were identified using Energy Dispersed Spectroscopy (XRD) and measured the concentrations of HMs using Atomic Absorption Spectrometer (AAS). Furthermore, the contamination levels and the risk indices of granite waste soils with HMs were determined by the pollution index (PI), integrated pollution index (IPI), Geo-accumulation index ( $I_{geo}$ ) and potential ecological risk index (RI). The calculated the contamination levels and the overall risk indices of mining waste soils were  $PI > 3$ ,  $IPI > 2$ ,  $2 < I_{geo} < 3$  and  $184 > RI > 223$  respectively, which indicated that the mining soils were highly contaminated and moderate ecological risk by the HMs, particularly Co, Cu and Zn. According to risk map analysis, the dump yard soils were highly contaminated than mineral bench and stockyard soils. It might be the reason that the accumulation of overburden soil at dump yards due to various opencast mining activities.

**Keywords:** Granite, Heavy metals, Geo-accumulation index, Risk index, EIA

Large quantity of granite waste generated and accumulated at overburden (OB) dumps in granite mining industry. The OB dumps are the most of possibly hazardous heavy metals (HMs) such as lead (Pb), arsenic (As), cadmium (Cd), zinc (Zn), copper (Cu) and manganese (Mn), which may have affect the local environment. Therefore, the physiochemical characterization for such contaminated soils are necessary and useful in the effective mitigation of toxic trace elements to improve environmental quality (Sierra et al 2013, Chen et al 2014). Recently, several governments have been promoted the research to investigate the geochemical background levels and contamination levels to serve as a basis for legislation to diagnose, prevent and reduce soil contaminations (Berglund et al 2000, Martínez et al 2007). The potential toxic metals usually be in polluted soils and could be accumulated into the human body via soil to crop to food chain or bioaccumulation or bio-magnification (Li et al 2016, Ko et al 2017). Generally, HMs were exist in water bodies, soil source, sediment zones, aerosol, living species and that they have both natural and man-made activities (Alvarez et al 2017). Human or animal exposure to HM pollutants could be caused neurons-disorder, renal failure, cardiovascular complications and reproductive inhibition (Christoforidis and Stamatis 2009). Therefore, the chemical characterization for such contaminated soils are necessary and useful in the effective removal of toxic metals in order to improve the environmental

quality. Recently, many characterization studies have been performed to assess the environmental impact and risk of mining and metallurgy industries based on their geochemical content and concentrations. The sequential acid digestion process was effectively used for determining HM content in the mining and tailing dumps, industrial waste disposal, municipal waste, sea beds, marine sediments and contaminated soils (Esshaimi et al 2013). Knowledge of the geochemistry of mining waste soils and contamination levels are important to optimize its exploitation and useful for assessing appropriate damage to the environment due to excessive deposition of mineral waste/HM content and to develop the strategies to mitigate environmental pollution during mining and excavation process. The present study is divided into two sections, first section focused on experimental physiochemical characterization of granite waste soils. Subsequent section focussed on assessment of the contamination levels and the associated environmental risks imposed by HMs through the various indices such as pollution index (PI), integrated pollution index (IPI), Geo-accumulation index ( $I_{geo}$ ) and potential ecological risk index (RI).

## MATERIAL AND METHODS

**Soil sampling and study area:** The granite mining waste and agricultural soil samples have been collected from a mining and mineral extraction industry at granite mining

industry in Chimakurthy, Andhra Pradesh, India, at coordinates: 15°34'0"N, 15°36'0"N, 79°48'0"E, 79°50'0"E (Fig. 1). The mining industrial area has a surface of five square kilometre and about fifty mining quarries are situated in Chimakurthy, where twenty surface soil samples (5–10cm depth) were collected from three locations of mineral bench site, stock yard/mineral processing site and dump yard using random sampling method. However, sequential sampling method was used to collect the agricultural soils near mining quarries for comparison of physiochemical properties between granite mining waste and agricultural soils (Koteswara Reddy and Kiran Yarrakula 2017).

**Physiochemical characterization:** Sieve analysis was performed for all the soil samples through a series of 4.75–0.002 mm mesh nylon fibre sieves by means of removal of any vegetation, large material and fragments. Finally, soil sub-samples were homogenized well and kept in zip plastic bags at ambient conditions for further study (Sierra et al 2013, Lockwood et al 2014, Sanderson et al 2015). Present study for chemical characterization, soil pH, redox potential, electrical conductivity, total dissolved salts (TDS), zeta potential, moisture, porosity, organic and inorganic content were determined using standard protocols (Quazi et al 2013, Fan et al 2014, Fang et al 2016). Soil pH and redox potential was recorded with a digital pH meter of glass electrode in a uniform suspension of soil with deionized distilled water in the ratio of 1:2.5 using Digital pH meter-MKVI, electrical conductivity and TDS were measured for the same extract with dilution in the ratio of 1:5 using Systronics Conductivity TDS meter 308. Soil moisture was determined by drying method using Box furnace at 125°C for overnight. Then, the organic and inorganic matter were determined by ignition method at 550°C weight loss basis, in Box furnace for four hours using INDFURR Superheat furnaces controller (Merdoud et al 2016).

**Characterization of heavy metals (HMs):** Quantitative elementary analysis of granite waste and agricultural soil samples were performed by Energy Dispersed Spectroscopy (EDX) (Instrument: X-act, ZEISS, Oxford instruments, United Kingdom). Quantitate elementary analysis was investigated with Aztec Energy EDS Software at an electrical field 10 keV for characterization of metals (Ramamurthy and Kannan 2009). The dried soil samples were subjected to EDX analysis for the identification of trace metals present in the soil samples. Representative soil sub-samples of fine powder, one gram was weighed accurately, and acid digested with strong acids (20 ml of HCl and HNO<sub>3</sub>), then heated at 50°C over hot plate chamber for 30 minutes. Then diluted with 100 ml distilled deionised water to acid digested samples and simultaneously filtered through 42 Whatman filter paper (Sasaki et al 2002). The filtered liquid extracts

were subjected to Atomic Absorption Spectrometer (AAS–Varian AA110 spectrophotometer) for determining the concentration of HMs (Fig. 2).

#### Assessment of soil contamination levels and ecological risk indices

**Pollution index (PI) and integrated pollution index (IPI):** The pollution index (PI) was defined by the following relation and integrated pollution index IPI is defined as the mean value of the pollution index (PI) of an element (Faiz et al 2009).

$$PI = \frac{C_i}{C_{b,i}} \quad (1)$$

Where, The  $C_i$  and  $C_{b,i}$  are the measured and the background concentration of the soil. The contamination levels and the corresponding index values of PI and IPI are provided (Table 1).

**Geo-accumulation index ( $I_{geo}$ ):** The geo-accumulation index ( $I_{geo}$ ) is used to estimate the soil contamination levels by potentially hazardous chemical species particularly, HMs, radio-nuclides and organic pollutants (Ji et al 2008). In this study, the Geo-accumulation index ( $I_{geo}$ ) was determined by using the following expression:

$$I_{geo} = \log_2 \frac{C_i}{1.5 C_{b,i}} \quad (2)$$

Where,  $I_{geo}$  is Geo-accumulation index used to estimate the levels of the environmental contamination via hazardous chemical species in the soil. The  $C_i$  and  $C_{b,i}$  are the determined and background concentration of the soil. The arbitrary constant value 1.5 used for natural fluctuations in the environment of a chemical species and allows for the identification of any small influences of anthropogenic activity (Faiz et al 2009). Geo-accumulation index values are graded in to seven types and the highest grade indicates that a value of 100 times more than the background values (Table 2).

**Ecological risk assessment:** The potential ecological risk of a given contaminant is defined as the following expression (Huang et al., 2009, Jiao et al., 2015).

$$RI = \sum_{i=1}^n E_r^i \sum_{i=1}^n T_Y^i \frac{C_i}{C_{b,i}} \quad (3)$$

Where, RI is the environmental risk index to assess the ecological toxicity levels by potentially harmful elements in the soil sample.  $E_r$  is the potential ecological risk index for  $i^{\text{th}}$  chemical species,  $T_r$  is the biological toxicity factor for  $i^{\text{th}}$  chemical species. The  $C_i$  and  $C_{b,i}$  are the measured concentration and the expected background concentration of the soil. Environmental risk assessment can be performed by variety of factors including the multi-element synergy, toxicity

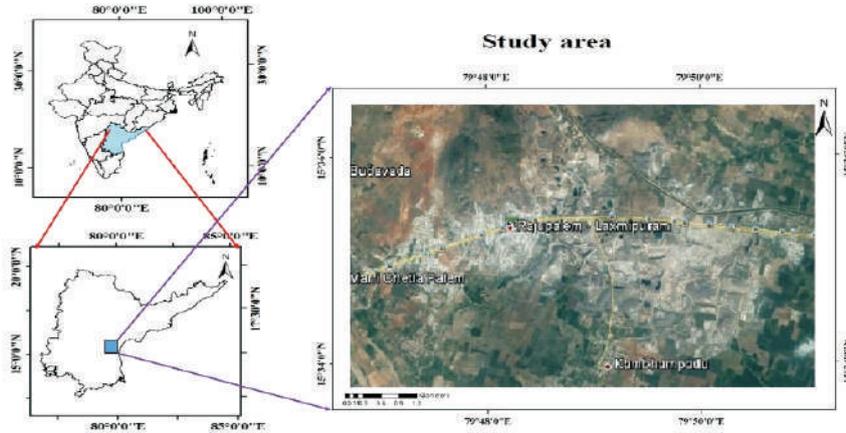


Fig. 1. The area map for collection of granite samples

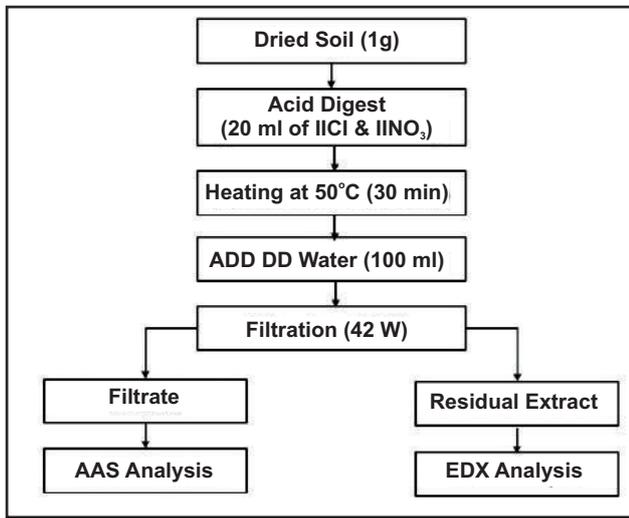


Fig. 2. The major steps involved in the characterization of heavy metals

Table 1. Classification of PI and IPI

PI value	Level of pollution	IPI value	Level of pollution
PI 1	Low	IPI 1	Low
PI 3	Middle	1 < IPI 2	Middle
PI >3	High	IPI >2	High

Table 2. The seven grades of the  $I_{geo}$  (Li et al 2014,; Han et al 2016)

Grade	Value	Soil quality
0	$I_{geo} 0$	Practically uncontaminated
1	$0 < I_{geo} 1$	Uncontaminated to moderately contaminated
2	$1 < I_{geo} 2$	Moderately contaminated
3	$2 < I_{geo} 3$	Moderately to heavily contaminated
4	$3 < I_{geo} 4$	Heavily contaminated
5	$4 < I_{geo} 5$	Heavily to extremely contaminated
6	$5 < I_{geo}$	Extremely contaminated

level, contaminated concentration and sensitivity to HM contamination to the environment. The equation 3, considered these factors to assess the environmental risk index or ecological risk index. The classification and the standard values of potential ecological risk index ( $E_r$ ) for  $i^{th}$  chemical species and the overall ecological risk index (RI) were reported (Table 3). According to the approach of Hakanson and Xu, the toxic-response factor for the HMs in the ascending order of Hg, As, Pb, Co, Ni, Cu, Cr, Zn and Mn are 40, 10, 5, 5, 5, 5, 2, 1 and 1 respectively (Hakanson 1980; Liu et al 2016). In the study, the environmental risk assessment was determined in order to investigate the level of potential ecological risk posed by the hazardous HMs for all soil samples.

**RESULTS AND DISCUSSION**

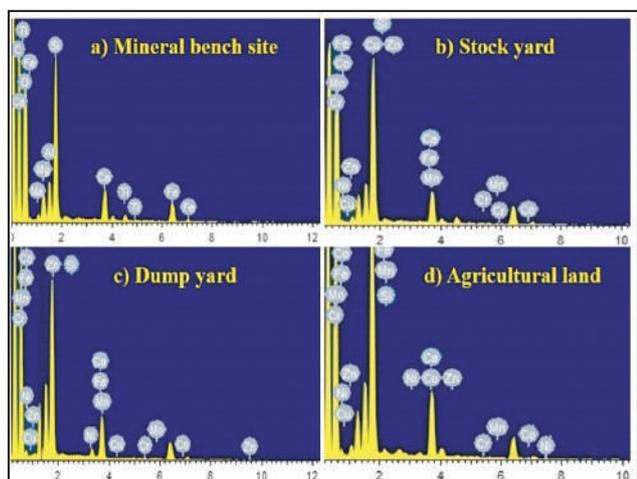
**Physiochemical characteristics:** The mineral bench and stockyard soil texture of the sub-samples were loam sandy type (Table 4). The distribution of particles size were observed as sand fractions for four types of soils with a high percentage of coarse with 13-14, medium with 13-14.5 and fine with 11-15 respectively, in the sieve analysis process. In case of agricultural soils, the percentage of sand and silt loam were 42 and 32 respectively. The porosity of the slit and clay soil showed that in the range of 0.38-0.45 for granite mining soils, whereas, for agricultural soils have more porosity (0.52) than granite soils. The representative soil sub-samples of three granite areas showed an alkaline pH (9.5-9.8), an electrical conductivity and high total dissolved salts (TDS) were in the range of 121-148µs/ppm and 136-200 ms/ppm, respectively. The redox potential in the range from -151mV to -181mV, which indicates that the soil was highly alkaline in nature due to low redox potential. However, in case of agricultural soil, redox potential was -78mV by means of slightly alkaline in nature. The granite mining soils had with

**Table 3.** Classification and standard values of  $E_r^i$  and RI (Jiao et al 2015, Hant et al 2016)

$E_r^i$	Single pollutant degree of environmental risk	RI	Comprehensive environmental risk level
$E_r^i$ 40	Low ecological risk	RI 150	Low ecological risk
40 $E_r^i$ 80	Moderate ecological risk	150<RI 300	Moderate ecological risk
80 $E_r^i$ 160	Considerable ecological risk	300<RI 600	Considerable ecological risk
160 $E_r^i$ 320	High ecological risk	RI>600	Very high ecological risk
$E_r^i$ 320	Very high ecological risk		

**Table 4.** The physical and chemical properties of four groups of soil

Soil texture analysis	Mineral bench site*	Stock yard*	Dump yard*	Agricultural land*
Gravel (>4.75 mm) (%)	33.25	34.70	36	12
Sand Coarse (4.75-2.00 mm)	13.9	13.72	12.81	12.97
Medium (2.00-0.425 mm)	13.0	13.22	13.06	14.47
Fine (0.425-0.075 mm)	12.8	10.85	11.91	15.10
Slit (0.075-0.002 mm) (%)	12.8	13.99	13.02	31.50
Clay (<0.002mm) (%)	14.1	11.48	14.12	12.90
Porosity	0.38	0.39	0.44	0.52
p <sup>H</sup>	9.7	9.5	9.8	8.3
Electrical conductivity (µs/ppm)	141.49	121.64	147.97	104.56
Redox potential	-179	-151	-181	-78
Zeta potential	-36.1	-33.3	-26.5	-25.3
TDS (ms/ppm)	199.41	136.41	173.18	103.14
Moisture (%) at 125°C	0.49	0.85	0.92	1.61
Total inorganic matter (%) at 500°C	98.15	97.14	97.57	93.45
Total organic matter (%) at 500°C	0.97	1.13	1.44	4.58

**Fig. 3.** Identification of HMs using XRD analysis; a) Mineral bench soil; b) Stock yard soil; c) Dump yard soil; d) Agricultural soil

high inorganic matter content around 98%, low moisture content (<1%) and less organic matter content (<1.64%). In case of agricultural soils, have more organic (5%) and moisture content (1.6%) than mining soils.

**Characterization of heavy metals:** Six HMs such as chromium (Cr), cobalt (Co), nickel (Ni), copper (Cu), zinc (Zn) and manganese (Mn) were identified by XRD analysis (Fig. 3) and the concentration of these HMs were determined by using acid digestion process followed by AAS analysis. Kumar *et al.* (2016) reported the HMs present in the granites and associated ultramafic rocks as chromium (Cr), cobalt (Co), nickel (Ni), copper (Cu), zinc (Zn), manganese (Mn), gold (Au), silver (Ag) and platinum (Pt) (Kumar et al 2016). The HM content well agreed with reported HMs in the literature for granite mining waste soils.

The relative concentrations of Mn, Zn and Cu were more than the rest of the HMs (Fig. 4, Table 5). The dump yard soil samples have comparatively more concentrated with HMs than other three groups of mineral bench (MB) the stock yard

**Table 6.** The PI values for three groups of mining soils

HMs	Mineral bench site*	Dump yard*	Stock yard*	Level of pollution
Cr	8.9-9.3	10.9-11.2	10.0-10.2	High
Co	13.9-14.5	16.5-16.7	12.1-12.2	High
Ni	6.5-6.6	8.0-8.1	7.2-7.3	High
Cu	9.5-9.6	12.0-12.2	10.4-10.8	High
Zn	13.1-13.5	15.1-15.2	15.8-16.4	High
Mn	3.4-3.5	3.5-3.6	3.6-3.7	High

**Table 7.** The IPI values of HMs for three groups of mining soils

HMs	Mineral bench site*	Dump yard*	Stock yard*	Level of pollution
Cr	9.0	11.0	10.0	High
Co	14.2	16.5	12.1	High
Ni	6.6	8.0	7.2	High
Cu	9.4	12.0	10.4	High
Zn	13.3	15.2	16.4	High
Mn	3.4	3.5	3.6	High

(SY) and agricultural farm soil samples. It might be the reason that the continuously accumulation of overburden soil at dumpsites, increased the concentration of HMs due to various opencast mining activities.

**Assessment of soil contamination levels and risk indices**

**Pollution index (PI):** The  $PI > 3$ , for all mining soil samples, which indicated that the soil under exposed to high level of pollution particularly for dump yard soils (Table 6). The soil samples S1-S15 were heavily contaminated by Co, Zn and Cu with  $PI > 10$ , which indicated that the HMs such as Co and Zn were the major contribution of contamination in all groups of soils (Fig. 5). It might be that the continuously accumulation of overburden soil at dump sites, increased the contamination levers worse.

**Integrated pollution index (IPI):** The  $IPI > 2$ , for all mining

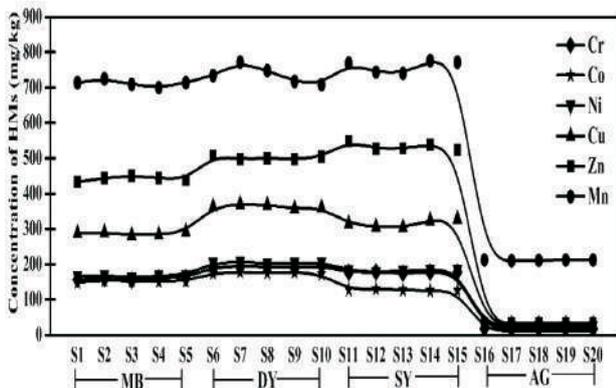
soil samples, which indicated that the soil were under high level of pollution (Table 7). The dump yard soils were heavily contaminated by Co, Zn and Cu with  $IPI > 12$ , which indicated that the major contribution of contamination in all groups of soils by these HMs; whereas, mineral bench site and stock yard soils were less contaminated by Cr, Ni and Mn (Fig. 6). The HMs, Mn, Ni and Cr had  $3 < IPI < 10$ ; therefore their pollution level is high. In the case of Cu, Zn and Co had  $IPI > 10$ ; therefore, their pollution level is extremely high.

**Geo-accumulation index ( $I_{geo}$ ):** Most of the soil sample had  $I_{geo} < 3$ , and which demonstrated that the soil quality was moderately to heavily contaminated by HMs (Fig. 7). The dump yard (DY) soil samples have  $I_{geo} > 3$ , which indicated that heavily contaminated than those of mineral bench (MB) and the stockyard (SY) soils (Table 8). It might be the reason

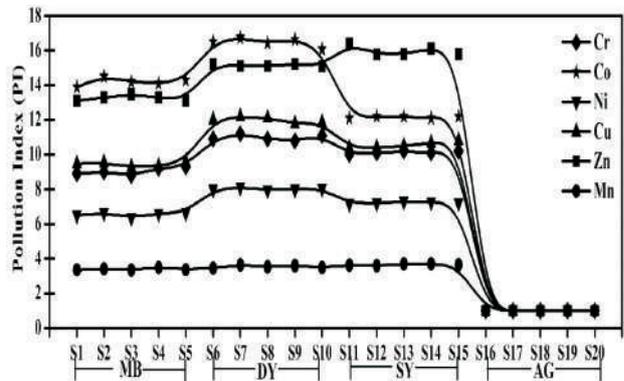
**Table 5.** Concentration of HMs for four groups of soils

Heavy metals	Mineral bench site (mg kg <sup>-1</sup> )*	Dump yard (mg kg <sup>-1</sup> )*	Stock yard (mg kg <sup>-1</sup> )*	Agri. Land (mg kg <sup>-1</sup> )*
Chromium	157-162	192-196	177-178	17.6-17.7
Cobalt	149-155	175-179	128-130.7	10.6-10.8
Nickel	166-169.5	204-207	183-185.2	25.2-25.5
Copper	287.9-290	363-370.6	315-328.7	30.1-30.4
Zinc	432.8-450.2	497.4-507.6	523-548	33-33.4
Manganese	714-725	734-772.2	769-776	210-212

\*Data are the range of five replicates



**Fig. 4.** Concentration of HMs in four groups of the soil samples



**Fig. 5.** Pollution indices (PI) of HMs for 20 soil samples

that the continuously accumulation of overburden soil at dumpsites, increased the concentration of HMs due to various opencast mining operations. The  $I_{geo} > 3$  for Co and Zn in three groups of mining soils by means that the soil quality was heavily contaminated by these HMs, whereas the  $I_{geo} < 3$  for Cr, Ni, Cu and Mn, by means of that the soil quality was moderately to heavily contaminated by these HMs.

**Ecological risk assessment:** Most of the mining waste soil sample have a potential ecological risk index (RI) <200, and which demonstrated that the soils were low to moderately ecological risk by HMs (Table 9). The potential ecological risk indices ( $E_r$ ) of individual HMs for three groups of mining waste soil samples were determined (Fig. 7). The dump yard (DY) soil samples have more  $E_r$  values than other three groups of mineral bench (MB) and the stockyard (SY) soil samples. The  $E_r > 30$  for Co, Cu and Ni in three groups of mining soils by means that the environment exposed to moderate ecological risk, whereas, The  $E_r < 30$  for Cr, Zn and Mn by means of that the environment was exposed to low risk by these HMs (Fig. 8). The  $E_r$  values of HMs in the order of  $Co > Cu > Ni > Cr > Zn > Mn$ , demonstrating that the higher biological toxicity factor directly related with higher levels of risk to the environment. The overall potential environmental risk index (RI) of six HMs for mineral bench soil, dump yard

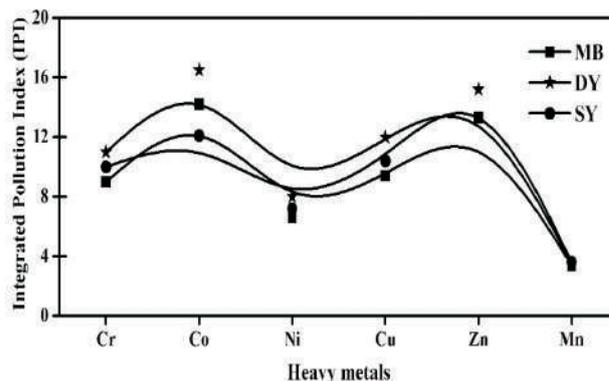


Fig. 6. Integrated pollution indices (IPI) of HMs for 20 soil samples

soil and stock yard soils were about 183.7-184.01, 221.94-222.5 and 187.66-188.8 respectively (Table 9). The results indicated that the mining soils belong to moderate ecological risk with excessive contamination of Co and Cu than other HMs.

From the risk map, the samples S1-S15 had exposed to moderate ecological risk with RI range of 201-224, whereas, the samples S15-S20 were exposed to low risk or no risk with  $RI < 150$  (Fig. 9). The dump yard soils had under moderate risk, whereas, agricultural soils had no risk. The

Table 8. Geo-accumulation index ( $I_{geo}$ ) values of HMs for three groups of mining soils

HMs	Mineral bench site*	Dump yard*	Stock yard*	Soil quality
Cr	2.57-2.64	2.86-2.89	2.74-2.75	Moderately to heavily contaminated
Co	3.21-3.27	3.44-3.47	2.99-3.02	Heavily contaminated
Ni	2.12-2.15	2.41-2.43	2.26-2.28	Moderately to heavily contaminated
Cu	2.66-2.68	2.99-3.01	2.79-2.85	Moderately to heavily contaminated
Zn	3.16-3.17	3.34-3.45	3.41-3.44	Heavily contaminated
Mn	1.16-1.18	1.15-1.21	1.22-1.28	Moderately to heavily contaminated

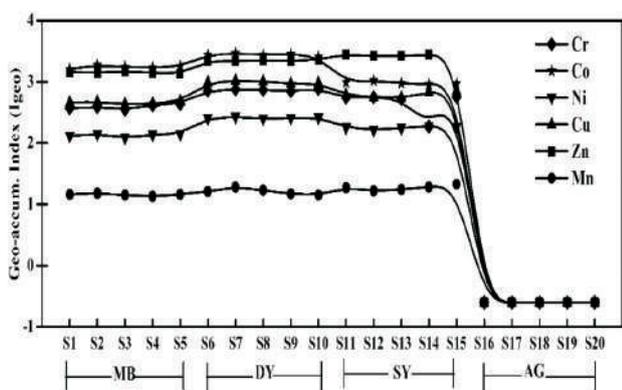


Fig. 7. Geo-accumulation indices ( $I_{geo}$ ) of HMs for 20 soil samples

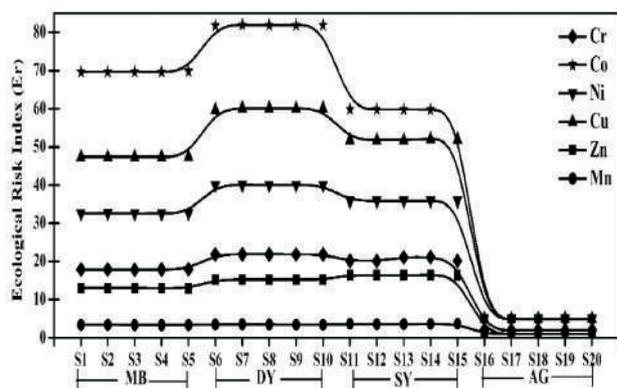


Fig. 8. The potential ecological risk index ( $E_r^d$ ) of HMs for 20 soil samples

soil in the east (E) zone was highly affected by the accumulation of potential hazardous metals than those in other zones. The soil in the northeast (NE) and southeast (SE) zones were moderately affected, the soils in west (W) and southwest (SW) zones were less affected by potential hazardous Hms.

**CONCLUSION**

The HMs such as Co, Zn and Cu were heavily contaminated the granite mining waste soils than those of Cr, Ni and Mn. The ecological risk index (E<sub>i</sub>) values of individual HMs were found in the order of Co>Cu>Ni>Cr>Zn>Mn, which demonstrating that the higher biological toxicity factor directly related with higher levels of risk to the environment. The overall risk index (RI) of all HMs for dump yard soils have more than the mineral bench and stock yard soils, which

indicated that the dump yard soils belong to moderate ecological risk with excessive contamination of Co, Cu and Zn than other HMs. From the risk map analysis, the soils in the E zone was highly affected and which belong to dump yard, in the NE and SE zones were moderately affected and which belong to mineral bench and stock yards; in W and SW zones were less affected and which belongs to agricultural lands by the accumulation of potential hazardous metals. It might be the reason that the continuously accumulation of overburden soils have enriched with HMs at E, NE and SE zones due to various opencast mining operations. The study is useful for the researcher's one who is working in the field of the environmental impact assessment (EIA) and the soil decontamination studies to prevent and reduce the pollution levels from contaminated sites by soil remediation technologies.

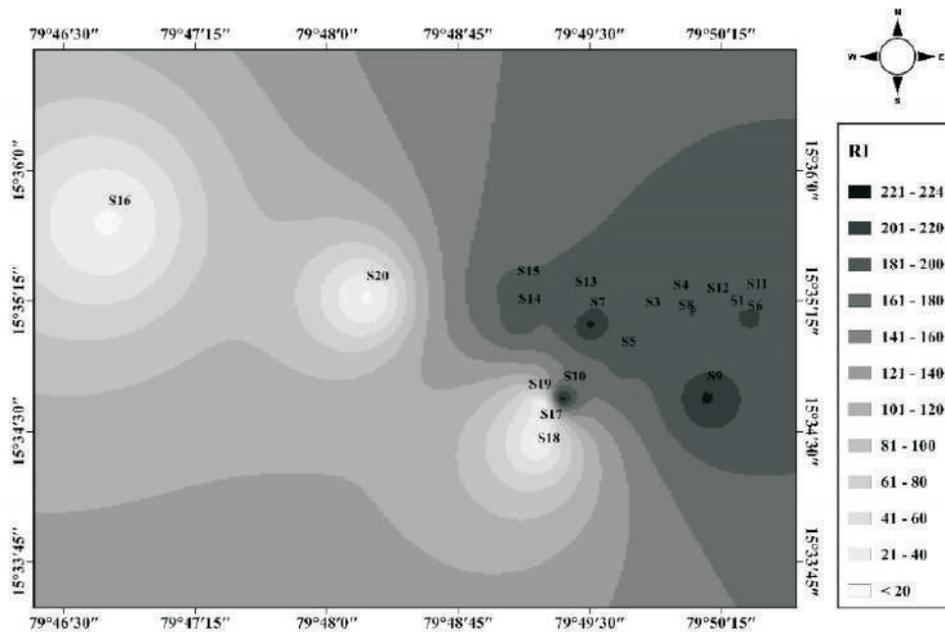


Fig. 9. Spatially risk map associated with hazardous HMs based on RI values

Table 9. Assessment of potential ecological risk index (E<sub>i</sub>) of HMs for mining waste soils

HMs	Mineral bench site (E <sub>i</sub> )	Dump yard (E <sub>r</sub> )	Stock yard (E <sub>r</sub> )	Environmental risk
Cr	17.84-17.92	21.82-21.85	20.11-20.12	Low ecological risk
Co	69.63-69.85	81.77-81.92	59.81-59.84	Moderate ecological risk
Ni	32.55-32.58	40.00-40.04	35.85-35.88	Low ecological risk
Cu	47.35-47.39	59.70-60.11	51.82-52.05	Moderate ecological risk
Zn	12.96-12.97	15.19-15.23	16.36-16.41	Low ecological risk
Mn	3.370-3.390	3.460-52.00	3.630-3.670	Low ecological risk
RI	183.7-184.01	221.94-222.5	187.66-188.8	Moderate ecological risk

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