

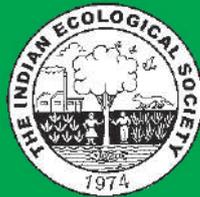
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Spatial Assessment of Water Quality in Kondurupalem Lagoon Inlet, South East Coast of India

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Abstract: A two-year study on the water quality and eco management of the Kondurupalem lagoon inlet located between 14°32'N latitude and 79°54' longitude on the east coast of India was conducted (2015 and 2016). The digital data image and spatial analysis were done using Digital Imaging Software and the seasonal variations in select physico-chemical parameters were recorded employing standard methods to describe the general water quality condition of the inlet. Alkaline pH was recorded throughout the study at all stations and this trend could be attributed to the high salinity of water. The DO levels were high during the monsoon season with a mean value of 6.8 mg/L. A significantly low DO of 2.2 mg/L observed at the sampling station located at the sea mouth area appeared to be linked to movement and temperature of water and salinity. The average pre-monsoon salinities ranged from 37 to 42.5 per cent during both the years. During monsoon, the values dipped between 21.3 to 24 per cent in 2015 and 22.3 to 26.1 percent in 2016, respectively. The turbidity during summer varied from 2.8 to 3.9 NTU and in pre-monsoon period from 2.4 to 3.1 NTU for 2015 and 2016, respectively. The turbidity during monsoon and post-monsoon varied from 4.1 to 8.2 NTU and 3.8 to 6.7 NTU, respectively for these years. The phosphates value during the pre-monsoon season were 208.53 and 288.66 µg/L for these years. This trend is an indication of excessive run-in of inorganic phosphates from fertilizers used in the nearby agricultural fields, into the lagoon. The mean nitrate concentrations during the monsoon and post-monsoon season were 52.60 and 39.52 µg/L in 2015 and 55.38 and 39.48 µg/L in 2016, respectively. However, there was a decrease in the mean value during the summer and pre-monsoon seasons. The high post-monsoon bicarbonate levels of 68–202 mg/L fell to 75–160 mg/L during monsoon and summer seasons. Monsoon precipitation, natural and human induced closing and/or opening of the inlet mouth and the consequential changes in the hydrodynamics and the anthropogenic inputs from the adjoining semi-urban habitation appear to influence water quality in this ecosystem.

Keywords: Water quality, Eco-management, Spatial analysis, ARCGIS, Anthropogenic activities

Tidal inlets are a common feature found along major part of the Indian coastline. Their role in coastal ocean processes and ocean navigation to sheltered waters are well documented (Kreeke, 2013). Changes in the morphology and hydro dynamics of the lagoons and anthropogenic inputs of nitrogen and phosphorus are the known to affect the water quality of lagoons. Several studies have highlighted the importance of the assessment of water quality of these ecosystems (Howarth and Marino, 2006; Schindler, 2006) for their effective management. Impacts and consequences of deterioration of water quality in implementation of management strategies have also been discussed by some authors (Newton and Mudge, 2005). A comprehensive account on the effects of nutrient fluxes and net metabolism in Lobos coastal lagoon, México is available in Valenzuela-Siu *et al* (2007). Though sporadic reports and publications on eco-management of the Pulicat lake ecosystem are available (Sanjeevaraj, 2010), such studies have not been extended to Kondurupalem tidal inlet in spite of its known hydrological and economic importance. The tidal inlet ecosystem has rich floral and faunal diversity, and is well known for its fish and

prawn resources. The vast expanse of water, the geo morphological features and also its location in the context of Pulicat ecosystem add ecological significance to the lagoon and call for detailed investigations on a multitude of aspects. The socio-economic assessment of fishing community of Pulicat lagoon has been published (Devi and Krishnaveni, 2012).

This paper presents part findings of a major eco management study of Kondurupalem tidal inlet. The study of coastal lagoons and estuaries requires the analysis of the interaction between land and marine zones as well as the factors that alter their original characteristics caused by anthropogenic activities. Often times, such activities lead to local and regional changes having an impact on the primary production, fishing and social components related to it. The present study has been designed keeping this aspect as the driving force. The main objective of this study is to assess the seasonal changes in the water quality within the defined spatial extent in the lagoon ecosystem. In addition, the study examines whether specific parameters such as species of nitrogen and phosphorus could be used as chemical

indicators of changing ecology of the lagoon which is being subjected to various anthropogenic and geomorphologic influences. The information collected and observations made in this study will be very useful in formulating management policies for the future of the Pulicat ecosystem in general and Kondurupalem tidal inlet, in particular.

MATERIAL AND METHODS

STUDY AREA

The two-year study was carried out in Kondurupalem Tidal Inlet (KTI) of Pulicat lagoon located between 14°32' N latitude and 79°54' longitude. The lagoon has three sea mouths: one at Kondurupalem, Rayadoruvu at the northern end of Sriharikota Island and the other one at Pazhaverkadu near Pulicat village of Tamil Nadu. The total water spread area of the Pulicat Lake in 1700 AD was around 481 km², but the present spread is 281 km² (Sanjeevaraj 2010). The developmental activities of the Sriharikota Space Research Centre (SHAR) located on the Sriharikota island are linked to water exchanges in the Pulicat Lake.

Notwithstanding the limitation (s) of expressing the water quality parameters as average value while studying a dynamic system like ocean, such a computation was resorted to for qualitative comparison across different stations. The month-grouping made for the study are: i) Post-monsoon (January – March), ii) Summer (April – June), iii) Pre-monsoon (July – September) and iv) Monsoon (October – December).

The samples were collected in one litre capacity plastic sample containers by immersing the container to a depth of 0.5 to 1 metre below the surface between 10 am and 4 pm and were stored at 26 °C for analysis. In all, there were nine sampling stations (S1 to S9), of which S1, S2 were at north, station S9 at the mouth of the lagoon while others were between S1 and S9. The distance between the sampling points S1 and S9 was approximately 2.3 km. The methods employed for analyzing the water quality are furnished in Table 1.

Spatial Distribution: Remotely sensed satellite data were taken as the primary source of information. The base map of the Kondurupalem tidal inlet was prepared by digitising the Survey of India (Sol) toposheets and Cartosat-1 (2011) satellite images. The digital data imaging and spatial analysis were done using the following software packages: Arc View 3.2A, Arc GIS 9.0 and ERDAS 8.4. The boundary of the lake was digitized using the polygon shape file. The concept of Inverse Distance Weighted (IDW) interpolation method (Lu and Wong 2008) was applied to obtain the spatial distribution. The sampling locations were captured as latitude / longitude data in Degree, Minutes, Seconds (DMS)

Table 1. Methods employed for the analysis of Kondurupalem tidal inlet water quality

| Parameter | Method |
|-----------------------|---|
| Temperature | Thermometer (°C) |
| pH | pH meter (Systronics–Digital model) |
| Turbidity | Nephelo Turbidity meter |
| Salinity | Argentometry ^{1,2} |
| Dissolved Oxygen | Modified Winkler's method ^{1,2} |
| Ammonia Nitrogen | Hypochlorite – indophenol blue method (630 nm) ^{1,2,3} |
| Nitrite Nitrogen | Cadmium column reduction/ Sulphanilamide-NEDA Azotisation technique (543 nm) and summation of the three inorganic fractions to give total dissolved inorganic nitrogen ^{1,2,3} |
| Nitrate Nitrogen | |
| Inorganic phosphate | Ascorbic acid Molybdate method ^{1,2,3} |
| Silicate | Molybdosilicate method ^{1,2,3} |
| Chloride | Mohr's Argentometric titration ^{1,2} |
| Calcium and Magnesium | Titrimetry method ^{1,2} |
| Bicarbonate | Titrimetry method ^{1,2} |

¹Strickland and Parsons (1968)

²Grasshoff, Kremling and Ehrhardt (1999)

³C-MARS (CSIR), Trivandrum (2005)

format. The data were converted to decimal degrees (Long DD and Lat DD) for all the sampling locations. Sorting these in Excel format file, the data were exported as text file structure. The Spatial Analyst tool in the GIS software was employed for interpretation of data (Rova 2015). Upon analysis, the results were stored as raster files. The data on water quality parameters obtained after laboratory analysis were used to create seasonal colour-coded spatial variation maps using Arc View 3.2A and Arc GIS 9.0.

RESULTS AND DISCUSSION

Detailed spatio temporal data on select parameters have been presented in the tables and figures in this section. For the sake of brevity and to capture their applicability the discussion is focused only on the trend observed during the study. The exchange and balance of energy and materials in the KTI are considered as spatial and temporal variables that depend on landward and marine water contributions, local morphology and bathymetry, and even on regular and eventual climatic factors including monsoon and cyclones that characterize the region.

The tidal inlet of the lagoon generally remains closed to varying degrees especially during the summer and pre monsoon months (April to September). Delayed or failure of monsoon which is not uncommon in this part of the country leads to accretion at mouth due to long-shore sediment

transport, weak tidal current, and reduced fresh water flow that is not strong enough to keep the sand out of the inlet. The physical 'confinement' of water leads to noticeable change in the water quality, as observed in the present study.

While the temperature of surface water ranged from 22 to 36.1 °C in the summer season, it ranged from 28 to 31.1°C during dry pre-monsoon period. Lower temperatures ranging from 21.2 to 25°C and 27.9 to 29.0°C were recorded in the monsoon and post-monsoon seasons, respectively. The alkaline pH of water recorded throughout the study at all stations (Table 2) could be attributed to the high salinity of water. In pre-monsoon season the pH was 7.91 near the sea mouth area and 7.43 at the northern sampling point. In monsoon season the pH was 8.22 at the inlet area and minimum was 7.89 at the northern sampling point. The high pH observed during monsoon season is testified by fresh water influx and the consequential dilution of sea water within the confines of the lagoon, coupled with low temperature and organic matter decomposition. Prabu *et al.*, (2008) in Pichavaram mangroves, Damotharan *et al.*, (2010) in Point Calimere coastal waters and Nayak *et al.*, (2004) in Chilika lake) too have reported similar trend in pH in confined saline ecosystems. A comparative analysis of the trend in pH variation in dynamic lagoon and lake systems in Indian coast would help evolve a common and effective strategy for neutralization while managing these fragile ecosystems. Studies in this direction are in progress in our laboratory.

The DO levels were high during the monsoon season with a mean value of 6.8 mg/L (Figure 1a and 1b). However, the GIS maps show some similarity in the distribution pattern throughout the lake during consecutive seasons. Higher DO recorded during monsoon season may be due to the cumulative effect of higher wind velocity, heavy rainfall and the resultant freshwater mixing as reported by earlier workers (Prabu *et al.*, 2008, Damotharan *et al.*, 2010). Renewal of water due to rains and freshwater discharge might have

increased the DO in the KTI during monsoon and post-monsoon seasons. Consumption of DO during the decomposition of organic matter is known to be dominant and is more effective in warm weather conditions (Gupta *et al.* 2008), which causes depletion of oxygen during pre-monsoon season. Closing of the inlet mouth during the pre-monsoon hot weather condition would not only restrict the free mixing of water but would favour the accumulation of autochthonous organic matter. These situations are bound to increase the oxygen debt and further depletion of DO (Nakamura and Kerciku, 2000). Low DO values recorded during some seasons in KTI bear testimony to this. A low DO viz., 2.2 mg/L recorded at sampling station 9 which is at the sea mouth area is probably due to low solubility of oxygen in sea water which is known to depend on water temperature, movement of water and salinity (Mahapatro and Padhy, 2001). Similar trend has been reported by Patra *et al.* (2010) in their studies on the variation in physio chemical parameters of Chilika lake after the opening of new mouth.

The salinity during the post-monsoon season ranged from 29 to 36‰ during both the years (Figure 2a and 2b). The average pre-monsoon salinities ranged from 37 to 42.5‰ during both the years. There was no significant variation in salinity in the estuary except during the monsoon period. A slight increase in salinity recorded during and especially at end phase of the pre monsoon season is probably due to elevated evaporation rate linked to high temperatures of the water surface. During monsoon, the percent salinity values were in the range of 21.3 to 24 in 2015 and 22.3 to 26.1 in 2016, respectively. The low values recorded during October to December of 2015 and 2016 may be attributed to rainfall of about 790 mm. Similar trend in salinity has been reported by workers in various parts of southeast coast of India (Prabu *et al.*, 2008, Soundarapandian *et al.*, 2009, Nayak *et al.*, 2004). While very high salinity concentrations have been recorded in tidal pools within marshy areas (Moore 1987), its significance

Table 2. Spatial and seasonal variation of pH in KTI water

| Sampling points | Post Monsoon 2015 | Summer 2015 | Pre-monsoon 2015 | Monsoon 2015 | Post Monsoon 2016 | Summer 2016 | Pre-monsoon 2016 | Monsoon 2016 |
|-----------------|-------------------|-------------|------------------|--------------|-------------------|-------------|------------------|--------------|
| S1 | 7.64 | 7.06 | 7.65 | 7.89 | 7.68 | 7.13 | 7.43 | 7.75 |
| S2 | 8.06 | 7.13 | 7.43 | 7.95 | 7.91 | 7.24 | 7.62 | 7.82 |
| S3 | 8.17 | 7.14 | 7.71 | 8.03 | 8.12 | 7.27 | 7.72 | 7.91 |
| S4 | 8.19 | 7.18 | 7.68 | 8.06 | 8.2 | 7.35 | 7.71 | 7.95 |
| S5 | 8.23 | 7.09 | 7.71 | 8.17 | 8.24 | 7.31 | 7.82 | 8.04 |
| S6 | 8.14 | 7.15 | 7.73 | 8.14 | 8.25 | 7.24 | 7.79 | 8.08 |
| S7 | 8.31 | 7.21 | 7.76 | 8.21 | 8.32 | 7.18 | 7.76 | 8.13 |
| S8 | 8.35 | 7.27 | 7.79 | 8.18 | 8.35 | 7.31 | 7.7 | 8.24 |
| S9 | 8.26 | 7.48 | 7.91 | 8.22 | 8.41 | 7.49 | 7.64 | 8.41 |

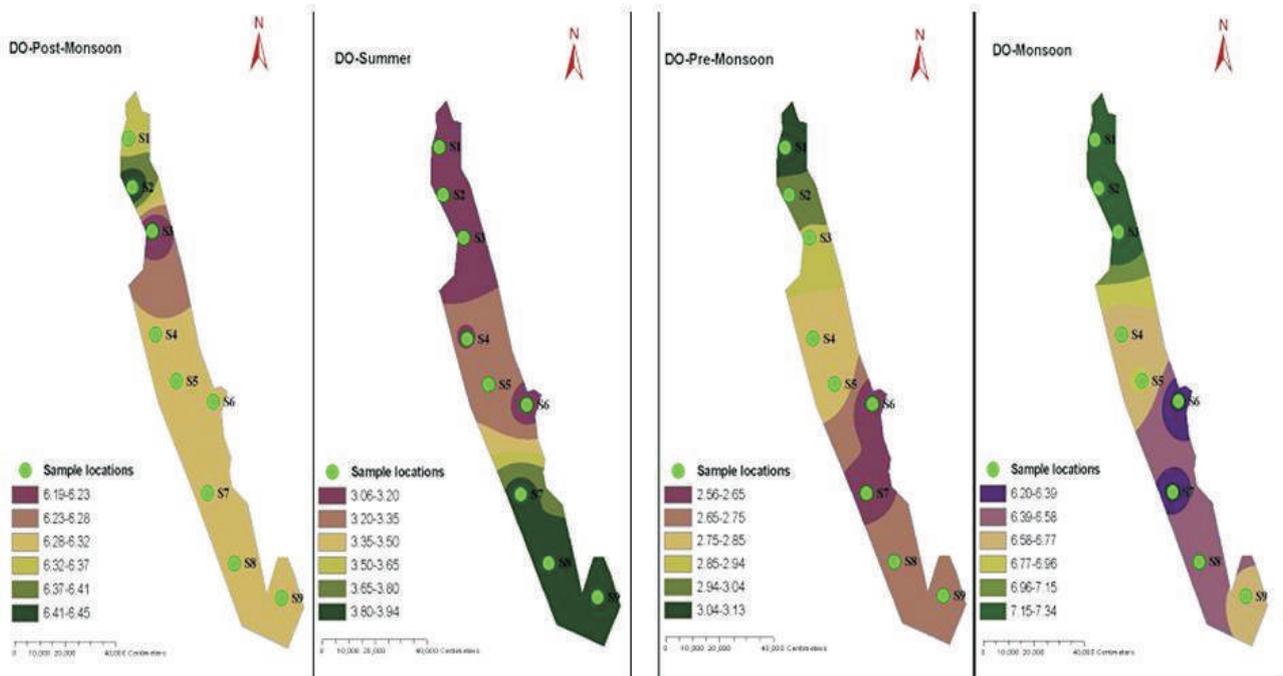


Fig. 1a. Locational and seasonal variation in DO of water in 2015

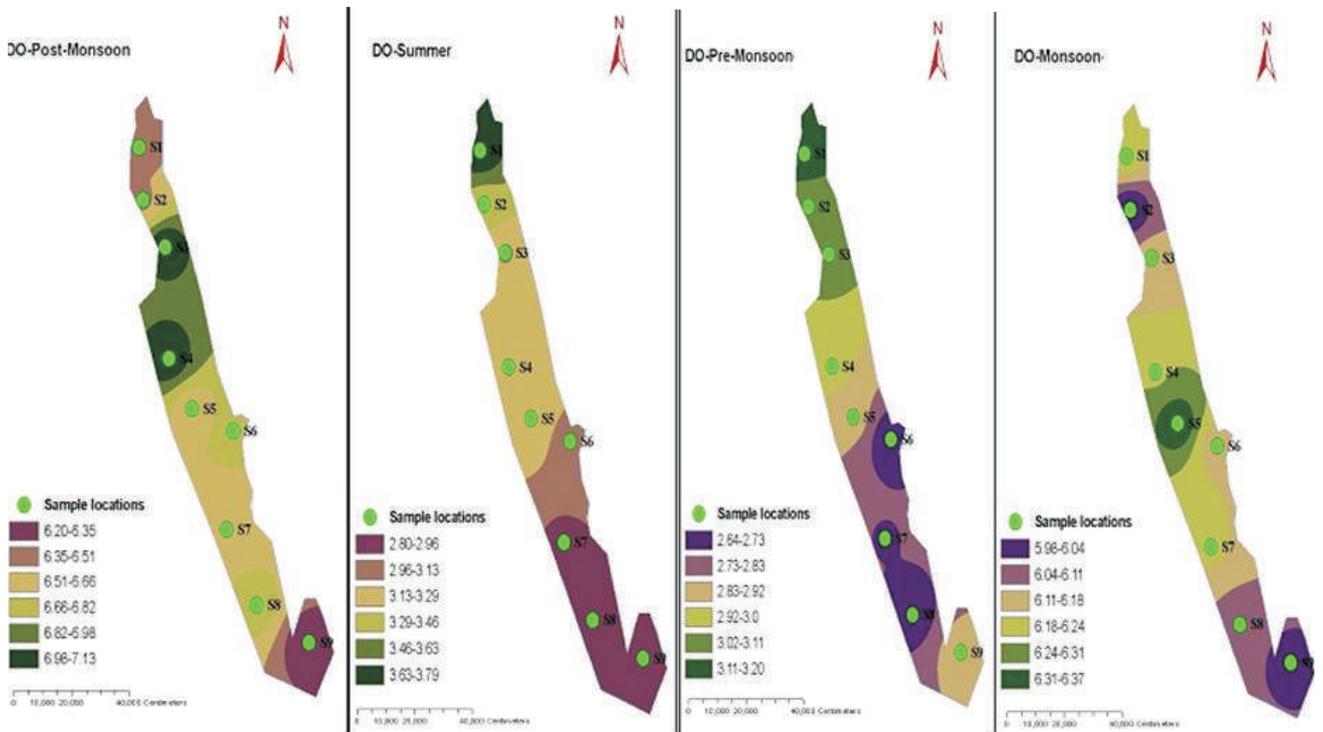


Fig. 1b. Locational and seasonal variation in DO of water in 2016

is limited when the estuary undergoes rapid change due to anthropogenic inputs. The salinity of water within the estuary indicates the approximate quantum of fresh water mixed with sea water. In the case of KTI, anthropogenic input from offshore sources is not significantly high.

Turbidity ranged from 2.4 to 8.2 NTU in KTI (Table 3). The average turbidity during summer varied from 2.8 to 3.9 NTU and in pre-monsoon period from 2.4 to 3.1 NTU for the years 2015 and 2016, respectively. The turbidity during monsoon and post-monsoon varied from 4.1 to 8.2 NTU and

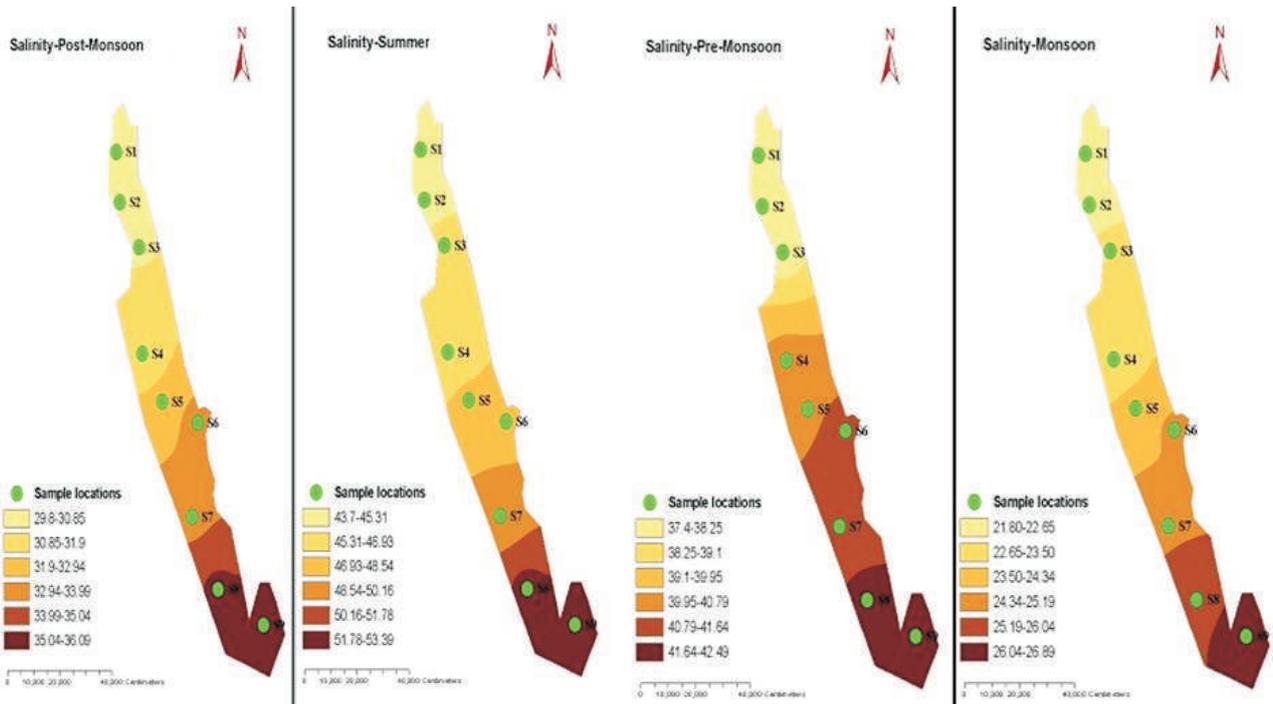


Fig. 2a. Locational and seasonal variation in salinity of water in 2015

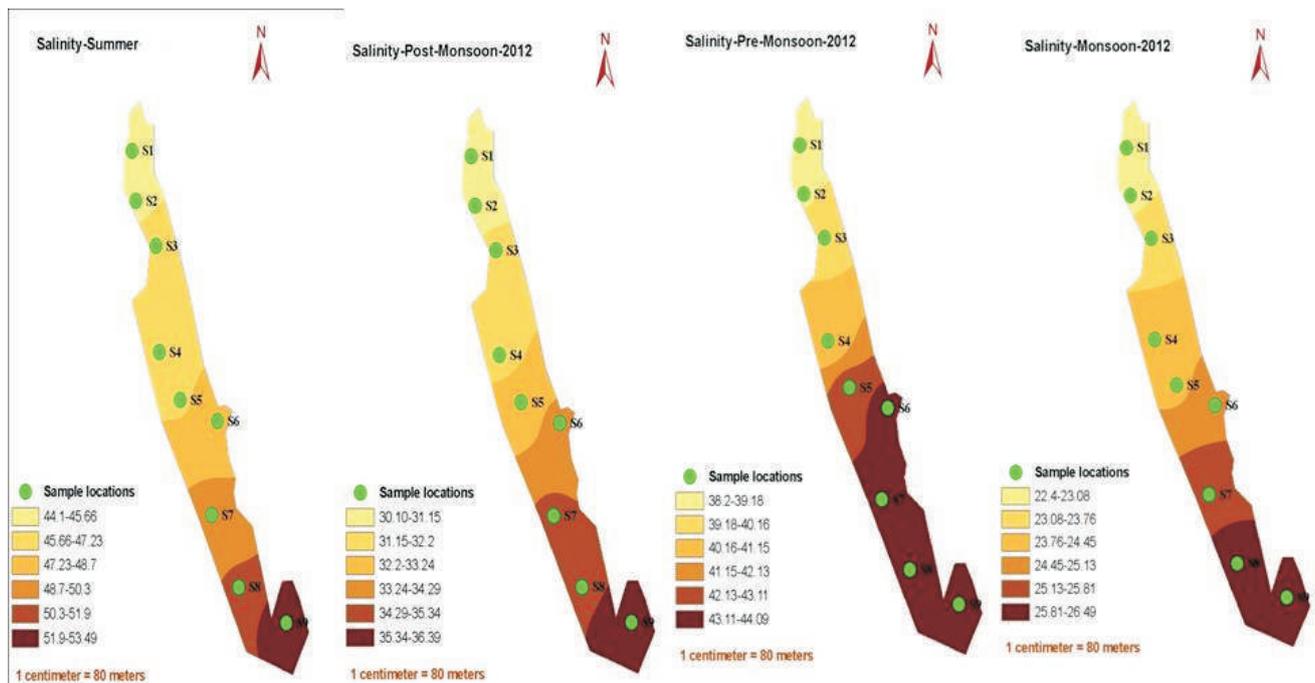


Fig. 2b. Locational and seasonal variation in salinity in 2016

3.8 to 6.7 NTU, respectively for the years 2015 and 2016. The maximum turbidity was recorded during monsoon season and minimum during summer. During monsoon season, silt, clay and other suspended particles are known to be washed into the inlet due to runoff and contribute significantly to the turbidity while during summer season settlement of silt and clay would result in the lowering of turbidity. It is also known that heavy monsoon precipitation increases turbulence and consequent higher oxygen diffusion favouring the abundant planktonic growth. The column dwelling planktonic forms do increase the turbidity.

The phosphate concentration was considerably low in the year 2015 (94.5 – 270.8 µg/L). Rapid increase was noticed during the following year, with values varying from 60.5 to 340.3 µg/L (Table 4). During both the years highest concentration was recorded in the Pre-monsoon season. The average values of phosphates during the pre-monsoon

season were 208.53 and 288.66 µg/L for the years 2015 and 2016, respectively. This trend is an indication of excessive run-in of inorganic phosphates from fertilizers used in the nearby agricultural fields, into the lagoon. Low phosphate levels recorded during summer and pre-monsoon seasons have been attributed to the limited flow of freshwater, high salinity and nutrient utilization by phytoplankton (Senthilkumar *et al.*, 2002, Rajasegar 2003) and this view is extendable to the instant study as well. Such variations are also known to be influenced by adsorption and desorption of phosphates and buffering action of sediment under varying environmental conditions (Rajasegar 2003).

The highest average concentration of ammonia nitrogen (NH₃-N) for the year 2015 was 956.78 µg/L during the post monsoon season while the highest value of 982.33 µg/L was recorded in the year 2016 during monsoon (Table 5). Further, during both the years, the values were greater at

Table 3. Spatial and seasonal variation in Turbidity* of water in NTU

| Sampling points | Post Monsoon 2015 | Summer 2015 | Pre-monsoon 2015 | Monsoon 2015 | Post Monsoon 2016 | Summer 2016 | Pre-monsoon 2016 | Monsoon 2016 |
|-----------------|-------------------|-------------|------------------|--------------|-------------------|-------------|------------------|--------------|
| S1 | 3.8 | 2.8 | 2.4 | 4.1 | 4.1 | 2.9 | 2.5 | 4.5 |
| S2 | 3.9 | 2.85 | 2.6 | 4.5 | 4.25 | 3.1 | 2.8 | 4.8 |
| S3 | 4.1 | 3.2 | 2.42 | 5.2 | 5.31 | 3.2 | 2.9 | 5.1 |
| S4 | 4.5 | 3.3 | 2.6 | 5.6 | 5.42 | 3.5 | 2.8 | 5.3 |
| S5 | 5.2 | 3.45 | 2.8 | 5.4 | 6.28 | 3.7 | 2.6 | 5.6 |
| S6 | 5.8 | 3.6 | 2.85 | 5.8 | 6.3 | 3.8 | 3.1 | 6.5 |
| S7 | 6.1 | 3.7 | 3.1 | 8.2 | 6.4 | 3.8 | 3 | 7.2 |
| S8 | 6.3 | 3.7 | 3 | 8 | 6.45 | 3.82 | 3.1 | 7.6 |
| S9 | 6.7 | 3.9 | 3.1 | 7.6 | 6.6 | 3.5 | 3.1 | 7.8 |
| AVG | 5.16 | 3.39 | 2.76 | 6.04 | 6.60 | 3.20 | 2.81 | 6.76 |
| SD | 1.16 | 0.38 | 0.27 | 1.51 | 0.30 | 0.44 | 0.19 | 0.41 |

Table 4. Spatial and seasonal variation of phosphate* concentration in KTI

| Sampling points | Post Monsoon 2015 | Summer 2015 | Pre-monsoon 2015 | Monsoon 2015 | Post Monsoon 2016 | Summer 2016 | Pre-monsoon 2016 | Monsoon 2016 |
|-----------------|-------------------|-------------|------------------|--------------|-------------------|-------------|------------------|--------------|
| S1 | 94.5 | 103.5 | 150.8 | 115 | 80.6 | 105.2 | 230.8 | 117.2 |
| S2 | 99.5 | 106.1 | 175.2 | 117.1 | 71.8 | 112.5 | 245.6 | 128.3 |
| S3 | 101 | 107.8 | 173.8 | 128.5 | 83 | 116.8 | 262.3 | 135.4 |
| S4 | 103.5 | 111.5 | 182.5 | 135.3 | 60.5 | 125.3 | 273.3 | 140.2 |
| S5 | 105.8 | 125.3 | 220.3 | 142.5 | 72.5 | 135.4 | 291.5 | 145.3 |
| S6 | 107.1 | 128.2 | 225.8 | 146.5 | 58.2 | 142.5 | 303.4 | 153.5 |
| S7 | 111.4 | 130.5 | 235.1 | 151.3 | 53.5 | 156.2 | 310.4 | 165.4 |
| S8 | 115.2 | 135.1 | 242.5 | 152.5 | 82.9 | 165.3 | 322.3 | 172.8 |
| S9 | 118.4 | 141.2 | 270.8 | 158.3 | 89.3 | 180.2 | 340.3 | 191.4 |
| AVG | 106.27 | 121.02 | 208.53 | 138.56 | 72.48 | 137.71 | 286.66 | 149.94 |
| SD | 7.69 | 13.96 | 39.53 | 15.62 | 12.63 | 25.45 | 36.38 | 23.34 |

*All values are in µg/L

sampling locations 1 to 3 which are far away from the mouth of the lagoon. This may be due to the poor exchange of water at the inlet or absence of mixing of water at the mouth of the lagoon or both. Working on the same lagoon system, Ramesh (2000) has reported that ammonia nitrogen dominates among the nitrogenous nutrients in the lagoon, indicating that the rate of ammonification is greater than the rate of nitrification.

The mean nitrate concentrations in study samples during the monsoon and post-monsoon season were 52.60 and 39.52 µg/L in the year 2015 and 55.38 and 39.48 in the year 2016, respectively (Table 6). However, there was a decrease in the mean value during the summer and pre-monsoon seasons. The increasing nitrate level can be accounted for by the fresh water inflow, litter fall decomposition and terrestrial run-off during the monsoon/post-monsoon seasons (Karuppasamy and Perumal 2000).

Another possible route of nitrates entry is through oxidation of ammonia form of nitrogen to nitrite formation (Rajasegar 2003). The low values recorded at KTI during summer and pre-monsoon period may be due to its utilization by phytoplankton as evidenced by high photosynthetic activity (Govindasamy *et al.*, 2000).

The possible anthropogenic contribution for the nitrite concentration in Kondurupalem estuary includes the excess run-in of fertilizers, pesticides and herbicides from agricultural fields, sewage and industrial effluents let out from surrounding areas. In 2015, the nitrite content in the Kondurupalem inlet water during the pre-monsoon months ranged from 31.8 to 40.6 µg/L, while it was in the range of 46.2 to 59.0 µg/L during monsoon season (Table 7). During post monsoon and summer seasons, the nitrite concentrations were significantly lower in both the years. Low values of nitrite observed during the summer may be due to

Table 5. Spatial and seasonal variation of Ammonia nitrogen*

| Sample points | Post Monsoon 2015 | Summer 2015 | Pre-monsoon 2015 | Monsoon 2015 | Post Monsoon 2016 | Summer 2016 | Pre-monsoon 2016 | Monsoon 2016 |
|---------------|-------------------|-------------|------------------|--------------|-------------------|-------------|------------------|--------------|
| S1 | 950 | 942 | 940 | 975 | 864 | 942 | 1002 | 975 |
| S2 | 975 | 956 | 942 | 978 | 857 | 968 | 1008 | 988 |
| S3 | 976 | 965 | 945 | 972 | 884 | 954 | 985 | 972 |
| S4 | 954 | 945 | 946 | 965 | 889 | 945 | 946 | 965 |
| S5 | 955 | 948 | 944 | 964 | 821 | 948 | 967 | 1002 |
| S6 | 945 | 975 | 948 | 968 | 948 | 965 | 989 | 1008 |
| S7 | 946 | 980 | 948 | 961 | 946 | 968 | 988 | 1005 |
| S8 | 948 | 985 | 951 | 880 | 948 | 985 | 991 | 958 |
| S9 | 962 | 991 | 957 | 887 | 962 | 998 | 957 | 968 |
| AVG | 956.78 | 965.22 | 946.78 | 950.00 | 902.11 | 963.67 | 981.44 | 982.33 |
| SD | 11.82 | 18.37 | 5.06 | 38.12 | 50.36 | 18.80 | 20.59 | 18.87 |

*All values are in µg/L

Table 6. Spatial and seasonal variation of nitrate* in KTI water

| Sample points | Post Monsoon 2015 | Summer 2015 | Pre-monsoon 2015 | Monsoon 2015 | Post Monsoon 2016 | Summer 2016 | Pre-monsoon 2016 | Monsoon 2016 |
|---------------|-------------------|-------------|------------------|--------------|-------------------|-------------|------------------|--------------|
| S1 | 36.2 | 11.2 | 16.1 | 48 | 35.8 | 11.9 | 15.3 | 49.5 |
| S2 | 36.8 | 11.9 | 16.9 | 49.2 | 37.8 | 12.3 | 17.2 | 52.3 |
| S3 | 37.4 | 12.8 | 18.2 | 49.8 | 36.4 | 14.8 | 19.2 | 54.5 |
| S4 | 38.9 | 14.5 | 19 | 51.3 | 39.2 | 16.2 | 22.5 | 53.8 |
| S5 | 40.4 | 15.3 | 20.1 | 52.5 | 40.5 | 17.5 | 24.8 | 56.2 |
| S6 | 40.9 | 16.5 | 20.4 | 53.5 | 41.2 | 18.2 | 25.2 | 57.2 |
| S7 | 41.5 | 18.5 | 22.8 | 54.1 | 40.9 | 20.3 | 21.3 | 57.8 |
| S8 | 41.7 | 20.2 | 24.3 | 56.2 | 41.5 | 20.9 | 25.8 | 58.1 |
| S9 | 41.9 | 21.5 | 25.9 | 58.8 | 42.0 | 22.0 | 26.8 | 59.0 |
| AVG | 39.52 | 15.82 | 20.41 | 52.60 | 39.48 | 17.12 | 21.92 | 55.38 |
| SD | 2.24 | 3.65 | 3.33 | 3.47 | 2.30 | 3.64 | 3.95 | 3.11 |

All values are in µg/L

Table 7. Spatial and seasonal variation of nitrite* in KTI water

| Sampling points | Post Monsoon 2015 | Summer 2015 | Pre-monsoon 2015 | Monsoon 2015 | Post Monsoon 2016 | Summer 2016 | Pre-monsoon 2016 | Monsoon 2016 |
|-----------------|-------------------|-------------|------------------|--------------|-------------------|-------------|------------------|--------------|
| S1 | 15.2 | 11.5 | 31.8 | 46.2 | 15.4 | 11.7 | 32.5 | 47.1 |
| S2 | 16.2 | 11.8 | 32.7 | 46.8 | 16.3 | 11.9 | 33.9 | 47.9 |
| S3 | 17.8 | 12.2 | 33.5 | 49.2 | 17.9 | 12.6 | 34.8 | 49.4 |
| S4 | 18.3 | 12.9 | 34.7 | 50.3 | 19.2 | 13.8 | 36.2 | 50.4 |
| S5 | 19.6 | 14.5 | 35.8 | 52.2 | 20.5 | 14.2 | 37.3 | 53.1 |
| S6 | 19.9 | 16.3 | 37.3 | 54.5 | 20.9 | 16.8 | 39.2 | 54.9 |
| S7 | 21.5 | 18.2 | 39.2 | 56.2 | 22.8 | 17.9 | 40.1 | 57.2 |
| S8 | 22.8 | 18.9 | 40.2 | 57.4 | 23 | 19.3 | 40.3 | 58.9 |
| S9 | 23.1 | 20.0 | 40.6 | 59.0 | 23.5 | 19.9 | 40.5 | 58.9 |
| AVG | 19.38 | 15.14 | 36.20 | 52.42 | 19.94 | 15.34 | 37.20 | 53.09 |
| SD | 2.77 | 3.29 | 3.29 | 4.63 | 2.95 | 3.19 | 3.01 | 4.62 |

*All values are in µg/L

Table 8. Spatial and seasonal variation of bicarbonates* in KTI water

| Sample points | Post Monsoon 2015 | Summer 2015 | Pre-monsoon 2015 | Monsoon 2015 | Post Monsoon 2016 | Summer 2016 | Pre-monsoon 2016 | Monsoon 2016 |
|---------------|-------------------|-------------|------------------|--------------|-------------------|-------------|------------------|--------------|
| S1 | 68 | 78 | 68 | 83 | 73 | 82 | 69 | 86 |
| S2 | 82 | 88 | 73 | 89 | 84 | 86 | 71 | 89 |
| S3 | 103 | 104 | 82 | 95 | 113 | 109 | 76 | 93 |
| S4 | 128 | 116 | 86 | 106 | 138 | 115 | 85 | 105 |
| S5 | 168 | 198 | 89 | 111 | 169 | 126 | 92 | 109 |
| S6 | 178 | 141 | 93 | 121 | 181 | 136 | 98 | 115 |
| S7 | 182 | 151 | 101 | 128 | 191 | 142 | 103 | 126 |
| S8 | 192 | 157 | 106 | 130 | 198 | 155 | 104 | 128 |
| S9 | 202 | 159 | 108 | 130 | 201 | 160 | 104 | 129 |
| AVG | 144.78 | 132.44 | 89.56 | 110.33 | 149.78 | 123.44 | 89.11 | 108.89 |
| SD | 50.49 | 38.79 | 13.97 | 18.22 | 49.63 | 27.92 | 14.33 | 16.9 |

*All values are in µg/L

minimal freshwater inflow and consequent higher salinity levels. Maximum and minimum nitrite values in monsoon and summer season, respectively have also been recorded by Prabu *et al.* (2008) in Pichavaram mangroves and Damotharan *et al.*, (2010) in Point Calimere coastal waters, India. The oscillation of aquatic plant populations during different seasons may also contribute to the uptake of nitrogenous species. Similarly, the input of N species through the metabolic route too would cause variation (Durand *et al.*, 2011).

High bicarbonate levels (68–202 mg/L) were observed during post-monsoon season (Table 8). These values are higher than those reported in earlier studies (Gayathri and Puranik 2000). During monsoon and summer seasons lower bicarbonate levels were observed (75–160 mg/l) compared to other seasons. However, the trend in bicarbonate ion profile was similar in both 2015 and 2016.

When the mouth of the system was open, there was slight increase in the chloride concentration at the lagoon entrance (13.55 to 18.95 g/L) (Table 9). This could be attributed to the copious influx of sea water which offsets the effect of freshwater entry into the lagoon from landward side. The present observations indicate that the spatial variations of chloride ions are similar to the spatial variations of salinity values. Similar observation has been reported by Gayathri and Puranik (2000) at the Pulicat mouth near the Pulicat village which is one of the mouths of the Pulicat lagoon.

CONCLUSION

Apparently heterogeneous and somewhat controversial results (as compared to those in literature) obtained during the study could be attributed to a large number of factors involved in water exchange. In the instant

Table 9. Spatial and seasonal variation of chloride* in KTI water

| Sampling points | Post Monsoon 2015 | Summer 2015 | Pre monsoon 2015 | Monsoon 2015 | Post Monsoon | Summer 2016 | Pre-monsoon 2016 | Monsoon 2016 |
|-----------------|-------------------|-------------|------------------|--------------|--------------|-------------|------------------|--------------|
| S1 | 11,200 | 12,800 | 11,628 | 10,624 | 11,250 | 12,923 | 11,240 | 10,424 |
| S2 | 11,800 | 13,600 | 11,896 | 10,826 | 11,914 | 13,287 | 11,920 | 10,984 |
| S3 | 12,600 | 14,700 | 12,414 | 11,284 | 12,205 | 14,682 | 12,286 | 11,683 |
| S4 | 12,700 | 15,380 | 12,424 | 11,686 | 12,286 | 15,683 | 12,326 | 12,524 |
| S5 | 13,510 | 16,764 | 12,618 | 12,084 | 13,184 | 16,643 | 12,944 | 13,068 |
| S6 | 14,210 | 17,433 | 13,214 | 12,486 | 13,683 | 17,682 | 13,341 | 13,923 |
| S7 | 15,100 | 17,922 | 13,388 | 13,233 | 14,186 | 18,341 | 14,088 | 13,500 |
| S8 | 15,650 | 18,928 | 14,165 | 13,054 | 14,233 | 18,689 | 14,285 | 13,254 |
| S9 | 15,690 | 19,500 | 14,645 | 13,456 | 14,946 | 19,464 | 14,525 | 13,911 |
| AVG | 13606.67 | 16336.33 | 12932.44 | 12081.44 | 13098.56 | 16377.11 | 12995.00 | 12585.67 |
| SD | 1658.70 | 2350.81 | 1008.76 | 1049.85 | 1250.52 | 2380.62 | 1146.07 | 1280.48 |

*All values are in µg/L

case, the open or closed status of the inlet assumes greater ecological significance owing to the fact that the neo-urban growth in its vicinity has been the cause of allochthonous conveyance of materials and intermediaries that have the potential to affect the water quality. To cite a specific example, during the monsoon, salinity decreased significantly as a consequence of pluvial runoffs and possible landside discharges; on the contrary, during the dry season there were only two contributors: landside discharges and the adjacent sea. This suggests that the exchange of salt and water within the system depends on the contributors. Therefore it is essential to carry out annual studies to describe the system correctly by considering the changes caused by hurricanes and windy season.

In sum, the spatio-temporal variability of water quality in the KTI of Pulicat lagoon appears to be influenced by the inter-play between the freshwater and sea water flux and the consequential tidal influence. This free exchange appears to be controlled by the periodic closing and opening of the mouth of the water body and the monsoon precipitation. The landward urbanization and industrial development add their mite to change the water quality through the run-in of wastewaters into the inlet. Time-trace data in respect of select parameters such as pH, DO, salinity and nutrients suggest such data sets when collected annually can be effectively utilized to evolve strategies for managing and maintaining the water quality through inter-and intra flow manipulation of water /wastewater from sea/land side. Of course this does not exclude or underplay the importance of data on the patterns of precipitation and mouth closing/opening while evolving management strategies for the sustainable use of this precious ecosystem. Studies in this direction are in progress.

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Canonical Correspondence Analysis for Determining Distributional Patterns of Benthic Macroinvertebrate Fauna in the Lotic Ecosystem

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Abstract: Canonical correspondence analysis (CCA) technique was used to determine the distributional patterns of benthic macroinvertebrate fauna in the rivers of central India. The central Indian rivers Ken, Paisuni and Tons were selected for this study. Four sampling stations were selected in each river i.e. Ken (K1–K4), Paisuni (P1–P4) and Tons (T1–T4). The analysis of benthic macroinvertebrate fauna revealed that abiotic substratum was most important variable in the Ken river, while current velocity in the Paisuni river. However in the river Tons, abiotic substratum and water temperature were the most important environmental variable for the distribution of benthic fauna. It indicated that the emergence of most important variables were similar in the larger rivers (the Ken and Tons) compared to the smaller river (the Paisuni). The distributional pattern of similar benthic macroinvertebrate taxon in each river was affected by common variables. Thus, the variables were important for the distribution of invertebrate fauna in different rivers though they lie in the same ecoregion.

Keywords: Ordination, Current velocity, Substratum, Macroinvertebrates, River linking

The benthic macroinvertebrate communities are widely used as indicators of environmental degradation or restoration as it broadly reflects to the change in environmental conditions. The complexity of benthic communities has led many researchers to adopt the ordination in determining the distributional patterns. The principal component analysis, principal coordinates analysis, non metric multidimensional scaling, correspondence analysis, detrended correspondence analysis and canonical correspondence analysis are various ordination methods used to determine the distributional patterns of benthic macroinvertebrate fauna. Canonical correspondence analysis (CCA) and related methodology has wide-spread use in aquatic sciences. CCA is frequently used as a preliminary analysis for determining the particular variables, whether it influences the present-day communities sufficiently to warrant palaeo-reconstruction from fossil assemblage. CCA is also used of studying seasonal and spatial variation in communities. The variance can be fully decomposed into seasonal, spatial, environmental and random components.

In India, studies on the distributional patterns of benthic macroinvertebrate fauna are fragmented (Nautiyal and Semwal, 2006; Mishra and Nautiyal, 2016; Nautiyal *et al.*, 2017). Further, there are no studies to determine the role of environmental variables in distribution of benthic

macroinvertebrate fauna. Thus, the aim of this study was to determine the environmental variables responsible for benthic macroinvertebrate distribution in the central Indian rivers; the Ken, Paisuni and Tons by using ordination technique especially canonical correspondence analysis (CCA). Since, the river Ken is one of the river of Ken–Betwa river link programme, therefore this study will be important to have knowledge about distribution of benthic macroinvertebrate fauna and governing factors and will be a bench marks for future such study.

MATERIAL AND METHODS

Study area: The Malwa, Bundelkhand and Chota Nagpur Plateaus that form the northern subdivision of the ancient (Gondwana) triangular shaped tableland – the Peninsular Plateau in Central India are source of many northflowing small, medium and large rivers (the Chambal, Kali, Sindh, Parbati, Betwa, Dhasan, Ken, Paisuni) that are tributaries of the lower Yamuna and Tons, Son that of the Ganga river. This geographical region is bound by the Gangetic Plains to the north and east, and the Deccan Peninsula to the south. The two nearby drainages the Ken (Yamuna river) and the Tons (the Ganga) along with in between Paisuni are the subject of this study. These rivers are the major source for irrigation, and have high religious significance. The Ken will be linked to Betwa under National River Linkng Project (NRLP) as this

link has been approved (NWDA, 2006; www.economictimes.indiatimes.com/news, 2017). These drainages lie within 24 to 26°N latitude, 79 to 82°E longitude and altitude 360 to 72 m above sea level from source to confluence. Locations sampled on the Ken are labelled K1 to K4, Paisuni P1 to P4 and Tons T1 to T4 (Figure 1), dividing the river into four gross sections including the upper (K1, P1, T1), middle (K2, P2, T2), and lower plateau (K3, P3, T3) and a mouth section (K4, P4, T4). The physiography, climate, and vegetation have been described earlier (Mishra and Nautiyal, 2011; Nautiyal and Mishra, 2012).

Sampling: For this one-time intensive sampling was conducted as suggested by Corkum (1989) and the rationale for which has been described earlier by the authors (Mishra and Nautiyal, 2011; Nautiyal and Mishra, 2012). A total number of 11 environmental variables (latitude, longitude, altitude, slope, landuse, abiotic substratum, biotic substratum, discharge, current velocity, water temperature and pH) were selected for the study. Water temperature (WT; Mextech, multi meter), current velocity (CV –EMCON current meter) and pH (Hanna portable digital meters) were analyzed with standard methods. Standard methods were adopted for categorization of substrates type (Resh and Rosenberg, 1984) and discharge calculation (Henderson, 2003). The map variables (latitude, longitude, altitude, slope) were

recorded with Global Positioning System (GPS, Garmin). Benthic macroinvertebrate fauna was sampled intensively (20 quadrats per station) using standard techniques described in earlier publications (Mishra and Nautiyal, 2011; Nautiyal and Mishra, 2012). Macroinvertebrate counts were used to determine relationship between benthic macroinvertebrate fauna and environmental variables with the ordination methods Canonical Correspondence Analysis (CANOCO ver. 4.1; ter Braak and Smilauer 2002).

RESULTS AND DISCUSSION

In the river Ken, the eigen values for CCA axis 1 and 2 explained cumulative variance in taxonomic composition and taxon-environmental relationships at all stations from K1 to K4 (Figure 2). Out of 11 environmental variables, abiotic substratum (stony boulder/cobble/pebble, silt, sand and clay) was the most important environmental variable which caused 67.3% variation in taxonomic composition at K1 ($r^2=0.6467$.) and 40.5% variation at K3 ($r^2=0.7558$). However, biotic substratum (aquatic vegetation; 38.8%) emerged as most important variable at K3 ($r^2=-0.685$). The positive or negative sign indicated the higher association of substrate variable with positive or negative axis of the quadrat. At K4, depth (30.7%; $r^2=0.477$.) along with abiotic substratum (30.7%; $r^2=-0.521$.) emerged equally as most important environmental

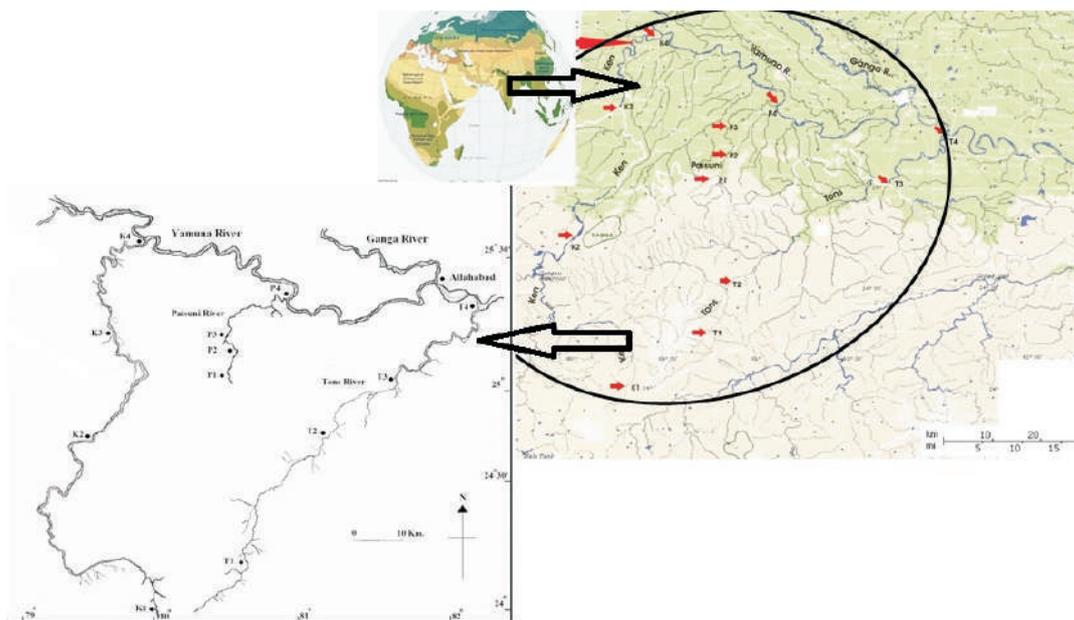


Fig. 1. The globe map indicates India location in the world. Arrow indicates central India in the Indian map and drainage systems. The rivers Ken, Paisuni and Tons along with sampling stations are shown in the map

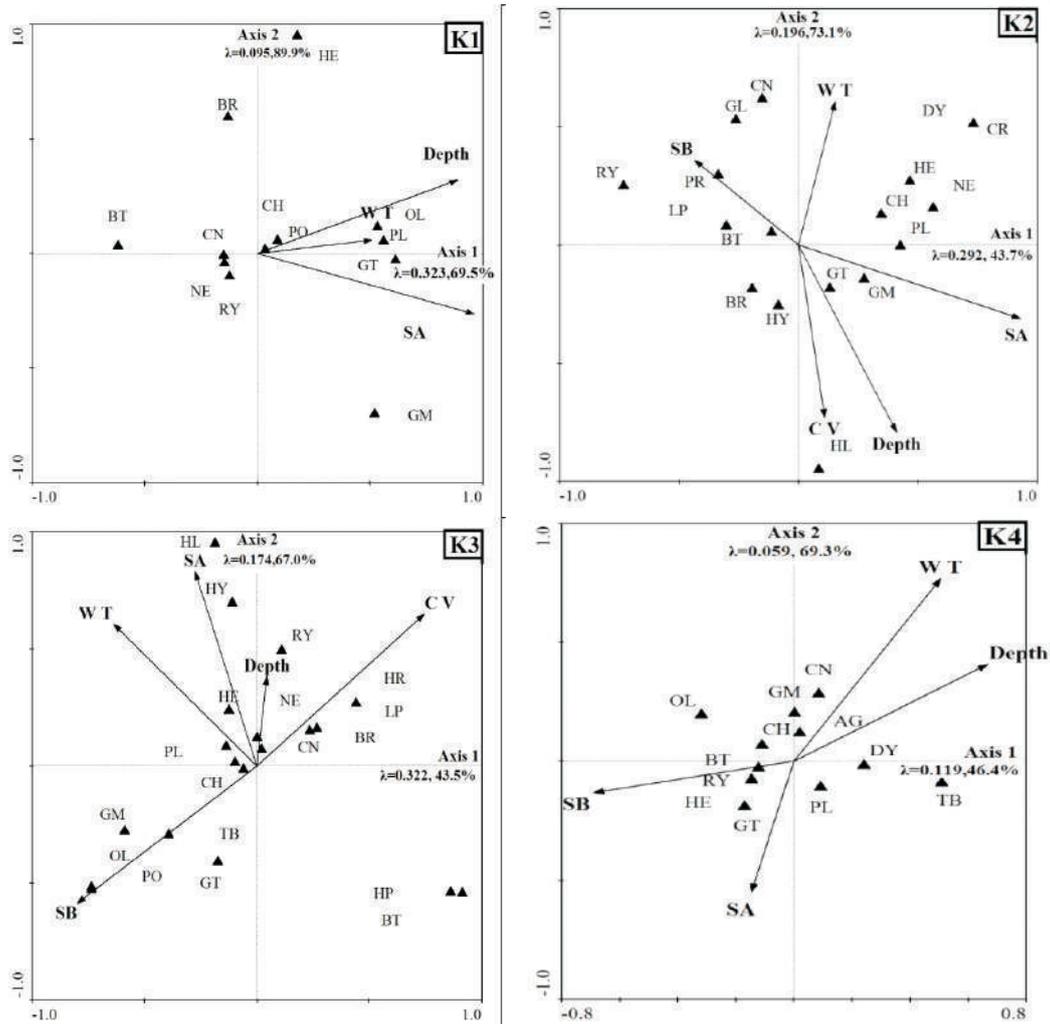


Fig. 2. CCA ordination in the river Ken at various stations (K1 to K4). The triangle indicates the benthic macroinvertebrate taxa and the arrow indicate environmental variables. Acronyms: SA- Substratum abiotic, SB-Substratum biotic, AG- Agrionidae, BT-Baetidae, BR-Brachycentridae, CH-Chironomidae, CN-Caenidae, CR-Crustacea, DY-Dytiscidae, EP-Ephemeroptera, GL Glossosomatidae, GM-Gomphidae, GT-Gastropoda, HP-Heptageniidae, HL-Hydroptilidae, HY-Hydropsychidae, LP-Leptophlebiidae, NE-Neophemeridae, OL-Oligochaeta, HE-Heleidae, PO-Polychaeta, PR-Perlidae, PL-Pelecypoda, RY-Rhyacophilidae, TB-Tabanidae

variable. The role of abiotic substratum on the distribution of benthic macroinvertebrate fauna gradually declined downstream of the river at K1, K3 and K4 (Table 2). The second important variable was depth at K1 and K3 while water temperature at K2 and biotic substratum at K4 (Table 2). The different environmental variables were responsible for the longitudinal variation in the distribution of invertebrate fauna (Table 5). Similarly, in case of Paisuni river, the eigen values for CCA axis 1 and 2 explained cumulative variance in taxonomic composition and taxon-environmental relationships from station P1 to P4 (Figure 3). Current velocity was the most important environmental variable at P1 35.7% ($r^2=-0.7343$), P2 33.3% ($r^2=0.7073$) and P3 55.5% ($r^2=-0.861$) and its share increased from P1 to P3. However,

at P4 abiotic substratum (48.7%, $r^2=-0.554$) was emerged as most important variable. The second most important variable was water temperature at P1 and P3, while abiotic substratum at P2 and depth at P4 (Table 3). The associated taxa varied with change in environmental variables (Table 5). In the river Tons, the eigen values of CCA explained axis 1 and 2 for cumulative variance in taxonomic composition and taxon-environmental relationships. The share of variation among the stations from T1 to T4 (Figure 4). The biotic substratum was major environmental factor responsible for variation in taxonomic composition at T1 ($r^2=0.7397$), while abiotic factor was important variable at T2 ($r^2=-0.9280$) and T3 ($r^2=0.9013$). However at T4, water temperature emerged as most important variable ($r^2=-0.8204$), for the distribution of

benthic macroinvertebrate fauna (Table 4). The taxonomic composition was also influenced by water temperature at T1, depth at T2, current velocity at T3 and biotic substratum at T4 accounting for 31.3, 11.1, 40.5 and 30.7 percent, respectively (Tables 4). The longitudinal distribution of benthic

macroinvertebrate fauna varied with respect to change in environmental variables (Table 5).

Several studies have been conducted to determine distributional patterns of the benthic macroinvertebrate fauna by using multivariate methods either simulation of data. In the

Table 1. Geographical co-ordinate of the sampling stations in different rivers of the Central Highlands region

| Sampling stations | Latitude (°N) | Longitude (°E) | A (m a.s.l.) | DS (Approx) |
|-------------------|---------------|----------------|--------------|-------------|
| K1-Shahnagar | 23°59'28.92" | 80°18'1.77" | 365 | 20 |
| K2-Panna | 24°44'17.38" | 80°0'41.16" | 200 | 142.5 |
| K3-Banda | 25°28'38.25" | 80°18'51.62" | 95 | 267.5 |
| K4-Chilla | 25°46'15.49" | 80°31'36.99" | 86 | 340 |
| P1-Anusuya | 25°04'25" | 80°52'05" | 180 | 10 |
| P2-Chitrakut | 25°10'25.65" | 80°52'12.31" | 135 | 26 |
| P3-Purwa | 25°13'01.36" | 80°54'09.33" | 131 | 42 |
| P4-Rajapur | 25°25'25" | 81°08'52" | 80 | 100 |
| T1-Maihar | 24°16'14.13" | 80°48'18.11" | 326 | 56 |
| T2-Satna | 24°33'42.88" | 80°54'26.34" | 290 | 98 |
| T3-Chakghat | 25°02'01.06" | 81°43'51.75" | 94 | 232.5 |
| T4-Meja | 25°16'29.99" | 82°04'59.07" | 72 | 305 |

Acronyms: DS-Distance from source (Km.), A-Altitude

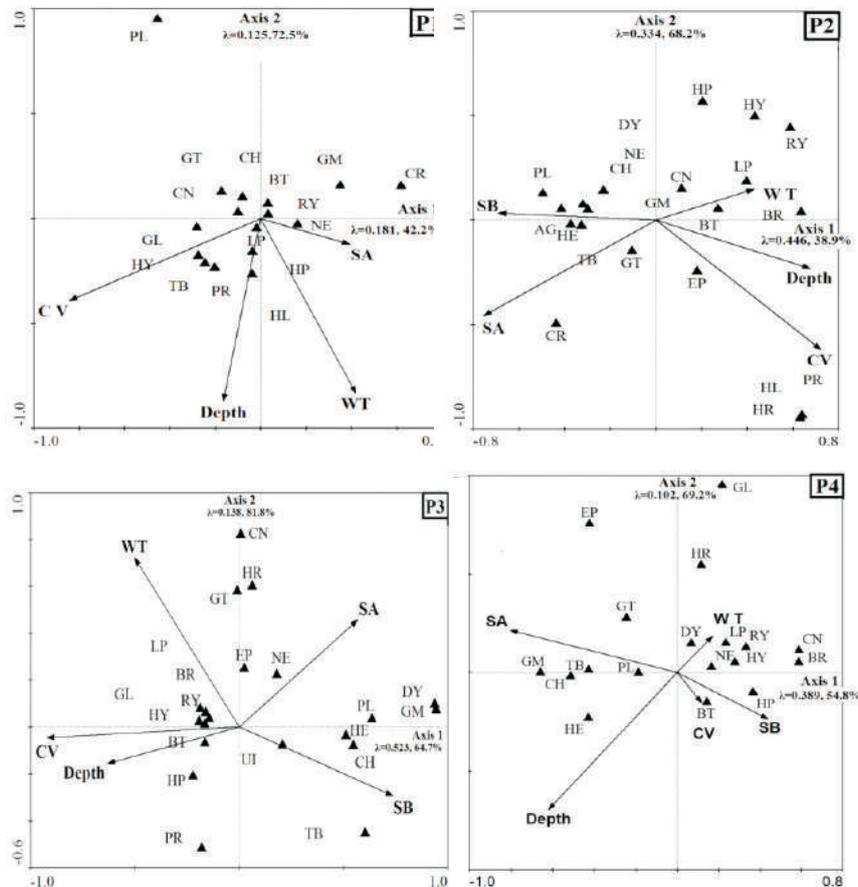


Fig. 3. CCA ordination in the river Paisuni at various stations (P1 to P4). The triangle indicates the benthic macroinvertebrate taxa and the arrow indicate environmental variables. Acronyms are similar as figure 2

Table 2. Correlation of significant environmental variables with respect to all the four ordination axes and percentage of variance caused by the environmental variables on the distribution of benthic macroinvertebrate fauna in the Ken river at various stations

| K1 | Axis 1 | Axis 2 | Axis 3 | Axis 4 | P-value | F-value | % of variance |
|-----------|--------|--------|--------|--------|---------|---------|---------------|
| Sa | 0.646 | -0.198 | -0.032 | 0.000 | 0.004 | 3.32 | 67.3 |
| D | 0.597 | 0.240 | -0.216 | 0.000 | 0.131 | 1.03 | 19.5 |
| W T | 0.341 | 0.044 | 0.571 | 0.000 | 0.682 | 0.68 | 13.0 |
| K2 | | | | | | | |
| Sb | -0.685 | -0.479 | 0.079 | -0.070 | 0.004 | 3.31 | 38.8 |
| WT | -0.545 | 0.495 | 0.252 | -0.204 | 0.004 | 2.70 | 28.3 |
| D | 0.037 | 0.313 | -0.640 | -0.185 | 0.156 | 1.44 | 13.4 |
| Sa | -0.236 | 0.680 | 0.095 | -0.326 | 0.472 | 1.02 | 10.4 |
| CV | 0.638 | 0.531 | -0.008 | -0.118 | 0.710 | 0.78 | 8.9 |
| K3 | | | | | | | |
| Sa | 0.755 | -0.245 | 0.162 | 0.035 | 0.002 | 2.98 | 40.5 |
| D | 0.333 | -0.623 | 0.230 | -0.149 | 0.118 | 1.52 | 20.2 |
| CV | 0.089 | -0.575 | 0.068 | 0.270 | 0.420 | 1.06 | 14.8 |
| Sa | -0.353 | 0.282 | 0.546 | 0.209 | 0.422 | 1.07 | 13.5 |
| WT | 0.125 | 0.477 | -0.323 | 0.363 | 0.558 | 0.86 | 10.8 |
| K4 | | | | | | | |
| Sa | -0.104 | -0.331 | -0.050 | -0.521 | 0.190 | 1.37 | 30.7 |
| D | 0.477 | 0.246 | -0.333 | 0.248 | 0.122 | 1.45 | 30.7 |
| Sb | -0.492 | -0.079 | -0.266 | -0.380 | 0.404 | 1.02 | 19.3 |
| WT | 0.361 | 0.464 | 0.084 | -0.237 | 0.518 | 0.93 | 19.3 |

Acronyms: Sa-Abiotic substratum, Sb-Biotic substratum, D-Depth, WT-Water temperature, CV-Current velocity

Table 3. Correlation of significant environmental variables caused by the environmental variables on the distribution of benthic macroinvertebrate fauna in the Paisuni river at various stations

| P1 | Axis 1 | Axis 2 | Axis 3 | Axis 4 | P-value | F-value | % of variance |
|-----------|--------|--------|--------|--------|---------|---------|---------------|
| CV | -0.734 | -0.333 | -0.102 | 0.151 | 0.076 | 1.68 | 35.7 |
| WT | 0.366 | -0.710 | 0.216 | 0.066 | 0.220 | 1.43 | 30.9 |
| Sa | 0.342 | -0.104 | -0.570 | 0.145 | 0.448 | 1.02 | 21.4 |
| D | -0.144 | -0.741 | -0.261 | -0.110 | 0.764 | 0.55 | 11.9 |
| P2 | | | | | | | |
| CV | 0.707 | -0.607 | -0.218 | 0.121 | 0.002 | 3.65 | 33.3 |
| Sa | -0.738 | -0.448 | -0.352 | 0.171 | 0.002 | 3.78 | 28.9 |
| D | 0.660 | -0.227 | 0.504 | -0.323 | 0.008 | 2.68 | 19.2 |
| WT | 0.420 | 0.144 | -0.401 | -0.522 | 0.026 | 1.81 | 12.2 |
| Sa | -0.675 | 0.032 | -0.126 | -0.047 | 0.546 | 0.93 | 6.1 |
| P3 | | | | | | | |
| CV | -0.861 | -0.037 | 0.110 | -0.206 | 0.002 | 7.27 | 55.5 |
| WT | -0.469 | 0.589 | 0.097 | -0.252 | 0.002 | 2.25 | 16.0 |
| Sa | 0.531 | 0.372 | 0.250 | -0.415 | 0.002 | 2.25 | 14.8 |
| Sb | 0.688 | -0.238 | -0.371 | -0.324 | 0.222 | 1.33 | 8.6 |
| D | 0.688 | -0.238 | -0.371 | -0.324 | 0.786 | 0.66 | 4.9 |
| P4 | | | | | | | |
| Sa | -0.554 | 0.138 | -0.078 | -0.199 | 0.032 | 2.05 | 48.7 |
| D | -0.415 | -0.485 | -0.416 | -0.023 | 0.252 | 1.24 | 30.7 |
| C V | 0.076 | -0.100 | 0.540 | 0.548 | 0.668 | 0.77 | 20.5 |
| WT | 0.144 | 0.124 | -0.349 | -0.371 | 0.696 | 0.79 | 17.9 |
| Sb | 0.306 | 0.110 | -0.378 | -0.395 | 0.716 | 0.75 | 17.9 |

Acronyms same as Table 2

Table 4. Correlation of significant environmental variables with respect to all the four ordination axes and percentage of variance caused by the environmental variables on the distribution of benthic macroinvertebrate fauna in the Tons river at various stations

| T1 | Axis 1 | Axis 2 | Axis 3 | Axis 4 | P-value | F-value | % of variance |
|-----------|--------|--------|--------|--------|---------|---------|---------------|
| Sb | 0.739 | 0.430 | -0.104 | -0.046 | 0.046 | 2.48 | 38.8 |
| WT | 0.699 | -0.483 | -0.034 | -0.122 | 0.006 | 2.12 | 31.3 |
| Sa | 0.661 | -0.340 | 0.383 | -0.114 | 0.536 | 0.85 | 13.4 |
| D | -0.419 | 0.267 | 0.013 | -0.543 | 0.804 | 0.62 | 8.9 |
| CV | -0.598 | 0.490 | 0.079 | -0.195 | 0.896 | 0.49 | 7.4 |
| T2 | | | | | | | |
| Sa | -0.928 | 0.011 | -0.079 | 0.229 | 0.002 | 9.22 | 63.8 |
| D | 0.450 | 0.310 | 0.597 | -0.309 | 0.018 | 1.81 | 11.1 |
| CV | -0.683 | 0.283 | 0.126 | 0.485 | 0.038 | 1.72 | 11.1 |
| WT | 0.478 | -0.419 | 0.365 | -0.343 | 0.258 | 1.26 | 8.3 |
| Sb | -0.649 | -0.366 | 0.177 | 0.248 | 0.580 | 0.91 | 5.6 |
| T3 | | | | | | | |
| Sa | 0.901 | 0.275 | 0.132 | -0.003 | 0.002 | 5.44 | 43.9 |
| CV | -0.188 | -0.935 | 0.088 | 0.007 | 0.002 | 6.48 | 40.5 |
| D | -0.400 | 0.618 | 0.332 | -0.377 | 0.206 | 1.28 | 8.6 |
| WT | -0.040 | -0.839 | -0.245 | -0.289 | 0.232 | 1.18 | 6.8 |
| T4 | | | | | | | |
| WT | -0.820 | 0.025 | -0.184 | 0.000 | 0.002 | 2.53 | 50 |
| Sb | 0.119 | 0.744 | -0.212 | 0.000 | 0.160 | 1.46 | 30.7 |
| D | 0.479 | -0.132 | -0.524 | 0.000 | 0.432 | 0.97 | 19.2 |

Acronyms same as Table 2

river Ken, substratum (abiotic substratum and biotic substratum) emerged as the major environmental variable responsible for the distributional patterns at most of the stations attributed to substrate heterogeneity. The substrate heterogeneity decreased from head water (rock, boulder, cobble, pebble, sand) to mouth (silt-clay), thus the amount of substrate variation decreased. In the Tons river, substrate was also important variable for the longitudinal variation in the invertebrate fauna because of substrate heterogeneity at T1 to T3. However, at T4, water temperature emerged as most important variable attributed to sampling time, which extended from noon to evening and morning to noon in contrast to the morning – evening schedule followed at other stations. In contrast to substratum in the Ken and Tons, current velocity was the most important environmental variable at P1 and P3 and abiotic substratum at P4 in the Paisuni river. The amount of variation explained by current velocity was not as high as by substratum in the Ken and the Tons. Thus, the physical gradient caused by type of substratum diminishes from source to mouth both in the Ken and the Tons in contrast to increase in the gradient set up by current velocity in the Paisuni. It can be safely assumed that the physical gradients become weak in the longer rivers such

as the Ken and the Tons compared with the shorter rivers. The slope is high for the Paisuni (ca. 2.0 m Km⁻¹) owing to small length compared with the Ken and the Tons (0.91, 1.02 m Km⁻¹, respectively), which may be a factor influencing the gradients of various physical parameters. Gastropoda and Pelecypoda were associated with the abiotic substratum at stations K1, K3, K4 in the Ken river and at T2 and T3 in the Tons river, because these stations have hard (stony) and soft (clay and sand) substratum along with agriculture land use at both the banks of the river. The presence of agriculture land use provides open area for the maximum penetration of the sunlight, results in the increase of producers in the river system and allow the presence of the scrapers. The taxa Glossosomatidae, Hydropsychidae, Perlidae, Caenidae, Brachycentridae, Hydropsychidae, Rhyacophilidae and Chironomidae were positively associated with current velocity in the Paisuni river at P1 and P3 because these stations have high variation in the current velocity. Similarly Leptophlebiidae and Heptageniidae were associated with water temperature and depth at P2 and P4 due to high variation in sampling time (morning to evening) and depth compared to other stations.

Mishra and Nautiyal (2011) reported that land use,

Table 5. The relationships of benthic macroinvertebrate taxa with the environmental variables at different station among the rivers, Ken Paisuni and Tons

| River | Station | Environmental variable and Associated taxa |
|----------|---------|---|
| Ken | K1 | Abiotic substratum: Gastropoda, Gomphidae Depth and water temperature: Heleidae, Chironomidae, Oligochaeta, Pelecypoda |
| | K2 | Biotic substratum: Oligochaeta, Polychaeta, Gomphidae, while Water temperature and abiotic substratum: Hydropsychidae, Heleidae and Pelecypoda Current velocity and depth: Rhyacophilidae, Neophemeridae, Brachycentridae, Hirudinea |
| | K3 | Abiotic substratum: Gastropoda, Pelecypoda Gomphidae Water temperature: Heleidae, Chironomidae and Neophemeridae Current velocity and depth: Hydroptilidae, Hydropsychidae |
| | K4 | Abiotic substratum: Gastropoda and Pelecypoda Depth and water temperature: Chironomidae, Gomphidae, Caenidae |
| Paissuni | P1 | Current velocity: Hydropsychidae, Glossosomatidae, Chironomidae Water temperature and depth: Leptophlebiidae, Perlidae, Heptageniidae and Hydroptilidae |
| | P2 | Current velocity: Ephemerillidae, Perlidae, Hydroptilidae, Oligochaeta and Hirudinea Water temperature: Leptophlebiidae, Brachycentridae, Baetidae, Heptageniidae, Hydropsychidae |
| | P3 | Current velocity and the depth: Perlidae, Brachycentridae, Hydropsychidae, Rhyacophilidae, Baetidae, Heptageniidae |
| | P4 | Abiotic substratum: Gastropoda, Tabanidae, Pelecypoda Water temperature: Leptophlebiidae, Glossosomatidae, Hydropsychidae, Hirudinea, Rhyacophilidae, Neophemeridae |
| Tons | T1 | Biotic substratum: Gomphidae, Tabanidae Gastropoda, Perlidae, Water temperature and abiotic substratum: Oligochaeta, Caenidae, Neophemeridae and Glossosomatidae |
| | T2 | Abiotic substratum and current velocity: Gastropoda, Polychaeta, Chironomidae, Gomphidae, Tabanidae Biotic substratum: Oligochaeta, other Coleoptera, Agrionidae |
| | T3 | Abiotic substratum: Gastropoda, Culicidae, Gomphidae, Heleidae and Tabanidae Current velocity & water temperature: Baetidae, Brachycentridae, Ephemerillidae, Heptageniidae, Hydropsychidae, |
| | T4 | Water temperature: Chironomidae, Agrionidae, Heleidae, Tabanidae Biotic substratum: Polychaeta, Gastropoda |

current velocity and abiotic substratum were the important variable in the river Paisuni of Central India. However, the taxa *Philopotamidae* - *Limnephilidae* - *Leptoceridae* - *Baetidae* - *Perlodidae* - *Leptophlebiidae* were associated with the slope in the Himalayan (Nautiyal *et al.* 2015) and *Nephthyidae* - *Glossoscolecidae* - *Gomphidae* - *Elmidae* - *Chironomidae* - *Dysticidae* - *Thiaridae* - *Agrionidae* were associated with abiotic substratum in the Vindhyan rivers (Nautiyal and Mishra 2012; Mishra and Nautiyal 2013). The current velocity was an important factor for abundance and distribution of *Glossosomatidae*-*Hydropsychidae*-*Brachycentridae* and *Baetidae* in a central Indian river the Paisuni (Mishra and Nautiyal 2011). Malmqvist and Maki (1994) observed that current velocity, water conductivity, substrate size and abundance of aquatic plants, elevation and water temperature affect the distribution of benthic macroinvertebrate fauna. Wang *et al.* (2012) reported that the distribution of benthic macroinvertebrate was mainly related to NO₃-N, altitude, streambed width, Chemical

oxygene demand, total Phosphorus and Ca⁺² in the south China rivers. Jun *et al.* (2016) also observed that altitude was the most significant factors followed by coarse particles and fine particles for the distribution of the benthic macroinvertebrate community in the Korean river. In the African river water current velocity, substrate size, conductivity and abundance of aquatic plants were important variables responsible for distribution of the benthic macroinvertebrate fauna (Miserendino 2001).

CONCLUSION

Study indicated that substratum emerged as the most important variable in the Ken river and Tons, while current velocity in the Paisuni river. It is also indicated that the effective environmental variables are similar in larger rivers (Ken and Tons) but different from smaller river (the Paisuni). Thus the proximate environmental variables are more important rather than river length (stream order) in the distribution of invertebrate fauna.

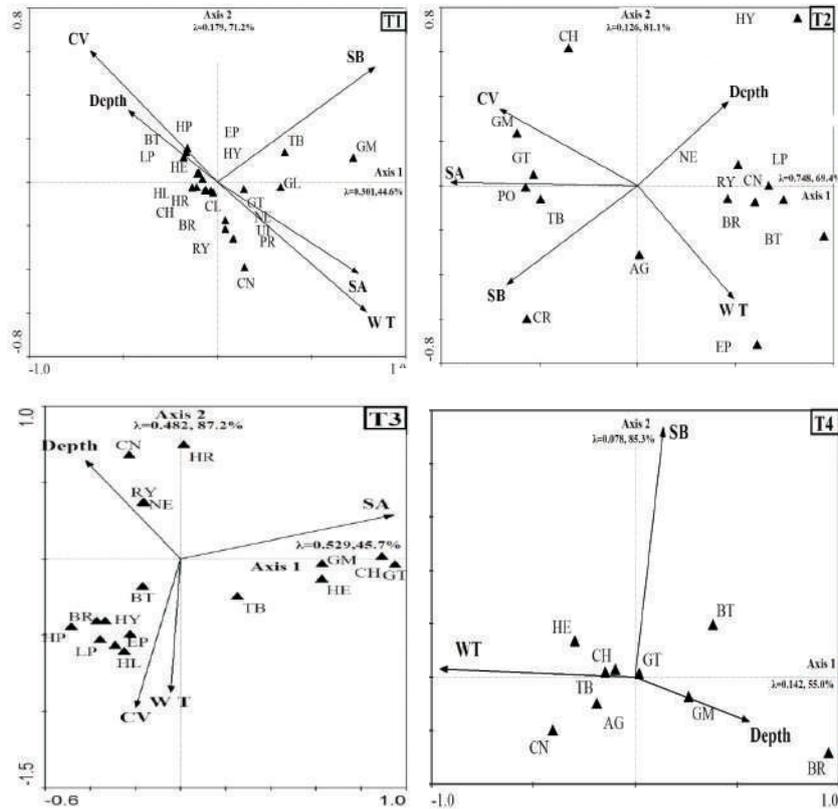


Fig. 4. CCA ordination in the river Tons at various stations (T1 to T4). The triangle indicates the benthic macroinvertebrate taxa and the arrow indicate environmental variables. Acronyms are similar as figure 2

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Biology of Macrofauna in Lotic and Lentic Facies at Dam "El Ghoress" on Za river (Morocco)

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Abstract: The inventory of 32 aquatic invertebrates' taxa sign of a relatively good water quality. The settlement of these macroinvertebrates of running water presents a balance of distribution at the study site that is characterized by an average altitude and relatively low water flow to disturb. This stand is marked by the absence of *Plecoptera*. These results were well check by calculating diversity and fairness. Pollutant species located further downstream are negative indicators because they are inferred from pure water. Among the indicators of clean water we will cite as benthic invertebrates: Ephemeroptera Heptageniidae, some families of coleoptera such as Elmidae and to a lesser extent trichoptera. The diagnoses using the presence of biological indicators species are based on two phenomena which appear jointly downstream from an allogeneic supply of substances liable to assimilation according to the classic schemes of self-purification processes. The organization of the stationary communities is close related to environmental conditions (current velocity, water temperature, substrate riparian vegetation and chemical characteristics impacts). The floods depend directly on the rainfall regime and appear as one of the conditions unfavorable to the life of the aquatic fauna by the sudden modifications of the environment and the disappearance of certain species. After the flood recolonization takes place according to species and habitats.

Keywords: Za river, Distribution, Ecology, Biological indicators, Benthic macrofauna

Management of natural aquatic environments responds to a double concern, protection of the ecosystem and its biological potentialities as an element of our major environmental and preservation of water resources in quantity and quality. The majority of the work is based on the examination of macroscopic invertebrate communities comprising in France about more than 150 families, 700 genera and 2 200 species listed (Berrahou *et al.*, 2001). The great merit of such statements is to provide the most complete picture of the settlement of a site at a given age could serve as a reference for future studies it is the gait of selective impact studies. The settlement of a site is the dependence of a set of natural conditions of sediments and structure of the mosaic of habitats and physicochemical qualities of water topography. The operation of the lotic system is dominated by flows whose direction is privileged from upstream to downstream (Hynes 1960). These flows of interest to the water itself the suspended solids organic and mineral and living organisms (Amuli, 2017; Berrahou, 1988). The present work has the main goal to establishment faunal inventory as complete as possible of benthic macrofauna on the dam site "EL Ghoress" on the Za river.

MATERIAL AND METHODS

Levies protocol of benthic macrofauna: The quantitative

harvest of the benthic fauna is composed of six samples carried out on a minimum surface of 0.1m (25cmx 40cm). With three samples of lotic's facies (fast water) and three in lentic's facies (slow water) taking into account the nature of the substrate and the flow of water. The suber used has an opening of 20 x 25 cm, is made of nylon mesh fabric of 0.80 mm. Method of harvesting used by several researchers (Bazairi *et al.*, 2005; Chavanon, 1979; Berrahou, 1988, Verneaux, 1984).

Sorting: The collected fauna was fixed on the terran with alcohol (10%) then sorted in the lab Then the animals were preserved in alcohol 90%.

Relative abundance:

$$Nr = \frac{r}{N} \times 100$$

Nr: relative abundance of taxa; r : absolute abundance of taxa; N : total number of individuals of the stand.

Overall structure stands across structural indices.

shannon diversity indices: The Shannon-Weaver diversity index reflects how individuals are distributed among the units in a systematic animal community. It also tracks overall temporal evolution of an animal population structure. It is given by the following formula:

$$H' = 3.322 (\log Q - \sum q_i \log q_i)$$

Where Q = total number of individuals and q_i = number of individuals of each taxon.

Equitability J' : This was estimated as:

$$J' = \frac{H'}{H' \text{ max}}$$

Where $H' \text{ max} = 1 \log_2 S$ and S is the total number of species

Description of study site: The area downstream of the dam site El Ghoress represents a mountainous strip of 20 to 30km wide which extends for about 100 Km from the plain to the Guercif WSW to the border of Morocco and Algeria (Fig.1). This area called horst in the river Za and presents a synclinal allure by crossing accidents WSW – ENE. The massive Narguechoum it culminates at an altitude of 1373m. The Layouts El Ghoress dam on the river Za located 40 km south of the city of Taourirt (a crow flies). The El Ghoress study site is located at the following coordinates:

$X = 752.900$; $Y = 404.200$; A coronation level of 694.50m NGM ; $Z = 624.50m$.

The floods of the Za River spread through the Highlands basin. The slope is relatively steep between the site of the dam and Taourirt (about 7%) causes erosion of the banks and the draining of the reservoir of the dam Mohamed V. The average flow of water is 2320 l/s.

RESULTS AND DISCUSSIONS

Inventory of fauna: The inventory fauna is given in Table 1.

Taxonomic richness: The taxonomic richness is low between February and April and then increases and becomes maximum in June and slightly relapse in July (Fig. 3). In March the taxonomic richness is low mainly due to the effects of the floods in this month. The taxonomic richness is dominated by ephemera in the rapid facies whereas in slow facies there are mainly dipteres that take over. This wealth increases from the source (or rapid facies there is a minimum) or the current speed is fast and the macroscopic aquatic vegetation is absent to downstream (slow facies).

Berrahou (1988) shows that mayflies are the largest group (50.5%) dominated by the rheophilic species: *B. pavidus* which represents 71% of the group's workforce. The Mollusks represented by a single species *M. praemorsa* constitute 25.9% of the total population of the station. The diptera represent only 13.9%. In our study station the maximum relative abundance is reached in June. When species richness is high and the distribution of individuals between the balanced cash (settlement shows no dominant species) the value of H' is high. Conversely when in the stand some species are largely dominant in effective compared to other H' is small. The overall value of H' of 3.1 bits. The primary advantage of such an index of diversity is that it holds



Fig. 1. Location of stations study

in that there is a good correlation between the values obtained by placing various taxonomic levels of increasing rank (species, gender and tribe family) in the quantitative analysis of a biocoenosis (Amuli, 2017; in Ramade, 1984). Thus H' is low in February While it has its maximum in June.

$H' \text{ max} = 4.0$ bits which gives us a value of Equitability $J' = 63.26\%$ (Tab. II).

Ecology main groups

Ephemeroptera: Of the 5 types of Ephemeroptera identified two deserve to be taken into consideration because of their frequency and their abundance high. The *Baetis* genres and *Caenis* can be considered as the common Ephemeroptera and characteristics of this sector. The genus *Baetis* is the most frequent and the most common of the *Baetidae* in the rivers of Morocco. The species of this genus disappear in summer this lomag be due to high temperatures during of July. In spring (April-May) there is a high larval density followed by a drop in July. This phenomenon is related to the flight period of the insects from May to October (in Roger and al. 1991). The smaller numbers were observed in winter (Fig 10) as embryonic stage of these species at temperature less than 10° C (stop that does not concern all eggs in a single spawning) when the temperature increases outbreaks resumed after a few days latency (Roger and al. 1991). The genus *Caenis* present at low densities facies Lotic which could be attributed to the rapid current. This type is common in the course of Moroccan waters and can lift up to 2000m even in cold springs but with low abundance (Dakki, 1979).

Trichoptera: Their abundance is low at the reference station. On the whole sector especially *Trichoptera* are represented

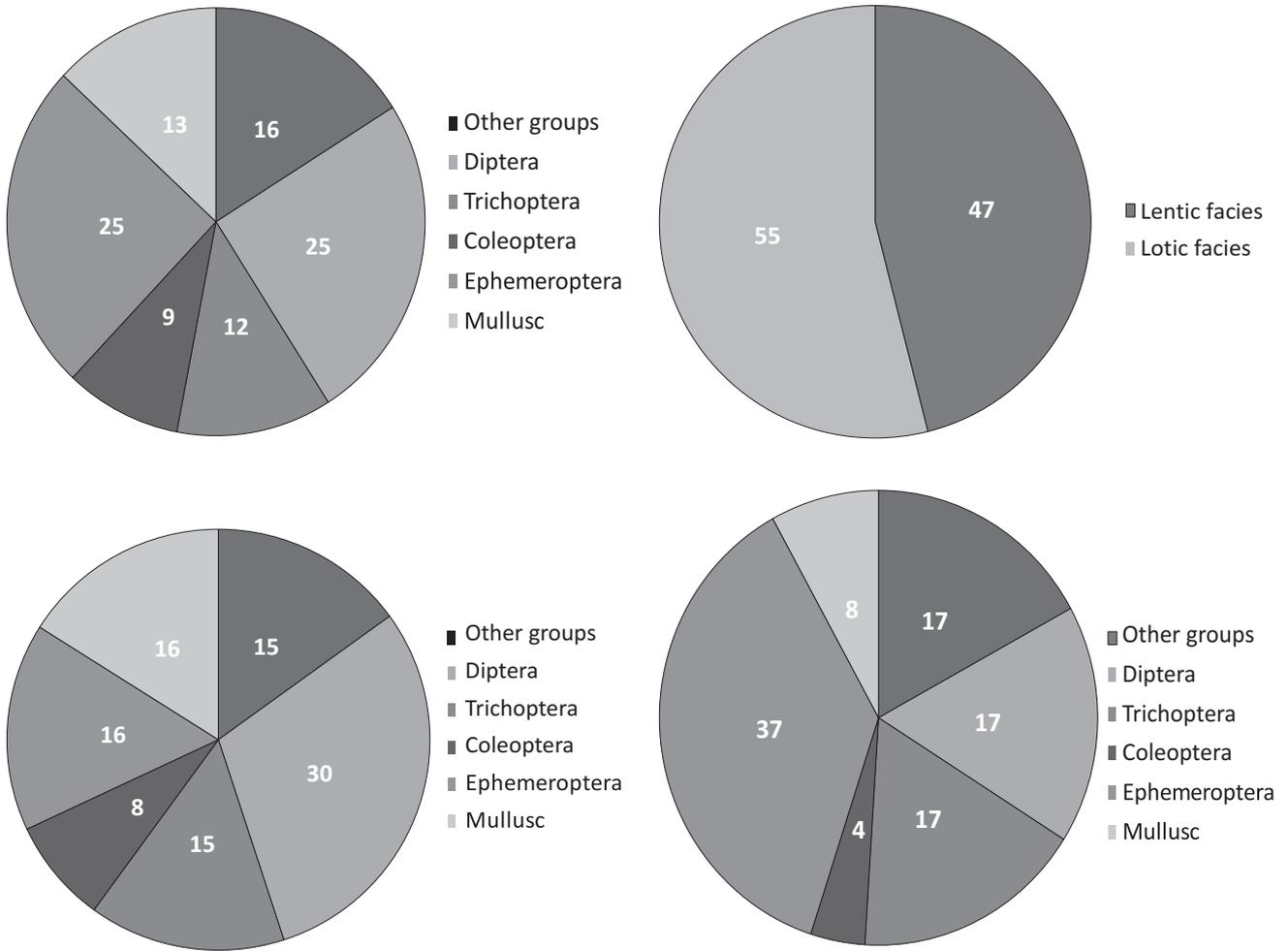


Fig. 2. Spectrum of different taxa in different facies

by *Hydropsychidae*, *Hydroptilidae* and *Rhyacophilidae*. The genus *Hydropsyche* is well represented at the study site where it develops during all months of study. Trichoptera larvae of the genus *Hydropsyche* are indicative of running water and also indicate a water loaded with matter (various) in suspension and that the flow of this matter is important. It should also be noted that from April onwards the diapause phenomena may be shortened as a result of the increase in the temperature of the summer or the warming of species of the genus *Hydropsyche* which are relatively thermophilous because of their abundance in June and July.

Diptera: They are largely dominated by the *Chionomidae* family whose abundance is highest in June and lowest in February. Other Diptera collected in this station the *Simuliidae*, the *Ceratopogonidae*, the *Tipulidae*, the *Psychodidae*, *Tabanidae* and *Empididae* (predatory form) which often feed on dependent predators (*in Roger and al., 1991*).

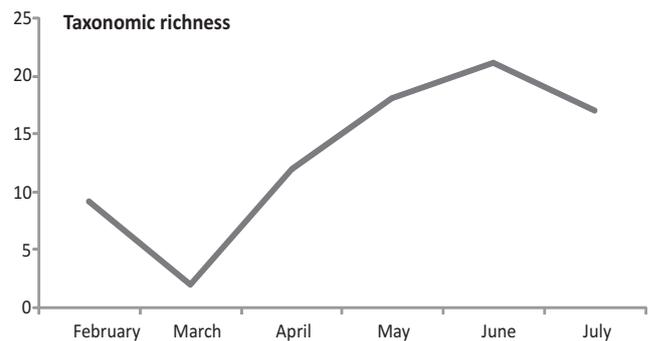


Fig. 3. Temporal variation of taxonomic richness

CONCLUSION

The settlement of the current water macroinvertebrate study presents a breakdown of balance at the study site which is characterized by an average altitude and a relatively low flow disrupted. This stand is marked by the absence of *Plecoptera*. The water of this site is a relatively good quality.

Table 1. Inventory of fauna

| Group | Order | Family | Genus / species | lotic facies | lentic facies |
|-------------|---------------|------------------|---|--------------|---------------|
| WORM | NEMATODA | | | + | + |
| OLIGOCHAETE | TUBIFICIDA | | | + | + |
| | LUMBRICIDA | | | + | - |
| MOLLUSC | GASTEROPODA | THIARIDAE | <i>Melanopsis pramorsa</i> <i>M. costellata</i> | + | + |
| | | PHYSIDAE | <i>Physa acuta</i> | + | - |
| | | LYMNAEIDAE | <i>Limnaea truncatula</i> | + | - |
| INSECT | EPHEMEROPTERA | BAETIDAE | <i>Baetis</i> <i>Procloen</i> | + | + |
| | | CAENIDAE | <i>Caenis</i> | - | + |
| | | HEPTAGENIIDAE | <i>Ecdyonurus</i> | + | + |
| | | LEPTOPHELEBIIDAE | <i>Habrophlebia</i> <i>Leptophlebia</i> | + | + |
| | | OLIGONEURIDAE | <i>Oligoneuriella</i> | - | + |
| | | EPHEMERILIDAE | <i>Ephemera</i> | + | + |
| | HETEROPTERA | PLEIDAE | <i>Plea leachi</i> | - | + |
| | | NOTONECTIDAE | <i>Notonecta</i> | + | + |
| | COLEOPTERA | HYDRANIIDAE | <i>Ochthebius</i> | + | - |
| | | LIMNEBIIDAE | <i>Limnebius</i> | + | - |
| | | ELMIDAE | <i>Normandia</i> | + | + |
| | TRICHOPTERA | RHYACOPHILIDAE | <i>Rhyacophila</i> | + | + |
| | | HYDROPSYCHIDAE | <i>Hydropsyche</i> | + | + |
| | | HYDROPTILIDAE | <i>Hydroptila</i> | + | + |
| | | LEPTOCERIDAE | | + | + |
| | DIPTERA | TIPULIDAE | | + | - |
| | | SIMULIIDAE | <i>Simulium</i> | + | + |
| | | CHIRONOMIDAE | <i>Chironominae</i> <i>Orthocladinae</i> <i>Tanypodinae</i> | + | - |
| | | CERATOPOGONIDAE | <i>Culcoides</i> | + | - |
| | | TABANIDAE | | + | + |
| | | EMPIDIDAE | | + | + |

+: present; -: Absent

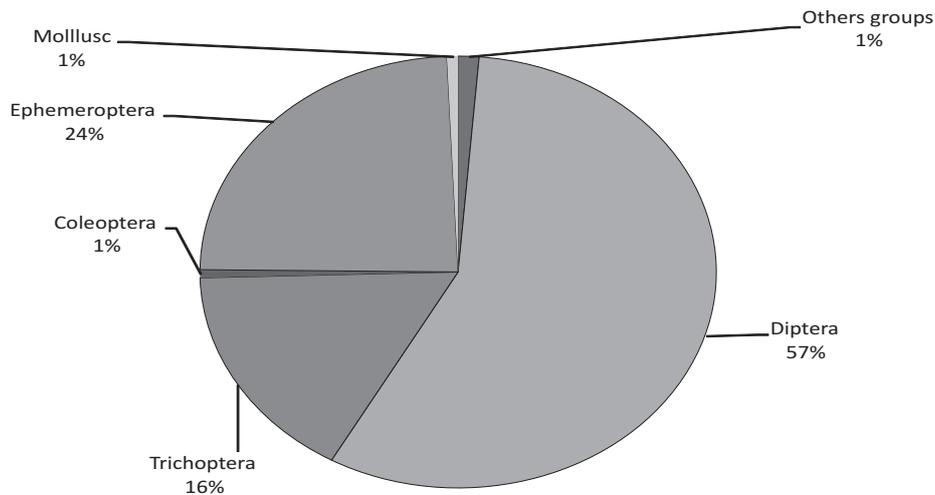


Fig. 4. Spectrum of the relative abundance of different taxa zoologic

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Evaluation of Water Quality by Trophic Diatom Index (TDI) in Tigris River within Wasit Province

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Abstract: Diatoms are commonly used as bioindicator for evaluating especially freshwater quality, their used in the biological assessment of rivers in Iraq. Trophic diatom index (TDI) that provided information about state of the aquatic ecosystem. In this study, the phytoplankton diatoms were collected from the Tigris River within Wasit province at five sites in June 2015 to May 2016. Total of 184 diatom taxa were identified and the water quality of the Tigris River. The results showed the dominance of some diatomic species such as: *Cyclotella meneghiniana*, *Achnanthe. affins*, *Anomoeoneis sphaerophora*, *Amphora bioculata*, *Cocconies. placentula*, *C. placentula var euglypta*, *C. pediculus*, *Cymatopleura sola*, *C. amphibaena*, *Cymbella. tumida*, *Diatoma vulgare*, *Fragilaria ulna var acus*, *Navicula venta*, *Nitzschia halophila*, *N. sigmoidea*, *Rhoicosphenia abbreviata*, *Suirella robusta* and *Synedra ulna*. These species indicated that the trophic status of the river ranged from oligotrophic to mesotrophic status and the Tigris river was moderate water quality.

Keywords: Phytoplankton diatoms, Water quality, TDI, Tigris River

Pollution of freshwater resources has become one of the most important problems of humanity and continuous monitoring of the quality of aquatic ecosystems is one of the best protection techniques. New methods of environmental monitoring, especially by using biological organisms. Diatoms were used as indicator to assess water quality in water bodies (Rott *et al.*, 2003; Tokatlı & Dayioğlu, 2011, Hassan *et al.*, 2017). They have been used in a number of countries as indicators of water pollution (Kalyoncu *et al.*, 2009). The aim of this study was to evaluate the water quality status of the Tigris River with Trophic Diatom Index by using phytoplankton diatom community.

MATERIAL AND METHODS

Study area: Wasit Province is located in the center of Iraq, with an area of 17.153 km², it's capital Kut city. Wasit province is about 180 kilometers north of Baghdad and links it to southern Iraq, its known as an agricultural area and is famous for the production of foodstuffs, especially grains such as wheat, barley, sesame, dates, also has a rich fish wealth. The Kut dam is one of the longest dams in Iraq. It is one of the important dams because of its effect on water storage. It can be used in generating electricity but its quality is not used for this purpose (General Commission for dams and reservoirs projects, 1999). Five sites were selected on the river to collect samples in this study. The geographical areas were determined using the GPS Positioning System (Garmin Ltd / Taiwan).

The first site Al-Aziziyah is about 80 km to the south of Baghdad. Samples were taken on the east bank of the river only, while the opposite bank was occupied by agricultural land. The second site is located southward from the first site above 20 km by the river.

The third site is about 55km from site 2. This site is characterized by agriculture with a wide irrigation network on both sides of the Tigris river. The fourth site was located before the river enters Kut city, and 55 km away from site 3. The site is characterized by reeds, papyrus and Nile flower plants, and in the fifth site after Kut dam, the river runs a distance of up to 3.5 km. It lies on the east bank and is 30 meters away from the river in Kut, and grows reeds, papyrus and Nile flower. The discharge of domestic water was noticed in this site. This site is distance from site 4 about 100 meters. (Figure 1, Table 1).

Biological analysis: The Tigris River within Wasit province was selected for the evaluation Trophic Diatom index (TDI). Monthly sampling was taken from five sites along the Tigris River during the period from June 2015 to May 2016, 2014 (Fig. 1). Phytoplankton collected by plankton net (mesh 20 µm). Phytoplankton samples put it in polyethylene containers and preserved by adding a few drops of Lugol's iodine solution. Clarifications of diatoms were done by using concentrated nitric acid and the methods described by Salman *et al.* (2017) and Hadi (1981). The identification of diatoms based on the work of earlier scientist (Fogged, 1976; Hadi *et al.*, 1984; Wehr and Sheath, 2003; Taylor *et al.*, 2007;

Table 1. The geographical positions (GPS) of the five study sites

| Sites | Longitude (eastwards) | Latitudes (northward) |
|-------|-----------------------|-----------------------|
| 1 | '9818.°35 | '9050.°54 |
| 2 | '9799.°35 | '8840.°55 |
| 3 | '9611.°35 | '7080.°57 |
| 4 | '1336.°36 | '5320.°60 |
| 5 | '1395.°36 | '6604.°60 |

Lavoie *et al.*, 2008; Blanco *et al.*, 2011 and Al-Handal, 2014).

Calculating trophic diatom index (TDI):

This index was based on a suite of 86 diatom taxa selected for their indicator value (tolerance to inorganic nutrients) and ease of identification. Trophic diatom index (TDI) was calculated based on Kelly and Whitton (1995) by using the following formula:

$$TDI = (WMS \times 25) - 25$$

$$WMS = \frac{\sum AR_j RS_j VR_j}{\sum AR_j VR_j}$$

Where WMS is the weighed mean sensitivity of the taxa present in the sample. AR_j is the abundance or proportion of valves of species j present in the sample, SR_j is the nutrient sensitivity (1-5) of species and VR_j its indicating value (1-3). WMS values ranged from 1 (for sites with very low nutrient concentrations) to 5 (for sites with very high nutrient concentrations) while TDI values ranged from 0-100 which illustrated in Table 2 with their corresponding ecological states:

Table 2. The guide value of the diatom index

| Pollution states | Index value |
|-------------------------|-------------|
| Oligotrophic State | TDI < 35 |
| Oligo-mesotrophic State | TDI 35-50 |
| Mesotrophic State | TDI 50 – 60 |
| Eutrophic state | TDI 60 – 75 |
| Hypertrophic state | TDI > 75 |

RESULTS AND DISCUSSION

Trophic diatom index (TDI) is a good tool for monitoring

river, diatom community are liable to alter of factors that not related to nutrients (Kelly and Whitton, 1995). The present study results of TDI mean values ranged from 38.69 at site 4 in June 2015 to 61.77 at site 2 in October 2015 (Table 3). The lowest value was recorded in early summer (June 2015) this can be attributed to several factors, such as reduce of nutrient concentration and some environmental factors which affects on the growth or activities of diatoms specially the species sensitive to the different environmental factors of the temperature and lack of nutrients (Kassim *et al.*, 2002), while the high value was in the autumn (October 2015) because many of the environmental conditions affect of phytoplankton, such as temperature, dissolved oxygen, and density of aquatic plants that provide an appropriate environment for these algae causing these species to appear in river water (Mohammed, 2007). According to this index the Tigris River was tended to be oligotrophic to mesotrophic, this might be confirmed by existence of species *C. placentula*, *Gomphonies olivaceum*, *F. crotonensis*, *Nitzschia spp* and *S. ulna* in the Tigris River at all study sites. This species found in oligo-mesotrophic river that indicates the nutritional status of the river. Exceeding this limit indicates the richness of the river which may be due to of the sewage waste disposal into the river the sewage which means river pollution (Kelly, 2003). The results in Table 4 showed the variation in the number of genera and species in the Tigris River between the sites can be attributed to provide nutrients for algae growth, such as nitrogen, phosphates, calcium and magnesium, and the similarities between species in the fifth sites are due to the unity of the main source of water, this may be due to the diatoms can grow and reproduce in a wide range of environmental changes (Al-Tamimi, 2006, Shaawiat and Hassan, 2017)).

The composition of diatom assemblages changed from one sampling site to another which generally is believed to change with nutrient loading and in response to pollutant levels (Irvine and Murphy, 2009). The following identified in species *A. granulate*, *C. placentula*, *Cymbella Spp*, *F.*

Table 3. Monthly variation of Trophic diatom index of phytoplankton diatoms in the five sites in the Tigris River, during the study period 2015-2016

| Months | 2015 | | | | | | | 2016 | | | | |
|--------|-------|--------|--------|-----------|---------|----------|----------|---------|----------|--------|-------|--------|
| | June | July | August | September | October | November | December | January | February | March | April | May |
| S1 | 50.95 | 48.67 | 49.71 | 55.43 | 61.77 | 45.22 | 49.13 | 50.33 | 49.87 | 52.13 | 47.51 | 51.73 |
| S2 | 52.33 | 50.69 | 50.2 | 55.66 | 60.23 | 46.5 | 50.53 | 48.97 | 49.66 | 49.03 | 50.71 | 52.43 |
| S3 | 49.5 | 46.83 | 45.66 | 50.6 | 42.32 | 44.72 | 50.2 | 50.16 | 48.4 | 51.2 | 50.4 | 51.56 |
| S4 | 38.69 | 50.16 | 44.31 | 45.66 | 50.2 | 44.03 | 48.7 | 45.91 | 49.11 | 39.43 | 46.5 | 50.2 |
| S5 | 47.03 | 50.61 | 47 | 52.5 | 56.08 | 46.03 | 48.67 | 48.65 | 49.13 | 50.2 | 44.13 | 50.37 |
| Mean | 47.7 | 49.392 | 47.376 | 51.97 | 54.12 | 45.3 | 49.446 | 48.804 | 49.234 | 48.398 | 47.85 | 51.258 |

Table 4. List of identifying epipelagic diatoms during the study period in Tigris River

(–=not present ; + = present)

| Sites | S1 | S2 | S3 | S4 | S5 |
|---|----|----|----|----|----|
| Bacillariophyceae | | | | | |
| Centrales | | | | | |
| <i>Aulacoseira ambigua</i> (Grunow) Simonsen | + | + | + | + | + |
| <i>A. granulata</i> (Ehr.) Simonsen | + | + | + | + | + |
| <i>Coscinodiscus granii</i> L.F.Gough | + | + | + | + | + |
| <i>C. denarius</i> A. Schmidt | + | + | + | + | – |
| <i>C. wailesii</i> Gran & Angst | + | + | + | + | + |
| <i>Cyclotella comta</i> Kützing | – | – | + | – | – |
| <i>C. meneghiniana</i> Kützing | + | + | + | + | + |
| <i>C. ocellata</i> Pantocsek | + | + | + | – | + |
| <i>Melosira ambigua</i> (Grunow) Otto Müller | + | + | + | + | + |
| <i>M. granulata</i> (Ehr.) Ralfs | + | + | – | + | + |
| <i>M. italica</i> (Ehr.) Kützing | – | + | + | – | – |
| <i>M. varians</i> Agardh | + | + | + | + | + |
| <i>Stenopteroberia delicalissinia</i> (F.W.Lewis) Brébisson ex Van Heurck | + | + | + | + | + |
| <i>Thalassiosira bramaputra</i> (Ehr.) Hakansson & Locker | + | + | – | + | + |
| <i>T. baltica</i> (Grunow) Ostenfeld | + | + | + | + | + |
| Pennales | | | | | |
| <i>Achnanthes affinis</i> Grunow | + | + | + | + | + |
| <i>A. linearis</i> (W.Smith) Grunow in Cleve & Grunow | + | + | + | + | + |
| <i>A. minutissima</i> Kutzing | – | – | – | + | + |
| <i>A. minutissima var. affinis</i> (Grunow) Lange–Bertalot | + | + | + | + | + |
| <i>A. longipes</i> C.Agardh | + | + | + | + | + |
| <i>Achnantheidium exiguum</i> (Grunow) Czarnecki | + | + | + | + | + |
| <i>A. catenatum</i> (Bily & Marvan) Lange–Bertalot | + | + | – | + | + |
| <i>Amphora bioculata</i> Cleve | + | + | + | + | + |
| <i>A. acutiuscula</i> Kützing | + | – | – | + | + |
| <i>A. ovalis</i> (Kütz.) Kützing | + | + | + | + | + |
| <i>A. pediculus</i> (Kütz.) Grunow ex A.Schmidt | + | + | + | – | + |
| <i>A. proteus</i> W.Gregory | – | + | – | + | + |
| <i>A. strigosa</i> Hustedt | + | – | + | + | – |
| <i>A. veneta</i> Kützing | + | + | + | + | + |
| <i>Anomoeoneis sphaerophora</i> Pfitzer | + | + | + | + | + |
| <i>Asterionella formosa</i> Hassall | + | + | + | + | + |
| <i>Bacillaria paradoxa</i> J.F.Gmelin, | + | + | + | + | + |
| <i>B. paxillifera</i> (O.F.Müller) T.Marsson | + | – | + | + | + |
| <i>Caloneis amphisbaena</i> (Bory.) Cleve | + | + | + | + | + |

Cont...

| | | | | | |
|--|---|---|---|---|---|
| <i>C. amphisbaena var. subsalina</i> (Donkin) Cleve | + | + | + | + | + |
| <i>C. bacillum</i> (Grunow) Cleve | + | + | + | + | + |
| <i>C. formosa</i> (Gregory) Cleve | + | + | + | + | + |
| <i>C. permagna</i> (Bailey) Cleve | + | + | + | + | + |
| <i>C. ventricosa</i> (Ehr.) F.Meister | + | – | + | – | – |
| <i>Cocconeis pediculus</i> Ehrenberg | + | + | + | + | + |
| <i>C. placentula</i> Ehrenberg | + | + | + | + | + |
| <i>C. placentula var. euglypta</i> (Ehr.) Cleve | + | + | + | + | + |
| <i>Cymatopleura solea</i> (Breb.) W.Smith | + | + | + | + | + |
| <i>Cymbella affinis</i> Kützing | + | + | + | + | + |
| <i>C. aspera</i> (Ehr.) Cleve | + | + | + | + | + |
| <i>C. cistula</i> (Hemp.) Grunow | + | + | + | + | + |
| <i>C. cymbiformis</i> C.Agardh | + | + | – | + | – |
| <i>C. lange-bertalotii</i> Krammer | + | + | + | – | + |
| <i>C. ovalis</i> (Kütz.) Brébisson & Godey | + | + | – | + | + |
| <i>C. minuta</i> Hilse | – | + | + | + | – |
| <i>C. prostrate</i> (Berk.) Cleve | + | + | + | – | + |
| <i>C. tumida</i> (Breb.) Van.Heurck | + | + | + | + | + |
| <i>C. turgida</i> (Greg.) Cleve | + | + | + | + | + |
| <i>C. turgidula var. kappii</i> Cholnoky | + | + | + | + | + |
| <i>C. ventricosa</i> (C.Agardh) C.Agardh | + | + | + | – | + |
| <i>Diatoma vulgare</i> Bory | + | + | + | + | + |
| <i>Diploneis elliptica</i> (Kütz.) Cleve | + | + | + | + | + |
| <i>D. smithii</i> (Brébisson) Cleve | + | + | + | + | + |
| <i>Encyonema silesiacum</i> (Bleisch) D.G.Mann | + | + | + | + | + |
| <i>E.silesiacum var. altensis</i> Krammer | + | + | + | + | + |
| <i>Epithemia adnata</i> (Kütz.) Brébisson | – | + | – | + | + |
| <i>Eunotia exigua</i> (Brébisson ex Kütz.) | + | + | + | + | + |
| <i>E. exigua var. tenella</i> (Grunow) Nörpel & Alles | + | + | + | + | + |
| <i>E. gracilis</i> (Ehr.) Rabenhorst | + | + | + | + | + |
| <i>E. minor</i> (Kütz.) Grunow | + | + | + | + | + |
| <i>Fallacia pygmaea</i> (Kütz.) Stickle & D.G. Mann | + | + | + | + | + |
| <i>Fragilaria acus</i> (Kütz.) Lange-Bertalot | – | + | + | + | + |
| <i>F. arcus</i> (Ehr.) Cleve | + | + | – | + | + |
| <i>F. biceps</i> Ehrenberg | + | + | + | + | + |
| <i>F. brevistriata</i> Grunow | – | + | + | + | – |
| <i>F. capucina</i> Desmazieres | + | + | – | + | + |
| <i>F. capucina var. gracilis</i> (Oestrup) Hustedt | – | + | + | + | + |
| <i>F. capucina var. rumpens</i> (Kütz.) Lange–Bertalot ex Bukhtiyarova | + | + | + | + | + |
| <i>F. construens</i> (Ehr.) Grunow | + | + | + | + | + |
| <i>F. construens f. binodis</i> (Ehr.) Hustedt | + | – | – | – | – |
| <i>F. crotonensis</i> Kitton | + | + | + | + | + |
| <i>F. elliptica</i> Schumann | + | + | + | + | + |

Cont...

| | | | | | | | | | | | |
|---|---|---|---|---|---|--|---|---|---|---|---|
| <i>F. fasciculata</i> (C.Agardh) Lange-Bertalot | + | + | + | + | + | <i>N. pygmaea</i> Kützing | - | + | + | + | + |
| <i>F. intermedia</i> Grunow | + | + | + | + | + | <i>N. pupula</i> Kützing | + | + | + | + | - |
| <i>F. ulna</i> (Nitzsch) Lange-Bertalot | + | - | + | + | + | <i>N. radiosa</i> Kützing | + | + | + | + | + |
| <i>F. ulna</i> var. <i>acus</i> (Kütz.) Lange-Bertalot | + | + | + | + | + | <i>N. rhyngocephala</i> Kützing | + | + | + | + | + |
| <i>F. ulna</i> var. <i>biceps</i> (Kütz.) Compère | + | + | + | + | + | <i>N. seminulum</i> Grunow | + | + | + | + | + |
| <i>F. virescens</i> Ralfs | + | + | + | - | + | <i>N. veneta</i> Kützing | + | + | + | + | + |
| <i>Gomphoneis olivaceum</i> (Horne)P.Dawson ex. Ross et Simith | + | + | + | + | + | <i>N. viridis</i> (Nitzsch) Ehrenberg | + | + | + | + | + |
| <i>Gomphonema angustatum</i> (Kütz.) Rabenhorst | + | - | + | - | + | <i>N. viridula</i> (Kütz.) Ehrenberg | + | + | + | + | + |
| <i>G. affine</i> Kützing | + | + | + | + | + | <i>N. viridula</i> var. <i>rostellata</i> (Kütz.) Cleve | - | + | - | + | + |
| <i>G. brasilinies</i> Lyngbya | + | + | - | - | + | <i>Nitzschia acicularis</i> (Kütz.) W.Smith | + | + | + | + | + |
| <i>G. clavatum</i> Ehrenberg | - | + | + | + | + | <i>N. amphibia</i> Grunow | + | + | + | + | + |
| <i>G. exilissimum</i> (Grunow) Lange-Bertalot & | + | + | + | + | - | <i>N. apiculata</i> (Greg.) Grunow | - | - | + | + | - |
| <i>G.geminatum</i> (Lyngbye) C.Agardh | + | + | + | + | + | <i>N. commutata</i> Grunow | + | + | - | - | + |
| <i>G. insignifine</i> E.Reichardt | + | + | + | + | + | <i>N. constricta</i> (Gregory) Grunow | + | + | + | + | + |
| <i>G. lagenula</i> Kützing | + | + | + | + | + | <i>N. delicatissima</i> Cleve | - | - | - | - | + |
| <i>G. micropumilum</i> E.Reichardt | + | - | - | + | + | <i>N. dissipata</i> (Kütz) Grunow | + | + | + | + | + |
| <i>G. mesta</i> (S.I.Passy-Tolar & R.L.Lowe) E.Reichardt | + | + | + | + | + | <i>N. filiformis</i> (W.Sm.) Hust | + | + | + | + | + |
| <i>G. minuta</i> P.Fusey | + | + | + | + | + | <i>N. fonticola</i> (Grunow) Grunow | + | + | + | + | + |
| <i>G. minutum</i> (C.Agardh) C.Agardh | + | + | + | + | + | <i>N. frustulum</i> Kützing | - | - | - | + | + |
| <i>G. olivaceum</i> (Lyng.) Kützing | + | + | + | + | + | <i>N. fruticosa</i> Hustedt | + | + | + | + | + |
| <i>G. pumilum</i> var. <i>elegans</i> E.Reichardt & Lange-Bertalot | + | + | + | + | - | <i>N. gracilis</i> Hantzsch | + | + | + | + | + |
| <i>G. paravalum</i> (Kütz.) Grunow | + | + | + | + | + | <i>N. granulata</i> Grunow | + | + | + | + | + |
| <i>G. rhombicum</i> Fricke | + | + | + | + | + | <i>N. hyngarica</i> Grunow | + | + | + | + | + |
| <i>G. tergestinum</i> (Grun.) Fricke | + | - | + | - | - | <i>N. linearis</i> W.Smith | + | + | + | - | + |
| <i>G. truncatum</i> Ehrenberg | - | + | + | + | + | <i>N. nana</i> Grunow | + | + | + | + | + |
| <i>Gyrosigma acuminatum</i> (Kütz.) Rabenhorst | + | + | + | + | + | <i>N. obtusa</i> W.Smith | + | + | + | + | + |
| <i>G. attenuatum</i> (Kütz.) Rabenhorst | + | + | + | + | + | <i>N. palea</i> (Kütz .) W.Smith | + | + | + | + | + |
| <i>G. eximium</i> (Thwa.) Bayar | + | + | + | + | + | <i>N. palea</i> var. <i>debilis</i> (Kütz.) Grunow | + | + | + | + | + |
| <i>G. fasciola</i> (Ehr.) J.W.Griffith & Henfrey | + | + | + | + | + | <i>N. paleacea</i> Grunow | + | - | + | + | + |
| <i>G. scalproides</i> (Rabenhorst) Cleve | + | + | + | + | + | <i>N. paleaeformis</i> Hustedt | + | + | - | + | + |
| <i>Hantzschia amphioxys</i> (Ehr.) Grunow | + | + | + | + | + | <i>S.rectilonga</i> Takano | - | + | + | + | + |
| <i>Mastogloia smithii</i> Thw. Ex.W. Smith | + | + | + | + | + | <i>N. scalaris</i> (Ehr.) W.Smith | + | + | - | + | + |
| <i>Mayamaea atomus</i> (Kütz.) Lange-Bertalot | + | + | + | + | + | <i>N. reversa</i> W.Smith | + | + | + | + | + |
| <i>Meridion circulare</i> Agardh | + | + | + | + | + | <i>N. sigma</i> (Kütz .) W.Smith | + | + | + | + | + |
| <i>Navicula affinis</i> Ehrenberg | + | - | - | - | - | <i>N. sigmoidea</i> (Ehr.) W.Smith | + | + | + | + | + |
| <i>N. bacillum</i> Ehrenberg | + | + | - | + | + | <i>N. thermalis</i> (Ehr.) Auerswald | - | + | + | + | + |
| <i>N. capitatoradiata</i> H.Germain | + | + | + | + | - | <i>N. vermicularis</i> (Kütz .) Grunow | + | + | - | + | + |
| <i>N. cryptocephala</i> Kützing | - | + | + | + | - | <i>N. vidovichii</i> (Grunow) Grunow | + | + | + | + | + |
| <i>N. cuspidata</i> (Kutz.) Kützing | + | + | + | + | + | <i>N. umbonata</i> (Ehr.) Lange-Bertalot | + | + | + | + | + |
| <i>N. decussis</i> Oestrup | + | - | + | + | + | <i>Peronia fibula</i> (Breb & Arn) Ross | + | + | - | + | + |
| <i>N. gregaria</i> Donkin | + | + | + | + | + | <i>Pinnularia acuminata</i> W.Smith | + | + | + | + | + |
| <i>N. halophila</i> (Grun.) Cleve | + | + | + | + | + | <i>P. brebissonii</i> (Kütz.) Rabenhorst | + | + | + | + | + |
| <i>N. lanceolata</i> Ehrenberg | + | + | + | + | + | <i>P. divergens</i> W.Smith | + | + | + | - | + |
| <i>N. protracta</i> Grunow | + | + | - | + | + | <i>P. viridis</i> (Nitzs.) Ehrenberg | + | + | + | + | + |
| | | | | | | <i>Rhoicosphenia abbreviata</i> (C.Agardh) Lange-Bertalot | + | + | + | + | + |

| | | | | | |
|--|---|---|---|---|---|
| <i>Rhopalodia gibba</i> (Ehr.) Otto Müller | + | + | + | + | + |
| <i>Surirella elegans</i> Ehrenberg | - | + | + | + | + |
| <i>S.linearis</i> W.Smith | + | + | + | + | + |
| <i>S. linearis var. constricta</i> (Ehr.) Grunow | + | + | + | + | + |
| <i>S. minuta</i> Berbisson ex Kützing | - | + | + | - | + |
| <i>S. ovalis</i> Berbisson | + | + | + | + | + |
| <i>S. robusta</i> Ehrenberg | + | + | + | + | + |
| <i>S. robusta var. splendida</i> (Ehr.) Van Heurck | + | + | + | + | - |
| <i>S. splendida</i> (Ehr.) Kützing | + | + | + | + | + |
| <i>Synedra acus</i> Kützing | + | + | + | + | + |
| <i>S. capitata</i> Ehrenberg | + | + | + | + | + |
| <i>S. fasciculate</i> (C.Agardh) Kützing | - | + | - | + | + |
| <i>S. rostrata</i> Meister | - | - | + | - | - |
| <i>S. rumpens</i> Kützing | + | + | + | + | + |
| <i>S. ulna</i> (Nitzs.) Ehrenberg | + | - | + | + | + |
| <i>S. ulna var. biceps</i> (Kütz.) Schönfeldt | + | + | + | + | + |
| <i>Tabellaria fenestrata</i> (Lyngbye) Kützing | + | + | + | + | + |

is moderate to the water quality in the Tigris River. The genus of *D. vulgare* was recorded during the present study, which is an indicator of water quality ranging from Mesotrophic to Eutrophic (Taylor *et al.*, 2005). The species *N. palea* is present in the highly food-rich waters (Tapia ,2008) and water quality index with the degree of organic pollution (Polysabropic) and *G. Parvulum* with high tolerant of water rich in nutrients and poor oxygen content (Potapova & Charles, 2003).

CONCLUSION

The trophic status of the Tigris River ranged from oligotrophic to mesotrophic. The Tigris River ranged from moderate to good water quality. This study demonstrated the applicant to use the tophic diatom index and can help in establishing the database for Tigris River.

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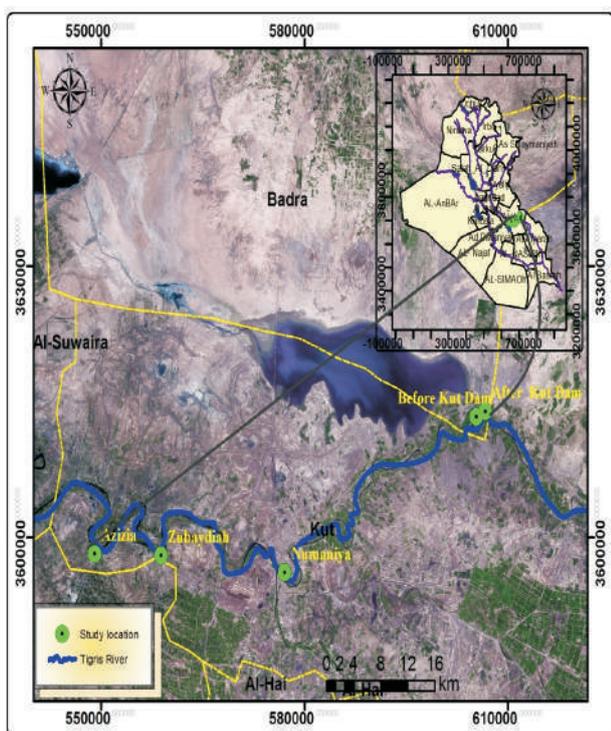


Fig. 1. Map of the Tigris River and the study area (Used Arc-GIS Map program)

capucina, *G. olivaceum*, *N. radiosa* and *S. ulna* found in oligotrophic to Eutrophic level (Hosmani, 2013) (Table 4).

The following results of the trophic diatom index (TDI), which was calculated phytoplankton diatoms based on TDI values (Table1), it was found to be on a trophic level ranging from Oligotrophic to Mesotrophic. The average level of water

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Seasonal Micro-Climatic Variation in Physical and Chemical Characteristics of the Soil on Different Forest Ecosystems under Mid hills Conditions of Himachal Pradesh

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Abstract: The present investigation entitled "Seasonal Micro-climatic Variations in Physical and Chemical Characteristics of the Soil on different forest ecosystems under mid hills conditions of Himachal Pradesh" was carried out during winter and summer seasons of the year 2015-16 under the Department of Environmental Science, College of Forestry, Dr. Y.S. Parmar University of Horticulture and Forestry, Nauni, Solan, Himachal Pradesh. A comparison of below forest canopy and open sites was carried out for abiotic and biotic factors under five forest ecosystems (Chir Pine Forest, Mixed Forest, Ban Oak Forest, Agriculture Field and Bare Area) and analysed the physico-chemical properties of soil. The collected soil samples from the forest ecosystem were analysed for soil moisture, bulk density, pH, electrical conductivity, soil organic carbon and available NPK. The results showed that the higher percent of moisture was found in forest ecosystem as compared to open area and having difference of (8.0-15.2%) and found higher in oak forest. The forest ecosystem indicate that the soil of oak forest was slightly acidic to pine forest. The forest ecosystem wise soil organic carbon and available K status followed the order of ban oak forest > mixed forest > chir pine forest > agriculture field > bare area. However the status of available N and P followed the order of agriculture field > ban oak forest > mixed forest > chir pine forest > bare area. Although the bulk density was observed highest in bare area (1.41 g cm^{-3}) and lowest was reported under ban oak forest (1.27 g cm^{-3}). Based on our results, we conclude that Ban oak forest generally had a greater moderating effect during both the season and are rich in nutrient availability as compared to chir pine and mixed forest and directly influenced the soil physico-chemical properties, nutrient cycling, microbial biomass and therefore, affects the natural regeneration process of native species.

Keywords: Microclimate, Edaphic parameters, Nutrient cycling and forest management

Knowledge of microclimate conditions is of great importance in the study of site conditions, bio-ecological characteristics of tree species and natural ecosystems (Babic *et al.*, 2015) and are key attributes for understanding the distribution of plants and wildlife in forests, as well as for understanding forest ecosystem processes like photosynthesis and nutrient cycling (Gray *et al.*, 2002). The importance of microclimate in influencing ecological processes such as plant regeneration and growth, soil respiration and nutrient cycling has become an essential component of current ecological research. Microclimate plays an important role to improve models, optimize forest management, and ultimately, secure future economical and ecological functioning of forest ecosystem (Arx *et al.*, 2012). Forest soils influenced the composition of forest stand and ground cover, rate of tree growth, vigour of natural reproduction and other silviculturally important factors. Physico-chemical characteristics of forest soils vary in space and time because variation in topography, climate, weathering processes, vegetation cover, microbial activities (Paudel and Sah, 2003) and several other biotic and abiotic

factors. The yearly contribution of surface vegetation to soil, in the form of needles, leaves, cones, pollen, branches and twigs, gradually decomposes and becomes a part of the soil. The nutrient thus, returned in the soil, exerts a strong feed back on the ecosystem processes. Plant tissues (above and below ground litter) are the main source of soil organic matter, which influences the physicochemical characteristics of soil such as, texture, water holding capacity, pH and nutrients availability. Nutrients supply vary widely among ecosystem resulting in differences in plant community structure and its production. The different seasons influence the diversity and productivity of plants as well as properties of soil environment. Thus the present investigation was undertaken to study differences in micrometeorological factors and nutrient dynamics in the soil under different forest ecosystem in structuring plant species richness and diversity in the habitat.

MATERIAL AND METHODS

Study Sites: The study was conducted in different forest ecosystem at Dr Yashwant Singh Parmar university of

horticulture and forestry Nauni, Solan during winter and summer season of 2015–16. The area is situated between 30.516° N and 77.099° E with elevation ranges from 1242 m. The research area was divided into five different sites as chir pine forest (f_1), mixed forest (f_2), ban oak forest (f_3), agricultural field (f_4) and bare area (F_5). The research area was located in stands of trees predominantly dominated by overstorey of *Pinus roxburghii*, *Quercus leucotricophora*, *Celtis australis*, *Grewia optiva*, *Bauhinia vaerigata*, *Populus spp*, *Salix spp*, and under story of *Bidens pilosa*, *Rubus ellipticus*, *Woodfordia floribunda*, *Urtica dioica*.

The soil characteristics were analysed by collecting the samples from five different sites at 15 cm depth in two seasons (winter and summer season) and total 30 samples were collected from each sites. The physical and chemical properties i.e soil moisture, soil bulk density, soil pH, electrical conductivity, organic carbon and NPK were analysed by different methods (Table 2).

RESULTS AND DISCUSSIONS

Soil moisture: The highest moisture content was noticed under ban oak forest which was followed by mixed forest and chir pine forest and less moisture content was found under bare area which was statistically at par with agriculture field as shown in (Table 3). The high moisture content under ban oak forest may probably due to the dense canopy of oak forest and produced higher amount of organic matter which influenced the texture of soil resulting in higher water retention. On the other hand lowest value of soil moisture content in bare area may be due to maximum solar radiation and high wind speed leads to high evapotranspiration in open area was also reported by (Chandra *et al.*, 2016; Joshi and Negi 2015; Godefroid *et al.*, 2007; Sheikh and Kumar 2010). The soil moisture in summer season was significantly higher than winter season. Maximum soil moisture was found in ban oak forest during summer season and minimum in bare area during winter season which was statistically at par with bare area in summer season and agricultural field in winter season due to the maximum rainfall received in summer season as shown in (Fig. 1).

Soil Bulk density: The highest soil bulk density was noticed

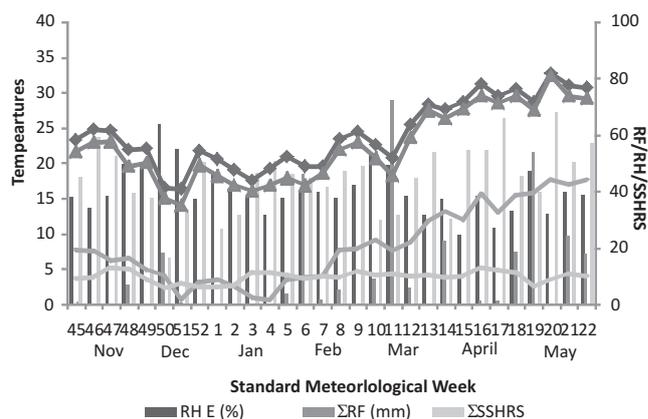


Fig. 1. Climatograph of the study area

under bare area (F_5) followed by agriculture field as shown in (Table 3). The results were probably due to compaction of soil as a result of various activities. The lowest bulk density of soil was recorded under ban oak forest may possibly be due to its higher soil organic carbon status and undisturbed conditions as reported by earlier worker by (Chandra *et al.*, 2016; Jina *et al.*, 2009; Bhandari and Ficklin 2009; Zang *et al.*, 2006). The highest soil bulk density was recorded during summer season which was significantly at par with winter season.

Table 2. Edaphic elements and methods

| Physico-chemical properties of soil | Instruments/Methods |
|-------------------------------------|---|
| Soil Moisture | Gravimetric Method |
| Soil Temperature | Soil Thermometer |
| Nitrogen | Alkaline potassium permanganate Method (Kjeldahl Distillation Assembly Jackson, 1958) |
| Phosphorus | Olsen Method (0.5 N NaHCO ₃ pH 8.5, Olsen <i>et al.</i> , 1983) |
| Potassium | Merwin and Peach Method (Neutral 1 N ammonium acetate) |
| Organic Carbon | Wet Combustion Method (Walkely Black Method, 1934) |
| Electrical Conductivity | Electric-Conductivity Meter |
| Bulk Density | Pycnometer |

Table 1. Site characteristics

| Forest Site | Ecosystem | Slope (% & °) | Aspect (Orientation) | Elevation (m) | Latitude (N) | Longitude (E) |
|-------------|-------------------|---------------|----------------------|---------------|--------------|---------------|
| Site I | Chir Pine forest | 50% (26.6°) | NE | 1245 | 30.52° | 77.10° |
| Site II | Mixed forest | 45% (24.2°) | NE | 1249 | 30.51° | 77.10° |
| Site III | Ban Oak forest | 75% (36.9°) | NE | 1264 | 30.52° | 77.09° |
| Site IV | Agriculture field | - | - | 1222 | 30.52° | 77.09° |
| Site V | Bare area | - | - | 1232 | 30.52° | 77.09° |

Soil pH and Electrical conductivity: The soil under different forest ecosystem varied significantly from 5.36–7 (Table 4). The highest mean soil pH value was found under bare area followed by agricultural field and lowest value was found in chir pine forest. The soil pH was found highest during winter season and lowest during summer season. Highly acidic pH was observed in chir pine forest because of low base content of pine needles in the forest and soil pH was slightly acidic as the soils had high humus content in ban oak and mixed forest. The acidic nature of the soil is also reported by (Sharma and Sharma, 2004; Godefroid *et al.*, 2007; Salim *et al.*, 2015; Sheikh and Kumar 2010; Semwal *et al.*, 2009) The electrical conductivity of soil was not significantly influenced by different forest ecosystem during two seasons and their microclimatic interaction was also found to be non significant in mid hills of solan district of Himachal Pradesh.

Soil Organic Carbon: The selected forest ecosystems ban oak forest registered the highest SOC of which was followed by mixed forest, chir pine forest, agriculture field and bare area (Table 4). The highest soil organic carbon in ban oak forest may be ascribed due to closed canopied forest result in

higher input of litter fall under such undisturbed forest. In agriculture field higher soil cultivation intensity had fastened the decomposition of organic matter and might have resulted decrease in its content. On the other hand lowest value of SOC under bare area may possibly be due to very less return of organic matter to the soil and which is again liable to be lost as surface run-off due to compacted surfaces. The results are in confirmity with the findings of (Chandra *et al.*, 2016; Joshi and Negi 2015; Li *et al.*, 2013; Sharma and Sharma, 2004)

Significantly higher SOC content was noticed during winter season whereas minimum was observed during summer season. The highest organic carbon content was found under ban oak forest in winter season and lowest in bare area during summer season may probably due to slow mineralization and decomposition under very low temperature prevailing in the season and results are in line with the findings of (Semwal *et al.*, 2009).

Available NPK

Nitrogen: The highest nitrogen content was recorded under agricultural field which was statistically at par with ban oak

Table 3. Seasonal variation in soil moisture and soil bulk density under different forest ecosystem in mid hills of Himachal Pradesh

| Forest ecosystem | Soil moisture | | | Soil bulk density | | |
|-------------------------------------|---|--------|-------|---|--------|------|
| | Winter | Summer | Mean | Winter | Summer | Mean |
| Chir Pine forest (F ₁) | 13.57 | 14.18 | 13.88 | 1.28 | 1.30 | 1.29 |
| Mixed forest (F ₂) | 16.10 | 17.40 | 16.75 | 1.27 | 1.29 | 1.28 |
| Ban oak forest (F ₃) | 17.99 | 24.21 | 21.10 | 1.25 | 1.28 | 1.27 |
| Agriculture field (F ₄) | 6.11 | 8.44 | 7.27 | 1.35 | 1.37 | 1.36 |
| Bare area (F ₅) | 5.43 | 6.26 | 5.85 | 1.41 | 1.42 | 1.41 |
| Mean | 11.84 | 14.10 | | 1.31 | 1.33 | |
| CD (p=0.05) | Forest ecosystem (F) : 0.98 Seasons (S) : 0.62 Forest x Season (F x S) : 1.39 | | | Forest ecosystem (F) : 0.01 Seasons (S) : 0.01 Forest x Season (F x S) : NS | | |

Table 4. Seasonal variation in soil pH, soil electrical conductivity and organic matter under different forest ecosystem in mid hills of Himachal Pradesh

| Forest ecosystem | pH | | | EC (dSm ⁻¹) | | | Organic carbon | | |
|-------------------------------------|---|--------|------|---|--------|------|---|--------|------|
| | Winter | Summer | Mean | Winter | Summer | Mean | Winter | Summer | Mean |
| Chir Pine forest (F ₁) | 5.51 | 5.20 | 5.36 | 0.27 | 0.38 | 0.33 | 1.65 | 1.56 | 1.61 |
| Mixed forest (F ₂) | 6.62 | 6.29 | 6.46 | 0.18 | 0.60 | 0.39 | 2.14 | 1.83 | 1.99 |
| Ban oak forest (F ₃) | 6.84 | 6.53 | 6.68 | 0.34 | 0.26 | 0.30 | 2.45 | 1.98 | 2.22 |
| Agriculture field (F ₄) | 6.94 | 6.87 | 6.90 | 0.29 | 0.28 | 0.28 | 1.22 | 1.11 | 1.17 |
| Bare area (F ₅) | 7.18 | 7.10 | 7.14 | 0.39 | 0.41 | 0.40 | 1.10 | 0.98 | 1.04 |
| Mean | 6.62 | 6.40 | | 0.29 | 0.38 | | 1.71 | 1.49 | |
| CD (p=0.05) | Forest ecosystem (F): 0.34 Seasons (S) : 0.21 Forest x Season (F x S): NS | | | Forest ecosystem (F): NS Seasons (S) : NS Forest x Season (F x S): NS | | | Forest ecosystem (F): 0.17 Seasons (S) : 0.11 Forest x Season (F x S): NS | | |

Table 5. Seasonal variation in Available Macronutrients under different forest ecosystem in mid hills of Himachal Pradesh

| Forest ecosystem | Available macronutrients (kg ha ⁻¹) | | | | | | | | |
|-------------------------------------|--|--------|--------|--|--------|-------|--|--------|--------|
| | Nitrogen | | | Phosphorus | | | Potassium | | |
| | Winter | Summer | Mean | Winter | Summer | Mean | Winter | Summer | Mean |
| Chir Pine forest (F ₁) | 428.47 | 382.49 | 405.48 | 19.16 | 16.51 | 17.84 | 228.08 | 176.13 | 202.11 |
| Mixed forest (F ₂) | 449.80 | 395.99 | 422.90 | 21.13 | 19.51 | 20.32 | 247.94 | 191.83 | 219.88 |
| Ban oak forest (F ₃) | 491.34 | 430.67 | 461.01 | 24.55 | 21.68 | 23.11 | 249.20 | 193.74 | 221.47 |
| Agriculture field (F ₄) | 494.43 | 433.32 | 463.87 | 26.63 | 20.16 | 23.40 | 232.36 | 154.17 | 193.27 |
| Bare area (F ₅) | 415.62 | 368.21 | 391.91 | 14.16 | 13.66 | 13.91 | 154.17 | 132.27 | 143.22 |
| Mean | 455.93 | 402.14 | | 21.13 | 18.31 | | 222.35 | 169.63 | |
| CD (p=0.05) | Forest ecosystem (F) : 4.45 Seasons (S) : 2.81 Forest x season (F x S): 6.29 | | | Forest ecosystem (F) : 1.24 Seasons (S) : 0.79 Forest x season (F x S): 1.76 | | | Forest ecosystem (F) : 1.83 Seasons (S) : 1.16 Forest x season (F x S): 2.59 | | |

forest and lowest under bare area as shown in (Table 5). The highest content of available N in soils under agricultural field may possibly be due to high input of fertilizers and organic manures and in ban oak forest may ascribed due to humus added to the soil by decomposition of nutrient rich leaf litter and that maintains the fertility of soil. Whereas, the lowest status of available N under bare area may be probably be due to relatively less SOC. The result is also reported by (Joshi and Negi 2015). The soil nitrogen content under winter season and summer season was significantly differed to each other. The highest nitrogen content was recorded in agricultural field during winter season which was statistically at par with ban oak forest during winter season and lowest in bare area in summer season may due to slow mineralization and decomposition under very low temperature prevailing in the season similar results were reported by (Salim *et al.*, 2015; Sheikh and Kumar 2010; Semwal *et al.*, 2009; Jina *et al.*, 2009).

Phosphorus: The soil available P content also varied significantly among different forest ecosystem as agriculture field was to contain highest soil available P which was statistically at par with ban oak forest (Table 5). The minimum available P content was found under bare area. The seasons of the year also resulted significant influence on the available P content of soil. Significantly highest available soil P was found during winter season probably due to more accumulation of minerals in winter season than summer season and was reported in the literature of (Semwal *et al.*, 2009). The highest phosphorus content was in winter season in agriculture field and lowest in bare area in summer season, which was statistically at par with bare area in winter season may possibly be due to high input of fertilizers and organic manures in agriculture field and in ban oak forest may ascribed due to humus added to the soil by decomposition of nutrient-rich leaf litter and that maintains the fertility of soil. The results are in confirmty with the findings of (Chandra *et*

al., 2016; Salim *et al.*, 2015; Sheikh and Kumar 2009).

Potassium: The potassium content of soil of five different forest ecosystem was significantly variable with a highest value under ban oak forest, which was statistically at par with mixed forest as shown in (Table 5). Potassium content in soil was highest in winter season as compared to summer season. In the interaction effect, the potassium content of soils of different forest ecosystem during two seasons. The potassium content was higher in ban oak forest during winter season, which was statistically at par with mixed forest in winter season. The results were probably due to more parent material in the soil and dense vegetation present in forest. The results of present study are in the line with (Chandra *et al.*, 2016; Joshi and Negi 2015; Salim *et al.*, 2015; Li *et al.*, 2013).

CONCLUSION

It can be inferred from the present study that the forest ecosystem plays important role towards abiotic and biotic factors by modifying micro-climate and edaphic parameters. This impact resulted from a biogeographic stand characteristics, forest type, dominant tree species, topography, slope orientation, soil type and soil health. Ban oak forest generally had a greater moderating effect during both the season and are rich in nutrient availability as compared to chir pine and mixed forest and directly influenced the soil physico-chemical properties, nutrient cycling, microbial biomass and therefore affects the natural regeneration process of native species. Therefore, oak forest wherever present should be protected and enhanced the plantation to enrich more soil nutrient supply and maintains the microclimatic conditions in the forest and study indicated that forest had potential for improving the soil health.

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Tree Species Diversity, Community Composition and Distribution Across Six Forest Stands of Uttarakhand, Central Himalaya, India

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Abstract: Density, Importance Value Index and diversity measures were calculated for tree, sapling and seedling layers. Overall tree density (Individuals ha⁻¹) ranged from 560 to 1100 across the studied forest stands. Species diversity ranged from 0.93 to 2.18, 0.50 to 1.84 and 0.20 to 2.02 for trees, saplings and seedlings, respectively. Tree species richness varied from 2 to 14. There was a significant negative relationship between altitude and species richness ($r = -0.348$, $P < 0.01$, $n = 60$) indicating a gradual decrease in richness with increasing altitude. Poor or no regeneration in higher altitudinal regions of the study area was due to anthropogenic activities. There is a need to develop proper management strategies to improve regeneration in the study area.

Keywords: Diversity Indices, Species diversity, IVI, Richness, Uttarakhand

Uttarakhand Himalaya is rich in having various life forms and ecosystems. The general composition of the forests in Himalaya is diverse and varies from place to place because of varying topography such as plains, foothills and upper mountains (Singh, 2006). Ram *et al.* (2004) stated that topography, soil, climate and geographical location of a region influence the vegetation diversity of the forest ecosystem. Vegetation is an important part of an ecosystem, which reflects the effect of the entire environment (Billings, 1952). The development and death or decay of plant species alters the pattern of the species distribution in a community (Watt, 1964). Assessment of forest community composition and structure is very helpful in understanding the status of tree population, regeneration, and diversity for conservation purposes (Mishra *et al.*, 2013). Knowledge of species composition and diversity of tree species is of utmost importance not only to understand the structure of a forest community but also for planning and implementation of conservation strategy of the community (Malik *et al.*, 2014; Malik and Bhatt, 2015). Quantitative information on composition, distribution, and abundance of woody species is of key significance to understanding the form and structure of a forest community and also for planning and implementation of conservation strategy of the community (Singh *et al.*, 2016). Species composition and vegetation of Uttarakhand Himalaya have been described by various workers (Hussain *et al.*, 2008; Mandal and Joshi, 2014).

The species richness and diversity of trees are fundamental to total forest biodiversity, because trees

provide resources and habitat for almost all other forest species (Malik, 2014). Regeneration is also a key process for the existence of species in a community under varied environmental conditions (Khumbongmayum *et al.*, 2005). In forest management, regeneration study not only depicts the current status but also hints about the possible changes in forest composition in the future (Sharma *et al.*, 2014). Some of the studies from Uttarakhand Himalayas have reported poor regeneration status in *Quercus* sp. forest because of anthropogenic pressure and climatic reasons. Anthropogenic activities such as constructions of hill roads, forest fires, overgrazing, lopping of trees for fodder and fuelwood, and removal of leaf and wood litter from the forest floor are also affecting plant diversity in the Garhwal Himalayan region, India (Malik *et al.*, 2016). Reliable data on regeneration trends are required for successful management and conservation of natural forests. Therefore, the present study was carried out to assess the regeneration status, distribution pattern and composition of tree species across various forest stands of Uttarakhand.

MATERIAL AND METHODS

The study was conducted in six different forest stands viz., Sandev (SND), Chaurani (CHN), Kafani (KFN) in Pithoragarh district; Mandal (MDL), Chopta (CPT) and Tungnath (TGN) in Chamoli district of Uttarakhand (Table 1 and Fig. 1). The altitude of these forests stands ranges between 1600–3300 m asl. CPT and TGN sites lie at the borderline of Chamoli and Rudraprayag districts. Except

Table 1. Geographic location of sample forest stands

| Name of forest | Abbreviation | Latitude (N) | Longitude (E) | Elevation (m) |
|----------------|--------------|--------------|---------------|---------------|
| Sandev | SND | 29° 48' | 80° 13' 07" | 1800 |
| Chaurani | CHN | 29° 49' | 80° 19' 14" | 1750 |
| Kaflani | KFN | 29° 49' | 80° 19' 46" | 1950 |
| Mandal | MDL | 30° 27' | 79° 16' 14" | 1645 |
| Chopta | CPT | 30° 29' | 79° 12' 18" | 2982 |
| Tungnath | TGN | 30° 29' | 79° 12' 41" | 3290 |

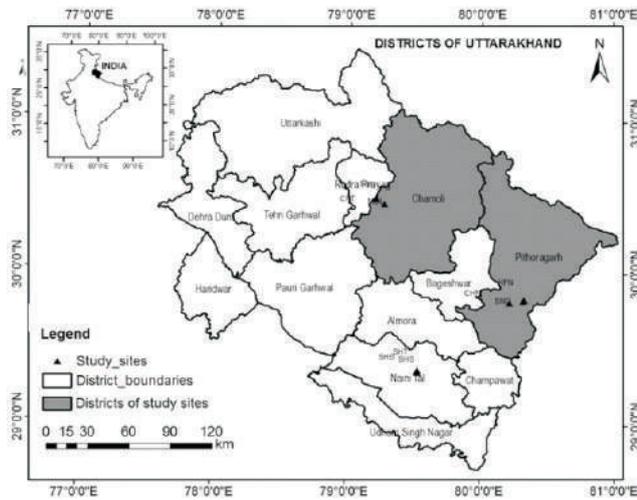


Fig. 1. Location map of the study area

SND; CHN and KFN forests are constituent habitat of Askote-wildlife sanctuary while MDL, CPT and TGN are the part of Kedarnath wildlife sanctuary. The landscape of the selected sites is mountainous, with moderate to steep slopes. Soils are coarse-textured loam or sandy loam at lower altitudes, sandy at higher altitudes, and are well drained and acidic (Sundriyal, 1992). The climate of the area is influenced by monsoon pattern of rainfall. Precipitation occurs as rain, hail, snow, and showers over the year. Snowfall is from November to April (eg. TGN), and snowmelt occurs during April and May providing an abundance of soil water prior to the monsoon period. Maximum rainfall occurs in July-August. Most of the

studied forest stands are represented by *Quercus spp.*, *Cedrus deodara*, *Alnus nepalensis*, *Pinus roxburghii*, *Rhododendron barbatum* and *Abies spectabilis*.

A sum of 60 sampling plots having 10 m x 10 m (0.1 ha) size were randomly laid down to analyze the vegetation composition (trees, saplings, and seedlings) in the selected forest sites. Within each sampling plot, individuals of tree species were counted and their cbh (circumference at breast height) was measured. On the basis of cbh, the individuals were categorized into tree (> 31.5 cm cbh), sapling (10.5 – 31.5 cm cbh) and seedling (<10.5 cm cbh) by following Knight (1975). The composition of vegetation (tree species) was analyzed by calculating various phytosociological attributes such as density, frequency, abundance, and importance value index (IVI) following Curtis and McIntosh (1951). Total basal area was calculated following Mishra (1968).

The total number of species was considered as species richness. Evenness or equitability (*J'*) was calculated using the formula given by Pielou (1969): concentration of dominance (*C_d*) was calculated following Simpson's index (*D*).

RESULTS AND DISCUSSION

Community composition in the studied forests: Various forest types having different composition of tree species were observed in the study sites. They showed difference in terms of various phytosociological attributes such as diversity, density, frequency, abundance, IVI, etc. The overall tree density (Individual ha⁻¹) varied between 560 (CHN) and 1100 (KFN), whereas, sapling density (Individual ha⁻¹) ranged from 50 (CPT) to 270 (SND); and seedling density (Individual ha⁻¹) varied between 270 (CPT) and 490 (CHN). However, individuals of saplings and seedlings were not found at TGN. Total basal area ranged between 27.24 to 80.04 m² ha⁻¹ across the studied forest stands (Table 2).

IVI of tree species at SND: The distribution analysis of tree species in the SND showed that *Cedrus deodara* had the highest IVI (51.4) followed by *Alnus nepalensis* (34.8) while *Machilus duthiei* had the minimum IVI (5.8) in tree layer. In

Table 2. Characteristic features and community composition of the studied forest stands

| Parameters | SND | CHN | KFN | MDL | CPT | TGN |
|--|------------------------------|---------------------------------|--|--------------------------------|--------------------------------------|----------------------------------|
| Trees density (Ind. ha ⁻¹) | 900 | 560 | 1100 | 750 | 760 | 660 |
| Sapling density (Ind. ha ⁻¹) | 270 | 80 | 110 | 100 | 50 | – |
| Seedling density (Ind. ha ⁻¹) | 310 | 490 | 430 | 460 | 60 | – |
| TBA (cover m ² ha ⁻¹) | 56.12 | 31.58 | 29.07 | 80.04 | 54.70 | 27.24 |
| Dominant tree species (Highest Importance Value Index) | <i>Cedrus deodara</i> (51.4) | <i>Pinus roxburghii</i> (142.9) | <i>Quercus leucotrichophora</i> (60.3) | <i>Alnus nepalensis</i> (69.8) | <i>Quercus semecarpifolia</i> (75.0) | <i>Abies spectabilis</i> (176.2) |
| Regeneration status | Fair | Good | Fair | Good | Fair | No |

SND=Sandev; CHN=Chaurani; KFL=Kaflani; MDL=Mandal; CPT=Chopta; TGN=Tungnath

sapling layer, IVI ranged from 17.2 (*T. ciliata*) to 89.2 (*Q. leucotrichophora*), whereas, in seedling layer it varied between 25.3 (*M. duthiei*) to 55.9 (*P. roxburghii*). The tree density was recorded maximum for *C. deodara* (300 Ind ha⁻¹) followed by 150 Ind ha⁻¹ (*A. nepalensis*). Sapling density (Ind ha⁻¹) ranged from 10 (*T. ciliata*) to 100 (*Q. leucotrichophora*) while seedling density varied from 20 (*M. duthiei*) to 60 (eg. *C. deodara*). In the tree layer, the frequency ranged from 10 % (*Butea monosperma*) to 70 % (*Q. leucotrichophora*). In sapling layer, frequency ranged from 10 % (*A. nepalensis*) to 50% (*Q. leucotrichophora*). In the seedling layer, frequency varied between 10 % (*M. duthiei*) to 30% (*C. deodara*). Basal area (cover m² ha⁻¹) varied from 1.06 to 12.18, 0.11 to 0.67, and 0.02 to 0.06 in tree, sapling and seedling layer, respectively (Table 3).

IVI of tree species at CHN: *P. roxburghii* was the dominant tree species with the highest IVI (142.9) followed by *Q. lanuginosa* (37.5) and *Phyllanthus emblica* (10.6) was the least dominant species. In sapling layer, *Q. lanuginosa* was dominant with highest IVI of 72.2. In seedling layer, *Butea monosperma* was dominant with IVI of 157.9 followed by *M. esculenta*. The tree density (Ind ha⁻¹) ranged from 10 (*A. nepalensis*) to 410 (*P. roxburghii*). Sapling density (Ind ha⁻¹) ranged from 10 to 20. Seedling density (Ind ha⁻¹) ranged between 10 (*M. esculenta*) to 470 (*Butea monosperma*). In

tree layer, frequency varied from 10 % (*A. nepalensis*) to 100 % (*P. roxburghii*). 10 % frequency was observed for all the species in sapling layer. In seedling layer, frequency varied from 10% to 20%. BA (cover m² ha⁻¹) varied between 1.27 to 6.99, 0.16 to 0.60, and 0.01 to 0.02 in tree, sapling and seedling layer, respectively (Table 4).

IVI of tree species at KFN: In KFN forest, *Q. leucotrichophora* was observed as dominant tree species with the highest IVI of 60.3 and 95.6 in tree and sapling layer, respectively. In the

Table 3. Richness, evenness and diversity indices for trees, saplings and seedlings

| Parameters | SND | CHN | KFN | MDL | CPT | TGN |
|---------------------------------------|------|------|------|------|------|------|
| Richness (α) | | | | | | |
| Trees | 14 | 09 | 09 | 10 | 06 | 03 |
| Sapling | 08 | 05 | 06 | 03 | 02 | – |
| Seedling | 07 | 03 | 06 | 08 | 02 | – |
| Evenness (J') | | | | | | |
| Trees | 0.83 | 0.49 | 0.81 | 0.87 | 0.87 | 0.84 |
| Sapling | 0.88 | 0.97 | 0.92 | 0.86 | 0.72 | – |
| Seedling | 0.97 | 0.18 | 0.91 | 0.97 | 0.92 | – |
| Shannon (H') | | | | | | |
| Trees | 2.18 | 1.08 | 1.79 | 2.01 | 1.56 | 0.93 |
| Sapling | 1.84 | 1.56 | 1.64 | 0.95 | 0.50 | – |
| Seedling | 1.89 | 0.20 | 1.63 | 2.02 | 0.64 | – |
| Simpson (D) | | | | | | |
| Trees | 0.16 | 0.54 | 0.20 | 0.18 | 0.23 | 0.45 |
| Sapling | 0.17 | 0.11 | 0.15 | 0.38 | 0.60 | – |
| Seedling | 0.13 | 0.92 | 0.21 | 0.12 | 0.47 | – |
| Dominance (C_d) | | | | | | |
| Trees | 0.10 | 0.27 | 0.15 | 0.12 | 0.20 | 0.44 |
| Sapling | 0.16 | 0.21 | 0.20 | 0.36 | 0.55 | – |
| Seedling | 0.15 | 0.40 | 0.18 | 0.13 | 0.54 | – |

Table 4. Distribution analysis of tree species at SND

| Species | D | F | A | A/F | BA | IVI |
|---|-----|----|-----|------|-------|------|
| Tree layer | | | | | | |
| <i>Alnus nepalensis</i> D. Don | 150 | 40 | 3.8 | 0.09 | 4.54 | 34.8 |
| <i>Butea monosperma</i> (Lam.) Taub. | 60 | 10 | 6.0 | 0.60 | 2.08 | 12.9 |
| <i>Cedrus deodara</i> (Roxb.) G. Don | 300 | 50 | 6.0 | 0.12 | 3.15 | 51.4 |
| <i>Lyonia ovalifolia</i> (Wall.) Drude | 50 | 30 | 1.7 | 0.06 | 4.36 | 20.9 |
| <i>Machilus duthiei</i> King | 10 | 10 | 1.0 | 0.10 | 1.21 | 5.8 |
| <i>Myrica esculenta</i> Buch.-Ham. ex D. Don. | 40 | 40 | 1.0 | 0.03 | 1.52 | 17.1 |
| <i>Pinus roxburghii</i> Sarg. | 40 | 30 | 1.3 | 0.04 | 9.20 | 28.3 |
| <i>Pyrus pashia</i> Buch.-Ham. ex D. Don. | 20 | 20 | 1.0 | 0.05 | 1.06 | 9.1 |
| <i>Quercus lanuginosa</i> Sm. | 30 | 20 | 1.5 | 0.08 | 12.18 | 30.1 |
| <i>Quercus leucotrichophora</i> A. Camus | 90 | 70 | 1.3 | 0.02 | 2.74 | 32.4 |
| <i>Rhododendron arboreum</i> Sm. | 30 | 30 | 1.0 | 0.03 | 7.91 | 25 |
| <i>Symplocos chinensis</i> (Lour.) Druce | 40 | 20 | 2.0 | 0.10 | 1.68 | 12.4 |
| <i>Thuja orientalis</i> L. | 20 | 10 | 2.0 | 0.20 | 2.50 | 9.1 |
| <i>Toona ciliata</i> M. Roem | 20 | 10 | 6.0 | 0.60 | 1.99 | 10.7 |
| Sapling layer | | | | | | |
| <i>A. nepalensis</i> D. Don | 30 | 10 | 3.0 | 0.30 | 0.33 | 30.3 |
| <i>B. monosperma</i> (Lam.) Taub. | 30 | 10 | 3.0 | 0.30 | 0.67 | 43.2 |
| <i>M. duthiei</i> King | 20 | 20 | 1.0 | 0.05 | 0.20 | 28.4 |
| <i>P. pashia</i> Buch.-Ham. ex D. Don. | 20 | 10 | 2.0 | 0.20 | 0.26 | 23.9 |
| <i>P. roxburghii</i> Sarg. | 20 | 20 | 1.0 | 0.05 | 0.39 | 35.3 |
| <i>Q. leucotrichophora</i> A. Camus | 100 | 50 | 2.0 | 0.04 | 0.50 | 89.2 |
| <i>R. arboreum</i> Sm. | 40 | 20 | 2.0 | 0.10 | 0.11 | 32.4 |
| <i>T. ciliata</i> M. Roem | 10 | 10 | 1.0 | 0.10 | 0.18 | 17.2 |
| Seedling | | | | | | |
| <i>C. deodara</i> (Roxb.) G. Don | 60 | 30 | 2.0 | 0.07 | 0.06 | 36.6 |
| <i>M. duthiei</i> King | 20 | 10 | 2.0 | 0.20 | 0.03 | 25.3 |
| <i>M. esculenta</i> Buch.-Ham. ex D. Don. | 40 | 20 | 2.0 | 0.10 | 0.02 | 47.7 |
| <i>P. roxburghii</i> Sarg. | 50 | 20 | 2.5 | 0.13 | 0.04 | 55.9 |
| <i>Q. leucotrichophora</i> A. Camus | 60 | 30 | 2.0 | 0.07 | 0.04 | 38 |
| <i>R. arboreum</i> Sm. | 50 | 20 | 2.5 | 0.13 | 0.03 | 55.1 |
| <i>S. chinensis</i> (Lour.) Druce | 30 | 10 | 3.0 | 0.30 | 0.04 | 41.4 |

D=Density (Individuals ha⁻¹); F=Frequency (%); A=Abundance; BA= Basal Area (m² ha⁻¹); IVI= Importance Value Index

seedling layer, IVI varied between 28.2 (*P. roxburghii*) to 75.5 (*B. monosperma*). Tree and sapling density (Individual ha⁻¹) was recorded maximum for *Q. semecarpifolia* (380 trees and 40 saplings). Seedling density ranged from 30 (*Q. leucotrichophora*) to 150 (*B. monosperma*). Frequency varied from 10 % to 60 % in the tree layer. In the sapling layer, frequency ranged from 10 % to 30 % while in seedling layer, it ranged from 10 % to 40 %. BA (cover m² ha⁻¹) varied between 1.03 to 8.29, 0.29 to 0.71, and 0.02 to 0.04 in tree, sapling, and seedling layer, respectively (Table 5).

IVI of tree species at MDL: At MDL forest, *A. nepalensis* was recorded as dominant tree species with the highest IVI of 69.8 followed by *Q. semecarpifolia* (33.4). In sapling layer, IVI ranged from 80.4 (*Q. leucotrichophora*) to 136.7 (*D. salicifolia*), whereas, in seedling layer it varied between 24.5 (*P. roxburghii*) to 52.3 (*A. nepalensis*). The tree density (Ind ha⁻¹) ranged from 40 (*F. auriculata*) to 280 (*A. nepalensis*). Maximum sapling density was observed for *P. pashia* (60 Ind ha⁻¹); however, it was 20 Ind ha⁻¹ for rest of the species in sapling stage. Seedling density (Ind ha⁻¹) ranged from 20 (*P. pashia*) to 80 (*A. nepalensis*). Frequency varied between 20

% (*Q. leucotrichophora*) to 80 % (*A. nepalensis*); and 20 % to 40% in tree and sapling/seedling layer respectively. Basal area (cover m² ha⁻¹) varied between 2.87 to 12.24, 0.47 to 0.67, and 0.01 to 0.05 in tree, sapling and seedling layer, respectively (Table 6).

IVI of tree species at CPT forest: The IVI ranged from 21.8 (*R. arboreum*) to 75.0 (*Q. semecarpifolia*), 102.8 (*Q. semecarpifolia*) to 197.2 (*R. barbatum*), and 109.4 (*Q. semecarpifolia*) to 190.6 (*R. barbatum*) in tree, sapling and seedling layer respectively. Tree density (Ind. ha⁻¹) ranged from 30 (*R. arboreum*) to 260 (*Q. semecarpifolia*). Sapling and seedling density ranged from 10 to 40 and 20 to 40, respectively. In the tree layer, frequency varied between 30 % (*R. arboreum*) to 60 % (*A. spectabilis*). A 10 % to 30 % frequency was observed in sapling/seedling layer. Basal area (cover m² ha⁻¹) varied between 1.54 to 21.28, 0.56 to

Table 5. Distribution analysis of tree species at CHN

| Species | D | F | A | A/F | BA | IVI |
|--|-----|-----|------|------|------|-------|
| Tree layer | | | | | | |
| <i>Alnus nepalensis</i> D. Don | 10 | 10 | 1.0 | 0.10 | 1.68 | 11.9 |
| <i>Boehmeria rugulosa</i> Wedd. | 10 | 10 | 1.0 | 0.10 | 6.03 | 25.7 |
| <i>Cinnamomum tamala</i> Nees & Eberm. | 10 | 10 | 1.0 | 0.10 | 3.79 | 18.6 |
| <i>Cupressus torulosa</i> D. Don | 40 | 20 | 2.0 | 0.10 | 2.04 | 23.1 |
| <i>Ougeinia oojeinensis</i> (Roxb.) Hochr. | 10 | 10 | 1.0 | 0.10 | 2.41 | 14.2 |
| <i>Phyllanthus emblica</i> L. | 10 | 10 | 1.0 | 0.10 | 1.27 | 10.6 |
| <i>Pinus roxburghii</i> Sarg. | 410 | 100 | 4.1 | 0.04 | 6.99 | 142.9 |
| <i>Quercus lanuginosa</i> Sm. | 40 | 30 | 1.3 | 0.04 | 5.13 | 37.5 |
| <i>Terminalia chebula</i> Retz. | 20 | 10 | 2.0 | 0.20 | 2.24 | 15.4 |
| Sapling layer | | | | | | |
| <i>C. tamala</i> Nees & Eberm. | 10 | 10 | 1.0 | 0.1 | 0.16 | 39.5 |
| <i>O. oojeinensis</i> (Roxb.) Hochr. | 20 | 10 | 2.0 | 0.2 | 0.44 | 64.8 |
| <i>P. emblica</i> L. | 20 | 10 | 2.0 | 0.2 | 0.56 | 70.2 |
| <i>Q. lanuginosa</i> Sm. | 20 | 10 | 2.0 | 0.2 | 0.60 | 72.2 |
| <i>T. chebula</i> Retz. | 10 | 10 | 1.0 | 0.1 | 0.46 | 53.2 |
| Seedling layer | | | | | | |
| <i>B. monosperma</i> (Lam.) Taub. | 470 | 10 | 47.0 | 4.7 | 0.02 | 157.9 |
| <i>M. esculenta</i> Buch.-Ham. ex D. Don. | 10 | 10 | 1.0 | 0.1 | 0.01 | 48.8 |
| <i>Q. leucotrichophora</i> A. Camus | 10 | 20 | 0.5 | 0.03 | 0.02 | 93.3 |

D=Density (Individuals ha⁻¹); F=Frequency (%); A=Abundance; BA= Basal Area (m² ha⁻¹); IVI= Importance Value Index

Table 6. Distribution analysis of tree species at KFN

| Species | D | F | A | A/F | BA | IVI |
|--|-----|----|-----|------|------|------|
| Tree layer | | | | | | |
| <i>Alnus nepalensis</i> D. Don | 20 | 10 | 2.0 | 0.20 | 1.68 | 10.7 |
| <i>Butea monosperma</i> (Lam.) Taub. | 150 | 50 | 3.0 | 0.06 | 2.27 | 37.0 |
| <i>Grewia eriocarpa</i> Juss. | 10 | 10 | 1.0 | 0.10 | 1.03 | 7.6 |
| <i>Myrica esculenta</i> Buch.-Ham. ex D. Don. | 160 | 50 | 3.2 | 0.06 | 2.68 | 39.3 |
| <i>Pinus roxburghii</i> Sarg. | 140 | 60 | 2.3 | 0.04 | 8.29 | 60 |
| <i>Q. lanuginosa</i> Sm. | 170 | 50 | 3.4 | 0.06 | 6.94 | 55 |
| <i>Quercus leucotrichophora</i> A. Camus | 380 | 60 | 6.3 | 0.10 | 2.03 | 60.3 |
| <i>Quirivelia frutescens</i> (L.) M. R. & S.M. Almeida | 10 | 10 | 1.0 | 0.10 | 2.03 | 11.1 |
| <i>Rhododendron arboreum</i> | 60 | 20 | 3.0 | 0.15 | 2.12 | 19 |
| Sapling layer | | | | | | |
| <i>A. nepalensis</i> D. Don | 10 | 10 | 1.0 | 0.10 | 0.29 | 30.8 |
| <i>G. eriocarpa</i> Juss. | 10 | 10 | 1.0 | 0.10 | 0.35 | 42.2 |
| <i>M. esculenta</i> Buch.-Ham. ex D. Don. | 20 | 10 | 2.0 | 0.20 | 0.24 | 38.3 |
| <i>Q. lanuginosa</i> Sm. | 20 | 20 | 1.0 | 0.05 | 0.46 | 48.2 |
| <i>Q. leucotrichophora</i> A. | 40 | 30 | 1.3 | 0.04 | 0.71 | 95.6 |
| <i>R. arboreum</i> Sm. | 10 | 10 | 1.0 | 0.10 | 0.67 | 44.8 |
| Seedling layer | | | | | | |
| <i>B. monosperma</i> (Lam.) Taub. | 150 | 40 | 3.8 | 0.09 | 0.02 | 75.5 |
| <i>M. esculenta</i> Buch.-Ham. ex D. Don. | 40 | 10 | 4.0 | 0.40 | 0.04 | 44.9 |
| <i>P. roxburghii</i> Sarg. | 40 | 10 | 4.0 | 0.40 | 0.02 | 28.2 |
| <i>Q. frutescens</i> (L.) M.R. & S.M. Almeida | 100 | 30 | 3.3 | 0.11 | 0.03 | 65.7 |
| <i>Q. lanuginosa</i> Sm. | 70 | 20 | 3.5 | 0.18 | 0.02 | 41.4 |
| <i>Q. leucotrichophora</i> A. | 30 | 20 | 1.5 | 0.08 | 0.04 | 44.3 |

D=Density (Individuals ha⁻¹); F=Frequency (%); A=Abundance; BA= Basal Area (m² ha⁻¹); IVI= Importance Value Index

0.77, and 0.01 to 0.05 in tree, sapling and seedling layer, respectively (Table 7).

IVI of tree species at TGN forest: In the tree layer, *A. spectabilis* was the dominant tree species with the highest of IVI 176.2 followed by *Q. semecarpifolia* (85.4), while *B. utilis* was the least dominant species with minimum IVI of 38.4. Tree density (Ind. ha⁻¹) ranged from 120 (*Q. semecarpifolia*) to 410 (*A. spectabilis*). A 90 % frequency was observed for *A. spectabilis* followed by *Q. semecarpifolia* (70 %). Basal area (cover m² ha⁻¹) varied between 2.07 to 17.47 in the tree layer. However, there were no individuals recorded in sapling and seedling layer (Table 8).

Species richness, evenness and diversity: Species richness ranged from 03 to 14 (tree layer) and 02 to 08 (sapling & seedling layer) across the studied forests. There

Table 7. Distribution analysis of tree species at MDL

| Species | D | F | A | A/F | BA | IVI |
|---|-----|----|-----|------|-------|-------|
| Tree layer | | | | | | |
| <i>Aesculus indica</i> (Camb.) Hook. | 50 | 40 | 1.3 | 0.03 | 7.96 | 26.1 |
| <i>Alnus nepalensis</i> D. Don | 280 | 80 | 3.5 | 0.04 | 10.67 | 69.8 |
| <i>Ficus auriculata</i> Lour. | 40 | 50 | 0.8 | 0.02 | 2.87 | 20.8 |
| <i>Myrica esculenta</i> Buch.-Ham. ex D. Don | 40 | 40 | 1.0 | 0.03 | 11.46 | 29.1 |
| <i>Pinus roxburghii</i> Sarg. | 50 | 40 | 1.3 | 0.03 | 5.67 | 23.3 |
| <i>Prunus cerasoides</i> D. Don | 60 | 30 | 2.0 | 0.07 | 10.53 | 28.3 |
| <i>Pyrus pashia</i> Buch.-Ham. ex D. Don. | 40 | 40 | 1.0 | 0.03 | 3.36 | 19.0 |
| <i>Quercus leucotrichophora</i> A. Camus | 100 | 20 | 5.0 | 0.25 | 12.24 | 33.4 |
| <i>Rhododendron arboreum</i> Sm. | 50 | 50 | 1.0 | 0.02 | 6.46 | 26.7 |
| <i>Toona ciliata</i> M. Roem | 40 | 30 | 1.3 | 0.04 | 8.82 | 23.5 |
| Sapling layer | | | | | | |
| <i>Debregesia salicifolia</i> (D. Don) Rendle | 20 | 20 | 1.0 | 0.05 | 0.47 | 136.7 |
| <i>Q. leucotrichophora</i> A. Camus | 20 | 20 | 1.0 | 0.05 | 0.62 | 80.4 |
| <i>R. arboreum</i> Sm. | 60 | 40 | 1.5 | 0.04 | 0.67 | 82.9 |
| Seedling layer | | | | | | |
| <i>A. indica</i> (Camb.) Hook. | 60 | 20 | 3.0 | 0.15 | 0.02 | 29.9 |
| <i>A. nepalensis</i> D. Don | 80 | 40 | 2.0 | 0.05 | 0.04 | 52.3 |
| <i>M. esculenta</i> Buch.-Ham. ex D. Don | 40 | 20 | 2.0 | 0.10 | 0.03 | 29.5 |
| <i>P. pashia</i> Buch.-Ham. ex D. Don. | 20 | 20 | 1.0 | 0.05 | 0.05 | 34.8 |
| <i>P. roxburghii</i> Sarg. | 60 | 20 | 3.0 | 0.15 | 0.01 | 24.5 |
| <i>Q. leucotrichophora</i> A. Camus | 60 | 40 | 1.5 | 0.04 | 0.02 | 38.3 |
| <i>R. arboreum</i> Sm. | 60 | 40 | 1.5 | 0.04 | 0.03 | 40.8 |
| <i>T. ciliata</i> M. Roem | 80 | 40 | 2.0 | 0.05 | 0.04 | 49.9 |

D=Density (Individuals ha⁻¹); F=Frequency (%); A=Abundance; BA= Basal Area (m² ha⁻¹); IVI= Importance Value Index

was a significant negative relationship between altitude and tree species richness ($r = -0.348$, $P < 0.01$, $n = 60$) indicating a gradual decrease in richness with increasing altitude (Fig. 2). Evenness varied between 0.49 to 0.87, 0.72 to 0.97 and 0.18 to 0.97 for tree, sapling and seedling layer respectively. Species diversity (Shannon diversity index) varied from 0.93 to 2.18, 0.50 to 1.84 and 0.20 to 2.02 in tree, sapling and seedling layer respectively. Concentration of dominance ranged from 0.10 to 0.44, 0.16 to 0.55 and 0.13 to 0.54 for tree, sapling and seedling layer respectively (Table 2).

Distribution pattern (A/F) and regeneration status: 10–89 % of tree species showed contagious distribution while 11–70 % species showed random distribution and 7–33 % species showed regular pattern of distribution across the various studied forest sites (Fig. 3). A total of 50 % individuals were found in sapling/seedling stage at CHN forest followed by 43 % at MDL while in other forests more than 60 % individuals were found in tree growth form (Fig. 4). It indicates that CHN and MDL had good regeneration status while other three studied forests (SND, KFN and CPT) showed fair regeneration status. However, there was no regeneration at TGN.

Species diversity and forest composition of any forest

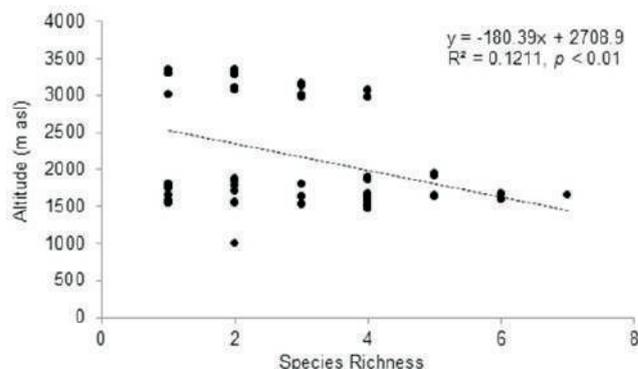


Fig. 2. Relationship between altitude and species richness

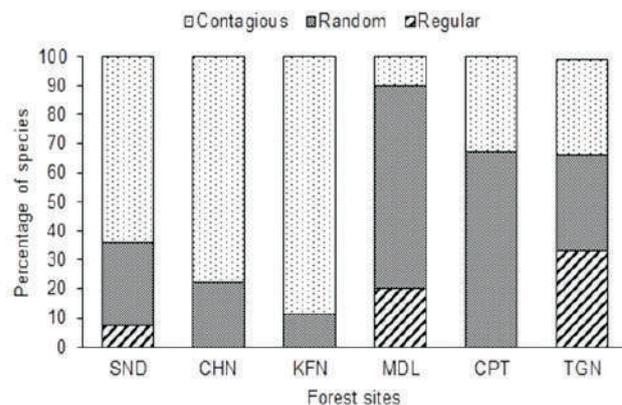
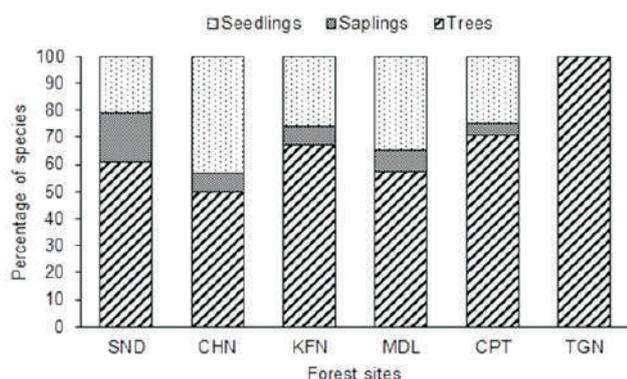


Fig. 3. Distribution pattern of tree species across the study sites

Table 8. Distribution analysis of tree species at CPT

| Species | D | F | A | A/F | BA | IVI |
|--|-----|----|-----|------|-------|-------|
| Tree layer | | | | | | |
| <i>Abies pindrow</i> (Royle ex D. Don) Royle | 70 | 40 | 1.8 | 0.04 | 21.28 | 62.9 |
| <i>Abies spectabilis</i> Wall ex D. Don | 220 | 60 | 3.7 | 0.06 | 10.52 | 70.3 |
| <i>Quercus semecarpifolia</i> A. Camus | 260 | 50 | 5.2 | 0.10 | 12.19 | 75.0 |
| <i>Rhododendron arboreum</i> Sm. | 30 | 30 | 1.0 | 0.03 | 3.65 | 21.8 |
| <i>Rhododendron barbatum</i> Wall. ex G. Don | 120 | 50 | 2.4 | 0.05 | 5.52 | 44.4 |
| <i>Taxus baccata</i> L. | 60 | 40 | 1.5 | 0.04 | 1.54 | 25.5 |
| Sapling layer | | | | | | |
| <i>Q. semecarpifolia</i> A. Camus | 10 | 10 | 1.0 | 0.10 | 0.77 | 102.8 |
| <i>R. barbatum</i> Wall. ex G. Don | 40 | 30 | 1.3 | 0.04 | 0.56 | 197.2 |
| Seedling layer | | | | | | |
| <i>Q. semecarpifolia</i> A. Camus | 20 | 30 | 0.7 | 0.02 | 0.01 | 109.4 |
| <i>R. barbatum</i> Wall. ex G. Don | 40 | 20 | 2.0 | 0.10 | 0.05 | 190.6 |

D=Density (Individuals ha⁻¹); F=Frequency (%); A=Abundance; BA= Basal Area (m² ha⁻¹); IVI= Importance Value Index

**Fig. 4.** Percentage of individuals in various stages (trees/saplings/seedlings) across the study sites**Table 9.** Distribution analysis of tree species at TGN

| Species | D | F | A | A/F | BA | IVI |
|---|-----|----|-----|------|-------|-------|
| <i>Abies spectabilis</i> Wall ex D. Don | 410 | 90 | 4.6 | 0.05 | 17.47 | 176.2 |
| <i>Betula utilis</i> D. Don | 130 | 20 | 6.5 | 0.33 | 2.07 | 38.4 |
| <i>Quercus semecarpifolia</i> A. Camus | 120 | 70 | 1.7 | 0.02 | 7.70 | 85.4 |

D=Density (Individuals ha⁻¹); F=Frequency (%); A=Abundance; BA= Basal Area (m² ha⁻¹); IVI= Importance Value Index

depends on their ecological and climatic conditions. SND and KFN forest indicates good ecological as well as forest composition. Ecological slopes and north facing aspect of SND, MDL and KFL also supports for the diversity and density of the vegetation of the area. The vegetation analysis of the studied forest stands revealed that the tree species diversity (H') ranged between 0.93 (TGN) to 2.18 (SND). It was under the ranged values of 0.68–2.39, 1.86–2.73, 0.70–3.08, 0.78–3.45, 0.74–2.66, 0.66–2.69 and 1.49–1.86 reported by Dhar *et al.* (1997); Ghildiyal *et al.* (1998); Uniyal *et al.* (2010); Raturi (2012); Pant and Sammant (2012); Singh *et al.*

(2014) and Singh *et al.* (2016), respectively. Species diversity for sapling and seedling (0.50 to 2.02) was less as compared to tree diversity (0.93 to 2.18); this indicates that the future forest may be less diverse than present generation. In the present study, concentration of dominance (C_d) ranged from 0.10 (SND) to 0.44 (TGN). Gairola *et al.* (2011) reported C_d values between 0.12 and 0.25 in the MDL-CPT forests of Garhwal Himalaya. Raturi (2012), while working in different temperate and subtropical forests of Rudraprayag (Garhwal Himalaya), recorded C_d values between 0.09 and 0.63. Malik and Bhatt (2015) reported C_d values ranging between 0.06 and 0.37 from a protected area of Western Himalaya. In the present study, tree species richness varied from 03 to 14, which is comparable with others reported from the different temperate forests of Uttarakhand (Gairola *et al.*, 2011; Rikhari *et al.*, 1997; Sharma *et al.*, 2016).

CONCLUSION

TGN forest found highly disturbed and CPT, SND and KFN are moderately disturbed forests. In these areas regeneration should be improved by controlling overgrazing, lopping of trees and tourism activities. Regeneration can also be improved by plantation and developing nurseries. In the high altitudinal regions (TGN), the fallen seeds of tree species (eg. *Q. semecarpifolia*) crawled down due to steepness of the slopes and flow in runoff. At the same time, if forest department must officials collect these seeds and sow them in their natural habitats (forests), the regeneration status could be improved. It can be possible only by imparting knowledge about peak time of seed maturation and seed fall among the local inhabitants and department officials. Besides, management and sustainable lopping of forest resources could also improve regeneration status.

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Seasonal and Temporal Variation of Fluoride Level in Different Water Resources over Western Zone of Tamil Nadu

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Abstract: The water samples (144) were collected from open wells and bore wells, which are being extensively utilized for drinking and farming purposes from different locations of Coimbatore, Thiruppur, Erode and part of Dindugul, Karur, Namakkal districts of Tamil Nadu. The latitude and longitude values were taken at all the locations for mapping the fluoride endemic areas using GPS. Concentration of fluoride measured in groundwater after the monsoonal rains were higher than the preceding months. This was because evaporation resulted in the precipitation of fluoride rich salts on the soil, which reached the groundwater along with percolating rainwater. This study demonstrates that the use of GIS and water quality methods could provide useful information for water quality assessment. On seeing the spatial variation of fluoride content the problematic class of groundwater was occurred in 37 blocks of western zone.

Keywords: Drinking water, Fluoride, Western zone, Spatial variation

Fluoride is widely dispersed in nature and is estimated to be the 13th most abundant element on our planet. Water is the elementary requirement for sustenance of all kinds of life forms but water containing dissolved ions beyond the WHO permissible limit is harmful and not suitable for domestic use and irrigation. Fluoride ion in drinking water is known for both beneficial and detrimental effects on health. The World Health Organization (WHO) and Indian Council of Medical Research (ICMR) described the drinking water quality guideline value for fluoride is 1.5 mg l⁻¹ (WHO, 1963; ICMR, 1975). Abnormal level of fluoride in water is common in fractured hard rock zone with pegmatite veins. Fluoride ions from these minerals leach into the groundwater and contribute to high fluoride concentrations. Drinking water can be polluted with fluoride naturally or by human action (Roy *et al.*, 2017). The bioavailability of soluble fluoride ingested with water was nearly 100 per cent, because soluble fluoride in drinking water was easily absorbed by the gastrointestinal tract without intervention of interfering elements such as calcium, magnesium and aluminium. So, water fluoride level is a primary factor for the cause of fluorosis. In addition to dental fluorosis, ingesting too much fluoride can cause twisting of bones in growing organisms and neurological harm in adults (Liu *et al.*, 2015). Fluoride beyond desirable concentration that is (0.6 to 1.5 mg/l) in water is a major health problem in many parts of the world. About 200 million people from 25 nations have health risks because of high fluoride in ground water (Ayoob and Gupta, 2006). High

fluoride in groundwater has been reported from 19 states in India (CGWB, 2010). The permissible limit of fluoride level in ground water is 1.5 mg/L and if it is exceeded, it causes fluorosis and about 3.2 per cent people have been affected by this disease worldwide (Dhanasekaran *et al.*, 2017). The occurrence of high fluoride content has been reported in 13 States in India (Hema and Subramani, 2017). Based on the extensively documented relationship between caries experience and both water fluoride concentration and fluoride intake, the adequate intake and recommended dietary allowance for fluoride from all sources is set at 0.05 mg kg⁻¹ day⁻¹. Agencies also set the adequate intake level for infants below 6 months at 0.01 mg day⁻¹ (NRC, 2001). Concentrations in drinking water of about 1 mg l⁻¹ are associated with a lower incidence of dental caries particularly in children, whereas excess intake of fluoride can result in dental fluorosis. In India about 62 million people are living at risk of high fluoride concentration in drinking water (IPCS, 2001).

MATERIAL AND METHODS

Study area: Western Zone of Tamil Nadu state includes mainly Coimbatore, Tiruppur, Erode districts and parts of Karur, Dindugul and Namakkal districts in Tamil Nadu (Fig. 1). The districts are classified under western agro-climatic region of Tamil Nadu. It comprises of all the revenue taluks of Coimbatore and Erode districts, Thiruchengodu of Namakkal, Karur and Manapparai of Karur, Nilakottai and

Palani of Dindugul, Usilampatti of Madurai and Uthamapalayam and Periyakulam of Theni districts (Table 1). The zone has undulating topography sloping towards west to east with small hillocks here and there having an altitude ranging from 171 to 1525 m above MSL.

The groundwater samples were collected from open wells and bore wells, which are being extensively utilized for drinking and farming purposes. The systematic sampling method is used to find out the water sample points. The whole study area is divided into grid. The centroid of each grid is considered as a sample point. The centroid is cross checked with the help of Google Earth whether the point is located in the field or out of the way. Some points are located in the remote areas and were adjusted accordingly.

A total of 144 water samples (Fig. 1) were collected from open well, bore well and surface water from different locations and analysed. The study confined to western zone of Tamil Nadu which consist of 12 blocks with 25 villages in Coimbatore, 13 blocks with 37 villages in Tiruppur, 14 blocks with 43 villages in Erode, 5 blocks with 20 villages in Dindigul, 4 blocks with 15 villages in Karur and 3 blocks with 4 villages Namakkal. All the samples were collected in pre cleaned and sterilized plastic cans of one-liter capacity and was preserved at 4°C. The latitude and longitude values were taken at all the locations for mapping the fluoride endemic areas using GPS. The base map has been prepared using survey of India topographic sheets 1:50,000 scale from the toposheet the major roads, rivers, blocks headquarter locations are traced in tracing films, scanned geo-referenced and digitized using ArcGIS 9.2. The base map for Western Agro climate region for Tamil Nadu is collected and data is converted into digital data with the help of scanning. The scanned map is referenced using GPS (Global Positioning System). The map is geo-referenced with the suitable projection. Projection is a mathematical method of converting 3D to 2D. The datum used for Geo-reference is WGS 1984 and projection is UTM Co-ordinates. After Geo-reference the map is digitized. *i.e.*, converting raster to vector format. Once the base file setup is finished the analysis is carried out. The water sample point is collected from the GPS and the tested data is added into the attribute table of each point. Then the suitable interpolation technique is used to bring out the result. Here the Spline method of interpolation technique is used to find out the result. The final output is brought in to layout. Then the layout is exported in the form of PDF file or Image file as a map. Interpolation predicts values for cells in a raster from a limited number of sample data points. It can be used to predict unknown values for any geographic point data, such as elevation, rainfall, chemical concentrations, noise levels, and so on. The Regularized method creates a smooth, gradually

Table 1. Sample locations in western zone of Tamil Nadu

| Block | Sample points | Latitude | Longitude |
|-------------------|-----------------------|-----------|-----------|
| Coimbatore | | | |
| Anamalai | Somadurai | 10.343 | 76.581 |
| Pollachi South | Thondamuthur | 10.344 | 77.040 |
| Pollachi North | Pollachi | 10.394 | 77.003 |
| | Anupparpalayam | 10.403 | 77.040 |
| Kinathukadavu | Govindapuram | 10.464 | 76.575 |
| | Devanampalayam | 10.464 | 77.040 |
| | Karacheri | 10.524 | 77.040 |
| Madukkarai | Arasipalayam | 10.525 | 76.575 |
| Sultanpet | Poorandampalayam | 10.524 | 77.100 |
| Thondamuthur | Karuparayan kovil | 10.584 | 76.580 |
| Sulur | Peedampalli | 10.584 | 77.040 |
| | Mathapur | 11.045011 | 77.100393 |
| | Kaduvettipalayam | 11.104627 | 77.100676 |
| | Mylampatti | 11.044647 | 77.040264 |
| Sarkarsamakulam | Chinnavedampatti | 11.044741 | 76.575668 |
| PN Palayam | Veerapandi | 11.104228 | 76.575908 |
| | Thanneer Pandhal | 11.044519 | 76.515170 |
| Karamadai | Nellithurai | 11.164123 | 76.455449 |
| | Muthukallur | 11.124452 | 76.493891 |
| | Thekkampatti | 11.165746 | 76.515022 |
| | Chikkampalayam | 11.145935 | 76.534761 |
| | Forest College | 11.195522 | 76.561228 |
| | Sittapalayam | 11.231107 | 77.035866 |
| Annur | Mookanur | 11.165950 | 77.035921 |
| | Semmainisettipalayam | 11.105415 | 77.040329 |
| Thiruppur | | | |
| Udumalaipet | GVG College for Women | 10.345049 | 77.154731 |
| Madathukulam | Kolumam | 10.285017 | 77.215416 |
| | Sholamadevi | 10.345891 | 77.215047 |
| Gudimangalam | Puthupalayam | 10.405358 | 77.094680 |
| | Murungapatti | 10.405632 | 77.154861 |
| | Kallapalayam | 10.465559 | 77.155486 |
| | V.Vellore | 10.465845 | 77.094448 |
| Dharapuram | Nattukalpalayam | 10.405576 | 77.215522 |
| | Dhalavoipattinam | 10.405729 | 77.275954 |
| | Madathupalayam | 10.470258 | 77.275805 |
| | Veerachimangalam | 10.465502 | 77.340299 |
| Kundadam | Maruthur | 10.465228 | 77.215764 |
| | Thumbalapatti | 10.530637 | 77.215516 |
| | Vengipalayam | 10.531127 | 77.275546 |
| Pongalur | Varapalayam | 10.530557 | 77.155017 |
| | Pongalur | 10.590067 | 77.215733 |
| | Nachipalayam | 11.051502 | 77.275668 |
| Palladam | Karadivavi | 10.584725 | 77.094696 |
| | Chinnur | 10.585161 | 77.155127 |

Cont...

| | | | | | | | |
|----------------|-----------------------|-----------|-----------|-----------------|---------------------------------------|-----------|-----------|
| Thiruppur | Attayampalayam | 11.045666 | 77.154932 | Thiruppur | Attayampalayam | 11.045666 | 77.154932 |
| | Jothinagar | 11.045989 | 77.215756 | | Jothinagar | 11.045989 | 77.215756 |
| | Kankkampalayam | 11.114732 | 77.222886 | Bhavani | Aapa koodal | 11.284103 | 77.335988 |
| | Mariyapuram | 11.165162 | 77.215541 | | Thottipalayam | 11.283133 | 77.401033 |
| Avinashi | Thevarayampalayam | 11.105620 | 77.154600 | Erode | Chithodu | 11.223018 | 77.401476 |
| | Kasilingampalayam | 11.165586 | 77.095235 | Perundurai | Kanjikovil | 11.222924 | 77.340405 |
| | Pongalur | 11.183439 | 77.090424 | | Perundurai | 11.163972 | 77.351920 |
| Uthukuli | Karatupalayam | 11.105674 | 77.275237 | | Chinnavirasangili | 11.162922 | 77.280477 |
| Kangayam | Nallroad | 11.050173 | 77.335044 | Chennimalai | Kavundampalayam | 11.163199 | 77.401101 |
| | Palayakottai | 11.044785 | 77.394676 | | Thottampatti pirivu | 11.103344 | 77.341225 |
| | Agathilingampalayam | 10.585681 | 77.274929 | Modakurichi | Attavanai Hanuman Pillai | 11.104308 | 77.401352 |
| | Kangayampalayam | 10.583158 | 77.300057 | | Karakattuvasal | 11.103548 | 77.461030 |
| | Mudalipalayam | 10.525827 | 77.335592 | | Nanjai uthukuli | 11.164323 | 77.461052 |
| Vellakoil | Olappalayam | 10.590147 | 77.395909 | Kodumudi | Nanjai kolanalli | 11.102742 | 77.520966 |
| | Lakkumanaickenpatti | 10.525953 | 77.400426 | | Kalathupalaya pudur | 11.043009 | 77.521094 |
| | Mayilrangam | 10.530274 | 77.455533 | | Ramanadhapuram | 11.043533 | 77.460901 |
| Moolanur | Polarai | 10.465309 | 77.395992 | | | | |
| | Edakkalpadai | 10.463361 | 77.460240 | Dindugul | | | |
| Erode | | | | Thottampatti | Kovilampatti | 10.350718 | 77.274904 |
| Thalavadi | Panahahali | 11.421591 | 76.531929 | | Vagarai | 10.350215 | 77.334668 |
| | Cheeragally | 11.404613 | 76.517116 | | Thirumalai gorenandalasu | 10.410902 | 77.395765 |
| | Thalavadi | 11.480166 | 77.002622 | | Sikkamanaickenpatti | 10.350792 | 77.395832 |
| | Ittarai | 11.350607 | 77.033191 | Palani | Kanakanpatti | 10.285491 | 77.335642 |
| | Bhavanisagar dam | 11.271843 | 77.005404 | | Palani Andavar Arts College for Women | 10.285379 | 77.274967 |
| Bhavanisagar | Erangattur | 11.284924 | 77.154466 | Oddanchatram | Odaipatti | 10.345880 | 77.460529 |
| | Puliyampatti | 11.351965 | 77.042125 | | Javathupatti | 10.343734 | 77.493212 |
| Sathyamangalam | Puduvadavalli | 11.324966 | 77.105198 | | Chatrapatti | 10.285415 | 77.100113 |
| | Hasanur | 11.402168 | 77.074746 | | Christian College of Engineering and | 10.292532 | 77.450621 |
| | Mavallam | 11.403749 | 77.110006 | Reddiarchatram | Gurunathanaickenur | 10.294661 | 77.522681 |
| | Kadambur forest | 11.404256 | 77.161744 | | Aadalur | 10.225052 | 77.455903 |
| | Thingalur | 11.445412 | 77.162024 | Kodaikanal | Rajavaikkal | 10.224924 | 77.275596 |
| | Gudhiyalathur | 11.421229 | 77.214404 | | Jain farms | 10.163854 | 77.280150 |
| | Koothampalayam | 11.463319 | 77.221709 | | Brick factory | 10.104368 | 77.275675 |
| | Gunderi pallam dam | 11.335912 | 77.220599 | | Kodaikanal Institute of Technology | 10.154544 | 77.335735 |
| | Sri Ram Krishna trust | 11.332795 | 77.180116 | | Kamanur | 10.174528 | 77.403907 |
| | Alathukombai | 11.290209 | 77.161781 | | Pachalur | 10.224675 | 77.395740 |
| Nambiyur | Irukalur | 11.223558 | 77.160616 | | Varathamanthi dam | 10.233294 | 77.324475 |
| Gobi | Ayalur | 11.233913 | 77.223872 | | Kuthiraiyaru dam | 10.224616 | 77.220891 |
| | Andavar polytechnic | 11.273686 | 77.220819 | Karur | | | |
| | Nanjaigobi | 11.285098 | 77.281339 | Karur | Thirkkatu thurai | 11.045485 | 77.575905 |
| | Siruvallur | 11.223823 | 77.275946 | | Kadamban kurichi | 11.045020 | 78.041413 |
| TN Palayam | Sangeeveraya | 11.330185 | 77.284015 | K.Paramathi | Monjanur west | 10.590263 | 77.454570 |
| Anthiyur | Thavittu palayam | 11.345262 | 77.351996 | | Semmandapalayam | 10.583832 | 77.520479 |
| | Kongadai | 11.414581 | 77.214001 | | VSB Eng. College | 10.583748 | 77.580346 |
| | Thattakarai | 11.510076 | 77.315163 | | Chinna Dharapuram | 10.513309 | 77.505794 |
| Ammamet | Poonachi | 11.355992 | 77.394768 | Thanthoni | Puliyur | 10.564949 | 78.095009 |
| | Ammamet | 11.374541 | 77.443423 | | Thulasi kodumbu | 10.521607 | 78.10385 |
| | Murali | 11.413204 | 77.392735 | | | | |

Cont...

| | | | |
|-----------------|-----------------|-----------|-----------|
| Thiruppur | Attayampalayam | 11.045666 | 77.154932 |
| | Mookan kurichi | 10.520889 | 78.045512 |
| | Vasanthakathi | 10.464096 | 78.041472 |
| Aravakurichi | Kodaiyur | 10.515905 | 77.592426 |
| | Pungambadi East | 10.464100 | 77.580576 |
| | Modakkur | 10.433025 | 77.504719 |
| | Jangalpatti | 10.402459 | 77.562773 |
| | Sendamangalam | 10.394286 | 77.510612 |
| Namakkal | | | |
| Pallipalayam | Alampalayam | 11.230486 | 77.453083 |
| Thiruchenkodu | Varagurampatti | 11.230132 | 77.510403 |
| | Muthalpalayam | 11.164830 | 77.514157 |
| Kabilarmalai | Rangampalayam | 11.103937 | 77.575743 |

changing surface with values that may lie outside the sample data range and is used.

Analysis of groundwater quality parameters and fluoride content:

Fluoride was analyzed using Fluoride Ion Selective Electrode 9609 BNWP with Orion Ion Meter, Total Ionic Strength Adjustment Buffer solution (TISAB) was prepared and added in 1:1 proportion in order to prevent the interruption of other ions while measuring fluoride (Barathi *et al.*, 2014). Calibration of the instrument is done with standards one with lower concentration and other with higher concentration, where the unknown lies between those two standards. Continuous stirring of standards and samples was done before measuring. The unknown concentration of fluoride was directly read from the digital display of the Orion ion meter. The advanced fluoride analysis kit can also be followed based on ion selective electrode method. To

determine that distribution pattern of the concentration of different elements and to demarcate higher concentration zones, contour maps were generated with use of ArcGIS software. The spatial distribution map was prepared for different seasons and the concentration values are classified according to WHO (2004) standards for drinking water. These classifications are highest desirable, maximum permissible and the values exceeding maximum permissible are termed as not permissible (NP). After analyzing the fluoride level in the water samples of western agro climatic zone, the fluoride level $>1.0 \text{ mg L}^{-1}$ and $<1.0 \text{ mg L}^{-1}$ was mapped using ArcGIS Software to clearly identify the places which require defluoridation and fluoridation. Fluoride endemic areas will be identified based on the fluoride content of the water sources. Areas with high fluoride are located, and a map of the region distinguishing the relatively low and high fluoride endemic area is drawn by the isopleth technique (Mankhouse and Wilkinson, 1980), a statistical methods. This technique will be employed here to explain the similar concentration of fluoride in different region of the block.

RESULTS AND DISCUSSION

Fluoride content ranged from 0.11 to 2.16 mg L^{-1} . The Bureau of Indian Standards (BIS) and the Indian Council of Medical Research prescribe a fluoride concentration of 1.0 mg L^{-1} as the maximum permissible limit in drinking water. Fluoride (F) occurs in almost all waters from trace to high concentration. Minerals that have the greatest effect on the hydrogeochemistry of fluoride are fluorite, apatite, mica, amphiboles, certain clays and villiamite. Fluoride is among

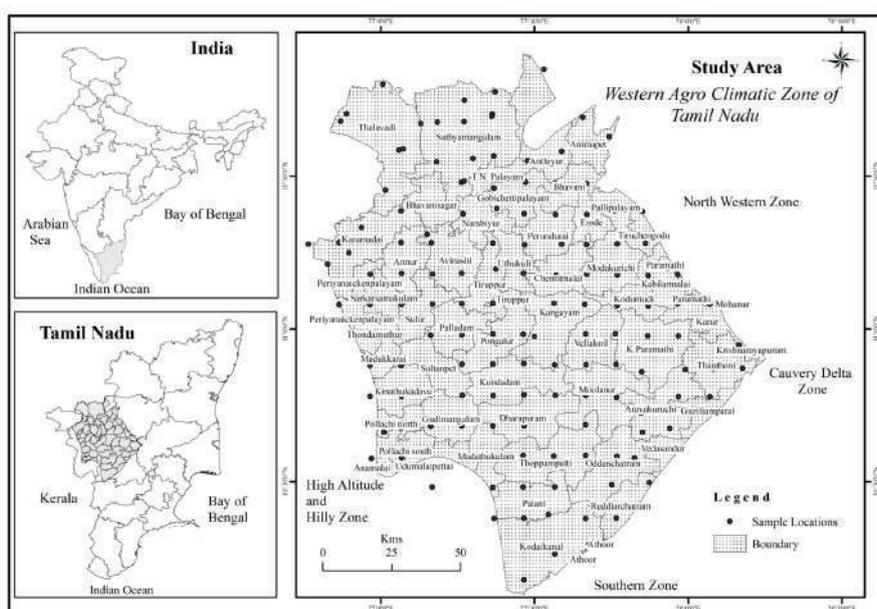


Fig. 1. Location and sampling point map of the study area

the substances for which there are both lower (0.6 mg L⁻¹) and upper (1.2 mg L⁻¹) limits of concentration in drinking water, with identified health effect and benefits for human beings (Indian Standard Institute). Very low doses of fluoride (<0.6 mg L⁻¹) in water promote tooth decay. In 144 samples collected, 35 samples contain fluoride ranged from 0.11 to 2.16 mg L⁻¹ of fluoride during North East monsoon 2013. 48 samples contain >1 mg L⁻¹ of fluoride during Winter season 2014 and it ranged from 0.19 to 2.35 mg L⁻¹. In 144 samples collected, 93 samples contain >1 mg L⁻¹ of fluoride during this Summer season 2014 and it ranged from 0.20 to 2.42 mg L⁻¹. In 144 samples collected, 84 samples contain >1 mg L⁻¹ of fluoride during this South West monsoon 2014 and it ranged from 0.17 to 2.37 mg L⁻¹. While taking the mean, 63 samples contain >1 mg L⁻¹ of fluoride during the year 2013 –2014 and it ranged from 0.18 to 2.33 mg L⁻¹. **Fluoride value ranges from 0.11 to 2.16, 0.19 to 2.35, 0.20 to 2.42, 0.17 to 2.37 and 0.18 to 2.33 mg L⁻¹ during North East monsoon, Winter season, Summer season, South West monsoon and Mean value of 2013 – 14 respectively (Fig. 2).**

The fluoride concentration in groundwater was maximum of 2.33 ppm in Thondamuthur village of Pollachi south block,

1.44 ppm in Sholamadevi village of Madathukulam block, 1.56 ppm in Puliampatti village of Bhavanisagar block, 1.85 ppm in Kuthiraiyaru Dam of Kodaikanal block, 1.90 ppm in Kadamban Kurichi village of Karur block and 1.31 ppm in Rangampalayam village of Kabilarmalai block of Coimbatore, Tiruppur, Erode, Dindigul, Karur and Namakkal districts respectively. The higher concentration of fluoride ions is recorded by Manivannan (2010) in the northern part of the madurai area which is represented by the Charnockite rocks and the same lithology extends to the Dindugal district where the higher concentration of fluoride was observed.

On seeing the spatial variation of fluoride content the problematic class of groundwater was occurred in Thalavadi, Sathyamangalam, Bhavanisagar, Karamadai, Annur, Avinashi, Thiruppur, Gobichettipalayam, Anthiyur, Bhavani, Kulathur, Ammapet, Erode, Pallipalayam, Thiruchengode, Kabilarmalai, Kodumudi, K.Paramathi, Karur, Pramathi, Krishnarayapuram, Thanthoni, Vellakovil, Pongalur, Palladam, Sultanpet, Kundadam, Tharapuram, Reddiarchatram, Oddanchatram, Kodaikanal, Palani, Madathukulam, Udumalaipettai, Anamalai, Pollachi South and North (Fig. 3).



Fig. 2. Spatial and seasonal variation of Fluoride content in the groundwater resources over Western Agro Climatic Zone of Tamil Nadu

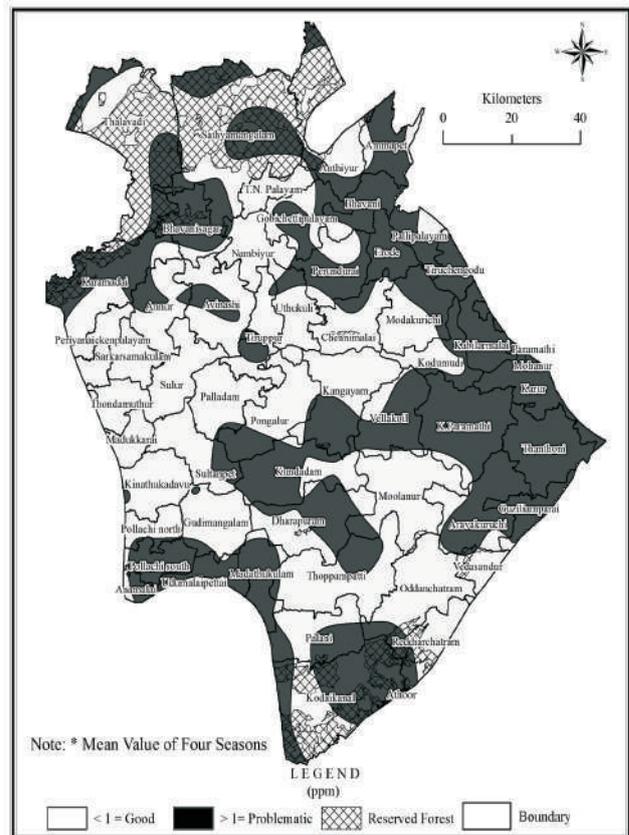


Fig. 3. Spatial variation of mean Fluoride content in the groundwater resources over Western Agro Climatic Zone of Tamil Nadu

CONCLUSION

The water samples in the western zone of Tamil Nadu area evidenced excess fluoride concentrations and were not meeting the standards. The samples collected from different groundwater that is used mainly for drinking purposes showed high fluoride concentration resulted in dental fluorosis among the local residents. Concentration of fluoride measured in groundwater after the monsoonal rains were higher than the preceding months. This was because evaporation resulted in the precipitation of fluoride salts on the soil, which reached the groundwater along with percolating rainwater. The excess fluoride concentration in the area may be attributed to the geological formation and over exploitation of groundwater. The results will be helpful to the government to install defluoridation plants in the severely affected areas identified by this study. Mapping of high fluorotic areas is useful to plan meticulously to bring safe drinking water from low fluoride areas. Awareness generation programmes, about fluorosis and remedial methods through audio and visual aids will be suggested.

ACKNOWLEDGMENTS

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People Perceptions of Climate Change and its Impacts on Phyto-diversity and Livelihood of the Inhabitants of Almora Kumaun Himalaya, Uttarakhand (India)

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Abstract: The present study was conducted in the Almora district of Kumaun Himalaya to know people's perceptions regarding climate. The inhabitants of Almora district were experiencing lots of modifications due to climate change. All the respondents agree that the climate is changing in the form of increasing temperature, decreasing precipitation, frequent floods, increasing incidences of droughts, unpredictable monsoon patterns, unseasonal flowering and fruiting, invasion of new plants, diminution of forest resources, increasing incidences of human and plant diseases and decrease of agricultural production with changes in the livestock patterns. The analysis showed that local people perceptions regarding increasing temperature, decreasing precipitation, frequent droughts and unpredictable monsoon pattern were in accordance with the meteorological data of the local station of the region. The persistent changes in climate have brought about changes in phenological events like flowering and fruiting in plants also. The majority of respondents perceived that flowering and fruiting had advanced by 20-25 days as compared to periods 10-15 years earlier. The climate change had adversely affected the natural regeneration of broad leafed trees and *Cedrus deodara*, along with a decrease in the yield of important fodder grasses. Meanwhile a good score of respondents (52.36%) observed increased natural regeneration and upward shift in *Pinus roxburghii*. All respondents observed that due to climate change crop productivity had decreased during the last decades. A significant percentage of respondents mentioned adverse impact of climate change on livestock population and dairy production.

Keywords: Phyto-diversity, Climate change, *Pinus roxburghii*, *Cedrus deodara* Almora, Livelihood

The Himalaya like other places on planet earth are experiencing signs of rapid climate change, already there are evidences to indicate that the Himalayan region is warming at a higher rate than the global average rate (Jainchu *et al.*, 2007). The fragile Himalaya mountain ecosystem is particularly vulnerable, with mean temperature to raise 3°C over next century (IPCC, 2007). According to report net increase in temperature in the Himalayan region in 2030s is forecasted to increase between 1.70°C to 2.20°C with respect to 1970s and seasonal air temperatures are also forecasted to rise in all seasons (GoU, 2012a). The climate change in the Himalayan region likely to significantly impact local ecosystems, biodiversity, agriculture and human well-being (Chowdhery *et al.*, 2011) which include shifting in geographical ranges of species (Harsch *et al.*, 2009), alterations in species composition of communities (Klanderud and Birks, 2003), changes in the time of phenology (Fitter and Fitter, 2002; Moza and Bhatnagar, 2005), extinction of species (Wallis and Bhawat, 2009; Rull and Vegas, 2006), poor regeneration of some important plant species (Singh, 2010), invasion of invasive weeds to higher ridges (Mooney and Hobbs, 2000; Gaira *et al.*, 2014), scarcity of fuel wood, fodder, spring water (Gene Campaign,

2012) reduction of crop productivity and other livelihood sources of people (Rawat, 2013).

The region is also known as "Water tower of the earth". Approximately 10-20% of the area is covered by glaciers while 30-40% remains under seasonal snow cover (Singh, 2006) and is the source of the 8 largest rivers in Asia. Being sources of water, the region constitutes the lifeline of billions of people, thus the consequences of climate change on biodiversity, agriculture as well as on human well-being are likely to be severe (Sharma *et al.*, 2009; Chaudhary and aryal, 2009). Evidences are that climate change is putting livelihood of farmers at risk (Misra *et al.*, 2002; IPCC, 2007). Climate change influences the socioeconomic setting in the Himalaya in a number of ways. Specific knowledge and data on human wellbeing in the Himalaya is limited, but it is clear that the effects of climate change will be felt by people in their livelihoods, health and natural resource security (Sharma *et al.*, 2009). Local communities' perceptions are much important to understand the climate change patterns as they are affected directly by climate change (Pratap, 2015). Climate change is already being experienced by the communities in the form of irregular rainfall and snowfall, increasing temperature and decreasing moisture content. As

a result some plant species have changed their phenological trends (Gaira *et al.*, 2014). Furthermore, changes in flowering and fruiting time, increased invasion of species alien plants (Rawat, 2013). Increased pest attack in agriculture and horticulture plants, increased rural urban migration, increased biodiversity loss, decrease of forest resources, decrease of livelihood sources, depletion of natural resources and increased health risks and the spread of infectious diseases has also been observed (Logan *et al.*, 2003; Abaje and Giwa, 2007). Climate change continues to be major threat to rural livelihood (IPPC 2007a, 2007b). People perceptions regarding climate change will help in developing and mitigation strategies especially in areas where data are inadequate and climate change is rapid (Chaudhary *et al.*, 2011). Keeping in mind the threat of climate change and need of people perceptions regarding climate change, the present study was conducted to understand people perceptions regarding climate change as climate change is experienced first at household level.

MATERIAL AND METHODS

Study area: Almora district of Uttarakhand is located between 29°37'N to 29°62'N latitudes and 79°40'E to 79°67'E longitudes, at an altitude of 1651 meters. The climate of Almora is characterized by relatively high temperature and evenly distributed precipitation throughout the year. The main seasons are summer (March –June), monsoon (July –November) and winter (December –February)

Livelihood framework of the study area: Agriculture and livestock rearing dominate the livelihood practices in the study area as well. It is rain fed and the crop production isn't very high, due to the small and fragmented land holdings. Besides agricultural practices, livestock rearing is practiced in the region and helps the rural people in earning additional income.

Methodology: Primary data on climate change and its impacts on phytodiversity and livelihood were collected by conducting a household survey from January to October 2016 in two blocks namely Hawalbagh and Lamgarah of Almora district. The data was gathered from 266 households of 12 villages using a semi structural questionnaire. For the questionnaire based study household heads (male/female) above the age of 40 years were selected.

Comparison between climate changes perceived by the people and the local Meteorological station data: The meteorological data collected from Vivekananda Parvatiya Krishi Anusandhan Sansthan (VPKAS) Almora, of more than three decades was compared with the climate change perceived by the respondents of the region, using temperature and rainfall data to assess the accuracy of perceptions.

RESULTS AND DISCUSSION

The minimum, maximum and average temperatures show a significant increasing trend and in the past 36 years it has risen by 0.90°C. The analysis of average rainfall shows a decreasing trend. The mean rainfall decreased by around 21.1 mm (annually 235.35mm) from the period between 1981 to 2016. Besides temperature and rainfall data, the drought climatology data also shows an increasing incidence trend. During the last few decades it was found that the disturbance in monsoons was predominant which has resulted in their late onset and early withdrawal.

Perceptions about experiences of climate change: All respondents agreed that climate change has been occurring over the past few years. They experienced climate change in the form of increasing temperature, decreasing precipitation, unpredictable monsoon pattern, frequent droughts, changes in flowering and fruiting time, increasing natural frequencies of forest fires, introduction and spread of alien plant species, increasing incidences of diseases, declining of forest resources, and decreasing agricultural productivity.

Temperature change: Most of respondent (98.64%) experienced climatic change by noticing increase in temperature, only 1.36% mentioned decrease in temperature. The statistical record of the average temperature data of Almora district, between 1981 and 2016 shows a significant increasing trend. The increasing trend has been observed in almost all seasons Figure 1. In the last 36 years, the temperature has risen by 0.90°C (Figure 2). The analysis reveals that local people's perceptions appear to be in accordance with the local meteorological temperature records of the region.

Precipitation changes: Overall, 98% of the respondents observed changes in precipitation during the last 40 years. Most of them (90.11%) noticed a decrease in the amount of

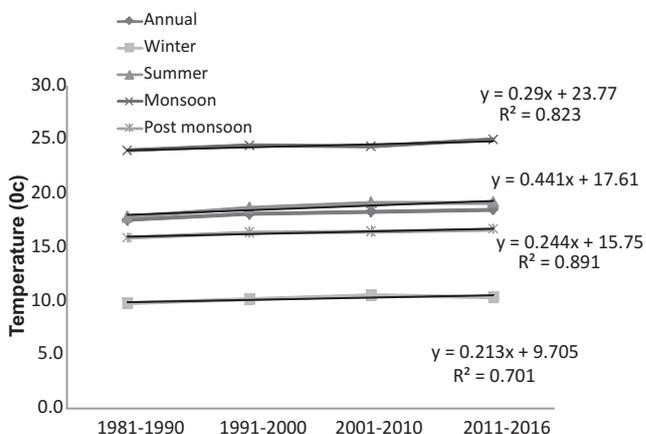


Fig. 1. Decadal variation in seasonal and annual average temperature (1981-2016)

rainfall, whereas 7.89% felt that rainfall had increased during the last few decades. Almost 2% did not observe any change in rainfall. The recorded data of rainfall from the last 36 years reveals a high declining trend in rainfall. The decreasing trend has been observed nearly in all season's (Figure 3). The highest rainfall (1150.9) was in the decade 1981-1990 and the lowest (897.55) in the last decade (2011-2016). The overall decadal mean rainfall decreased by about 21.1mm during the last 36 years, and the annual decrease was about 235.35mm (Figure 4). The results again strongly indicate that the local people have predicted the rainfall pattern in their region, well.

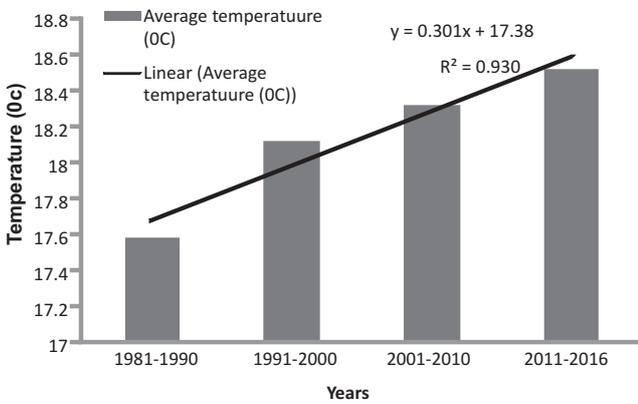


Fig. 2. Decadal mean of annual temperature (1981-2016)

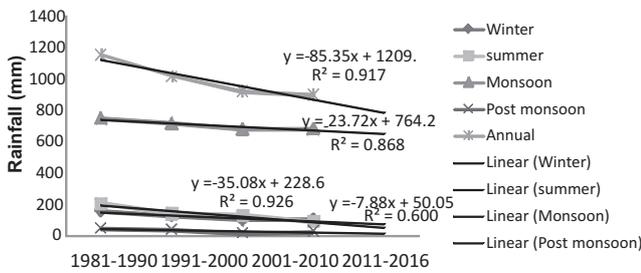


Fig. 3. Decadal variation in seasonal and annual rainfall (1981-2016)

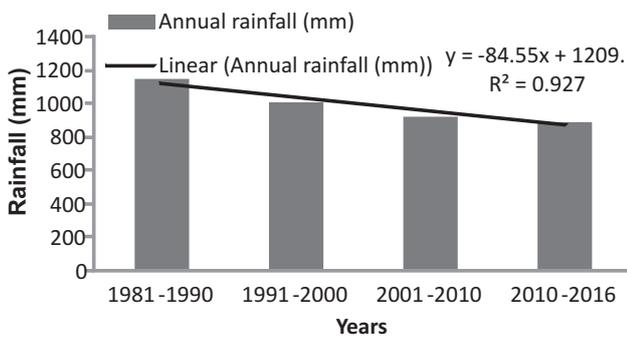


Fig. 4. Decadal mean of annual rainfall (1981-2016)

Drought occurrence: Almost 96 percent respondents observed frequent droughts and they link it with decreasing precipitation and unusual rainfall patterns of the last few decades. Meanwhile a small percentage (4%) said that incidences of drought had remained constant. According to them no change has occurred in the frequency of droughts over the years and hence drought climatology has remained static. The meteorological data of drought climatology of the study area between the period 1981 and 2016 has shown a significant increasing trend (Figure 5). Out of the 36 years, it has been observed that 6 years fall under moderate , 7 under large and 7 under the severe drought category. There were 6 drought years during 1981-1998 out of which, 2 were severe drought years. However, during 1999 to 2016, 13 drought years were observed, out of which 5 were severe. The increasing intensities and the decreasing recurrence intervals of drought are a matter of serious concern. The opinion of the local people regarding increasing incidences of droughts from last few decades also matches with local drought climatologically data.

Monsoon Pattern: A majority of respondents (66.65%) have observed increasing unpredictable monsoon patterns over the last few decades, and only 29.35 percent of the respondents noticed predictable monsoon in their region. The monsoon analysis conducted by Vivekananda Parvatiya Krishi Anusandhan Sansthan Almora, revealed deviation in monsoon patterns both during onset and withdrawal (http://vpkas.nic.in). Out of 50 years, monsoon arrived later than its normal date of arrival in 22 years (44% of years). Besides late arrival, changes were also observed in the early withdrawal of monsoons. Out of 50 years, the monsoon withdrawal occurred earlier than the normal date in 23 years (46%). Thus the opinion of a majority of respondents, regarding the unpredictable monsoon pattern was found true. In addition to changes in temperature, rainfall, drought incidences, unpredictable monsoon pattern the local people have also noticed climate change affecting phenological events like flowering and fruiting times (76.85%), invasion and proliferation of alien plant species (83.71%), declining of forest resources (82.56%) with increased incidences of the

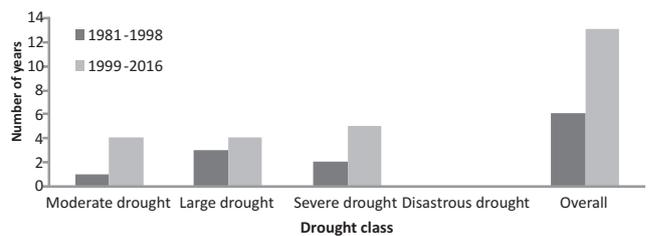


Fig. 5. Intensity of droughts of the Almora district (1981-2016)

spread of diseases in humans, plants and animals (84.13%), decreasing agriculture production (100%), increase in natural frequencies of forest fires (58.14%) and increased incidences of floods (64.80).

Climate change impact on different sectors in study area

Impact of climate change on forest resources: An average of 82.56% respondents of the study area has already experienced the impact of climate change on forest wealth. The climate change has adversely affected the natural regeneration and growth of various plant species. The poor regeneration of *Cedrus deodara* (6.24%), *Celtis australis* (7.96%), *Ficus palmata* (3.17%), *Myrica esculenta* (19.5%), *Pinus roxburghii* (4.18%), *Quercus leucotrichophora* (60.28%), *Rhododendron arboreum* (43.78%) and *Grewia oppositifolia* (16.11%) were observed. (Figure 6). Meanwhile, 52.36% observed increasing regeneration and upward shifting of *Pinus roxburghii*.

Introduction and spread of alien invasive plants: The majority of respondent has already perceived the emergence of invasive species in their locality (83.71%). Respondents mentioned that those species in their locality were not present earlier and only over the past 10–15 years were observed in lower altitudes. According to respondents, the main causes of the introduction and spread of alien invasive plants are persistent changes in climate (72.1%), deforestation (83.1%), over grazing (44.4%), land conversion (51.2%) and mismanagement of waste land (70.6%) and over cultivation (25.8%) (Figure7). Respondents reported that the alien invasive plant species prominent in their areas are *Biden pilosa* (83.64%), *Eupatorium adinophorum* (78.01%), *Parthenium hysterophorus* (71.33%) and *Pinus roxburghii* (71.01%) (Figure 8). Respondents also noticed that the invasive plants were generally non-edible and poisonous for cattle. Average 73.33 percent respondents said that the invasive species were responsible for the spread of various diseases. According to respondents the main diseases caused by invasive plants are respiratory problems (71.02%), Skin allergy (44.96%), headache and fever (62.19%).

Plant phenology: Data analysis revealed that significant percentage (76.63%) of respondents had already experienced changes in phenological events like flowering and fruiting in plants. An average of 72.43% respondents revealed early flowering and fruiting time in various plant species (Figure 9). The flowering and fruiting in plants were advanced by 20–25 days as compared to periods 10–15 years before. However, 23.36% respondents said that there was no change in the phenology of plants over the years. The maximum impact of climate change on phenology according to local people occurs in *Rhododendron arboreum* (72.15%)

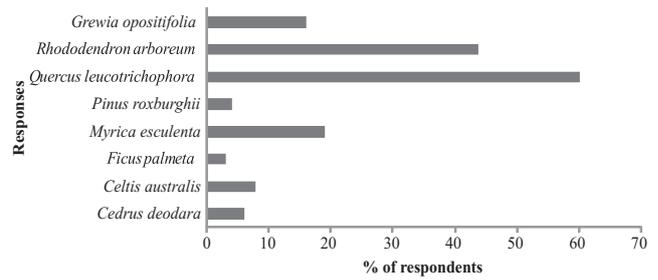


Fig. 6. Perceptions of local people regarding poor regeneration of plants due to climate change

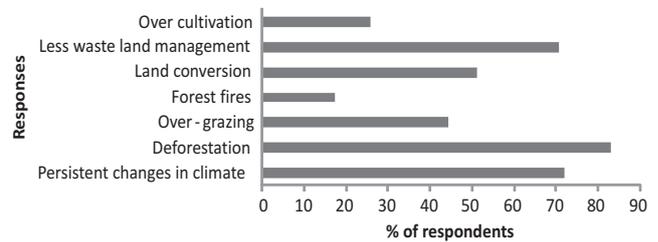


Fig. 7. Factors responsible for introduction and spread of alien invasive plant species

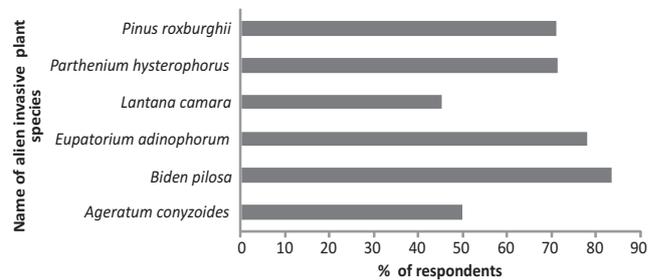


Fig. 8. People perceptions regarding presence of alien invasive plant species in their vicinity

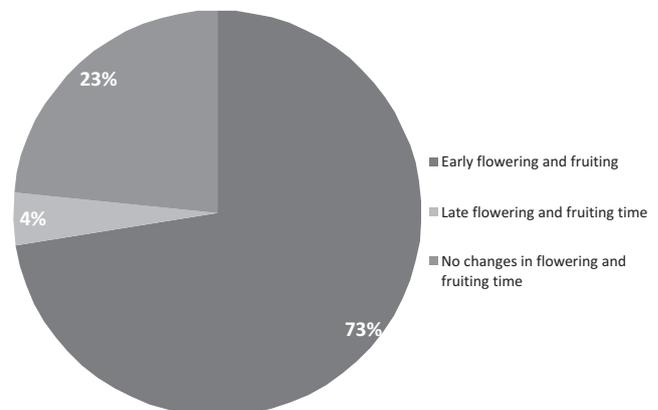


Fig. 9. Perceptions of local people regarding impact of climate change on plant phenology

followed by *Pyrus pashia*, *Prunus armeniaca*, *P. Persica*, *P. domestica*. However, a small percentage (4.2%) of respondents reported late flowering and fruiting in some plant species especially in *Myrica esculenta* and *Pyrus pashia* (Figure 10).

Plants and human health: An average of 84.13 percent respondents observed increased incidences of various diseases in human beings and plants. The most common diseases according to respondents are Viral fever /Influenza (78.59%), Asthma (59.97%), Jaundice (54.98%), Allergy (52.10), Diarrhea (42.15). Among the respondents, 58.58 percent noticed increasing pest and insect attacks on horticultural crops. Similarly, 45.33% and 43.11% reported increased pathogen attacks on agricultural crops and vegetables respectively (Figure 11). Respondents mentioned that 15-20 years earlier they were using pesticides in agricultural, horticultural and vegetable fields hardly one or two times but now they were using these several times but they proved ineffective.

Livestock: An average of 88.56 percent respondents agreed that climate change adversely affected livestock climate change directly or indirectly impacted regeneration of native broad leafed fodder plants and consequently there was a decrease of fodder and forage in forests, pastures and farm lands. Majority of respondents (68.22%) have decreased their livestock population whereas 20.20 percent said that

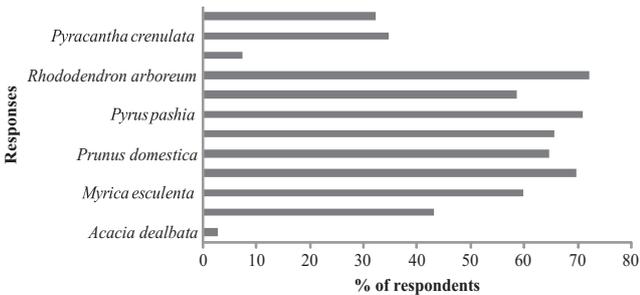


Fig. 10. Responses of people regarding the impact of climate change on phenology of various plant species

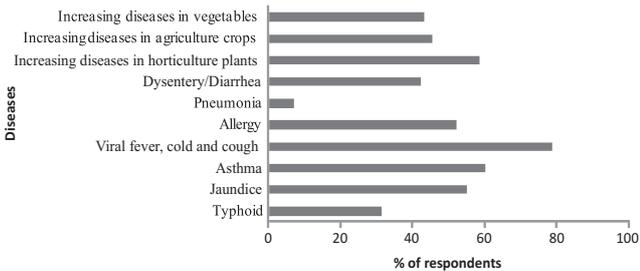


Fig. 11. Perceptions regarding impact of climate change on plants and human health

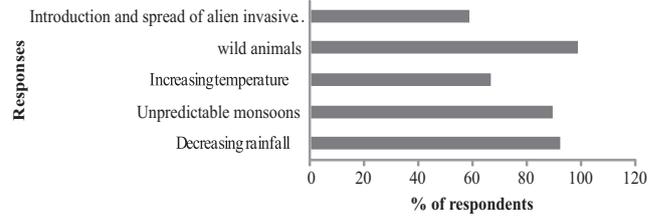


Fig. 12. Responses of local people regarding factors affecting agricultural production

there is no change in livestock population. Majority of respondents (79.51%) have noticed a decrease in dairy production whereas 9.04% have not experienced any such change. Significant percentage (84.26%) mentioned their income has decreased, while 2.51 percent people said that their income has increased due to the increase of demand and market value of meat and milk.

Decrease of rainfall and unpredictable monsoon on agriculture: The data analysis revealed that overall reduction in agricultural production from the last 15 years was found to be 56.71% due to climate change. The decline of crop yield was observed maximum in *Echinochloa frumentacea* (58.60%) followed by *Eleusine coracana* (55.25%), *Oryza sativa* (55.24%), *Triticum aestivum* (52.75%) and *Brassica juncea* (52.45%). Due to persistent changes in climate farmers have stopped the cultivation of various crops and has replaced them with *Zea mays*, *Allium cepa*, pulses and other cash crops.

Wild animals on agriculture: Wild animals such as Rhesus monkey threats to agricultural productivity. An average of 98.5 percent of respondents mentioned that Rhesus monkeys damage and destroys their crops and stopped the cultivation of various agriculture crops. Further the population of Rhesus monkey had increased from last 5-8 years and they also said that this species was previously confined to lower altitudes. They believe that increasing population of Rhesus monkey might have some link with climate change.

CONCLUSION

The average temperature shows a significant increasing trend, whereas the average rainfall shows a decreasing trend. The drought climatology data shows an increasing incidence trend. During the last few decades the disturbance in monsoon was predominant. The findings of study local people of the region are experiencing climate change by various means and their experiences are in accordance with the meteorological data of the local station. Furthermore, persistent changes in climate has resulted phenological changes, decline in the productivity of fodder grasses, Poor regeneration of plants, increasing proliferation of alien

invasive plants. Besides impact on forest resources and phenology, the adverse impact of climate was also observed in agriculture productivity, livestock population, dairy production, human health and hence socio-economic status of the inhabitants of the region.

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Modelling and Forecasting of Black Pepper Production in India

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Abstract: In present an attempt has been made to analyze the trends in area, production and productivity of pepper and production behaviour through the Box-Jenkins Autoregressive Integrated Moving Average (ARIMA) approach using area, production and yield data for the period 1971–2012 for Kerala, Karnataka and whole India. Subsequently with Generalized Autoregressive Conditional Heteroscedastic (GARCH) time-series model has also been used to study the same. Comparative study of the fitted ARIMA and GARCH models is carried out. On the basis of best fitted model, the pepper production has been forecasted to 2020. Except the whole India productivity, remaining data series the ARIMA models fitted well. For whole India productivity data series GARCH(1) was fitted well. Using best fitted models forecasted value of pepper is estimated for 2020 as for Kerala 185 thousand hectares of area, 46 thousand tonnes production, 307 kg/ha of productivity. Likewise Karnataka 31 thousand hectares of area, 9 thousand tonnes of production, 236 kg/ha of productivity. In case of whole India 283 thousand hectares of area, 51 thousand tonnes of production, 304 kg/ha of productivity respectively. So present investigation indicates that, Kerala will be most contributing states of India in production and productivity on pepper. Also this study will help to make policy implication as well as understand the pepper market in future.

Keywords: Pepper production, Trend analysis, ARIMA, GARCH and Forecasting

Black pepper, is a perennial crop grown for its berries, which is usually dried and used as spice. The global output of black pepper estimates for 2015 as per the statement of world pepper market scenario released by the International Pepper Community (IPC) was 407158 tonnes. India is the third largest producer of black pepper after Vietnam and Indonesia. The production of black pepper in India during 2014–15 was about 70000 tonnes out of which 33000 tonnes was produced in Karnataka and 28000 tonnes in Kerala (Spices Board of India, Cochin 2015) [4]. The emergence of Karnataka as the major producing state in the country is mainly attributed to the initiatives by the producers including the expansion of area under the crop which were mainly induced by the higher prices of black pepper in the recent past and fluctuations in coffee prices. The pepper output for 2015–16 in India is expected to be lower by more than 30 per cent over the previous year due to the erratic weather conditions in Kerala and Karnataka. In this section, an attempt has been made to examine the performance of pepper production in India and its major states during the period under consideration.

MATERIAL AND METHODS

The relative contribution of pepper to whole India pepper production, two major states Kerala and Karnataka along

with whole India is considered for the present study. Data related to area, production and productivity of pepper in major two states and whole India for the period 1970–2012 could be obtained. To develop forecast models and subsequently use these models to forecast the series for the years to come, data for the whole period excepting last three years are used for model building, while data for last three years are used for model validation purpose.

Descriptive statistics

Descriptive statistics are useful to describe patterns and general trends in a data set. It includes numerical and graphic procedure to summarize a set of data in a clear and understandable way. To examine the nature of each series these have been subjected to different descriptive measures. Statistical tools used to describe the above series are minimum, maximum, mean, standard error, skewness, kurtosis and simple growth rate.

Parametric trends models

Knowing the above overall performance, path of movement of the series was traced through parametric trends models. To workout the trends in area, production and yield different parametric model like polynomial, logarithmic, compound, growth, and exponential models are attempted. Among the competitive models the best model is selected on the basis of the maximum R^2 value, significance of the model

and its coefficients.

ARIMA model

The Autoregressive moving average (ARMA) model, denoted as ARMA(p,q) is given by [3]

$$Y_t = \phi_1 Y_{t-1} + \phi_2 Y_{t-2} + \dots + \phi_p Y_{t-p} + \varepsilon_t - \theta_1 \varepsilon_{t-1} - \theta_2 \varepsilon_{t-2} - \dots - \theta_q \varepsilon_{t-q}$$

or equivalently by

$$\varphi(B) y_t = \theta(B) \varepsilon_t$$

where

$$\varphi(B) = 1 - \phi_1 B - \phi_2 B^2 - \dots - \phi_p B^p$$

and

$$\theta(B) = 1 - \theta_1 B - \theta_2 B^2 - \dots - \theta_q B^q$$

In the above, B is the backshift operator defined by $By_t = Y_{t-1}$. A generalization of ARMA models, which incorporates a wide class of nonstationary time-series is obtained by introducing “differencing” in the model. The simplest example of a nonstationary process which reduces to a stationary one after differencing is “Random Walk”. A process $\{y_t\}$ is said to follow Autoregressive integrated moving average (ARIMA), denoted by ARIMA(p,d,q), if $y_t = (1-B)^d \varepsilon_t$ is ARMA(p,q). The model is written as

$$\varphi(B)(1-B)^d y_t = \theta(B) \varepsilon_t$$

where ε_t are identically and independently distributed as $N(0, \sigma^2)$. The integration parameter d is a nonnegative integer. When d=0, the ARIMA(p,d,q) model reduces to ARMA(p,q) model.

GARCH (Generalized Autoregressive Conditional Heteroskedasticity) model

Paul *et al.*[6] used the GARCH model to analysis for modelling and forecasting of India’s volatile spices export data. The basic GARCH/ ARCH model has two equations; one equation is to describe the behaviour of the mean and another to describe the behaviour of the variance.

The ARCH (q) model for the series $\{\varepsilon_t\}$ is given by $\varepsilon_t / \Psi_{t-1} \sim N(0, h_t)$ —(1)

Here Ψ_{t-1} denotes information available up to time t-1 and

$$h_t = a_0 + \sum_{i=1}^q a_i \varepsilon_{t-i}^2 \tag{2}$$

Where $a_0 > 0, a_i \geq 0$ for all i and $\sum_{i=1}^q a_i < 1$ and are required to be satisfied to ensure non-negativity and finite unconditional variance of stationary $\{\varepsilon_t\}$ series.

Bollerslev [1] proposed the Generalized ARCH (GARCH) model in which conditional variance is also a linear function of its own lags and has the following form

$$h_t = \alpha_0 + \alpha_1 \varepsilon_{t-1}^2 + \dots + \alpha_q \varepsilon_{t-q}^2 + \beta_1 h_{t-1} + \dots + \beta_p h_{t-p}$$

$$h_t = a_0 + \sum_{i=1}^q a_i \varepsilon_{t-i}^2 + \sum_{j=1}^p b_j h_{t-j} \tag{3}$$

A sufficient condition for the conditional variance to be positive is

$$a_0 > 0, a_i \geq 0, i = 1, 2, \dots, q; b_j \geq 0, j = 1, 2, \dots, p$$

The GARCH (p, q) process is weakly stationary if and only if $\sum_{i=1}^q a_i + \sum_{j=1}^p b_j < 1$. The most popular GARCH model in applications is the GARCH(1, 1) model. The express GARCH model in terms of ARMA model, denote $\eta_t = \varepsilon_t^2 - h_t$. Then from eq. (3)

$$\varepsilon_t^2 = a_0 + \sum_{i=1}^{\max(p,q)} (a_i + b_j) \varepsilon_{t-i}^2 + \eta_t + \sum_{j=1}^p b_j \eta_{t-j} \dots \tag{4}$$

Thus a GARCH model can be regarded as an extension of the ARMA approach to squared series $\{\varepsilon_t^2\}$.

Estimation of parameters

In order to estimate the parameters of GARCH model, method of maximum likelihood is used. The loglikelihood function of sample of T observations, apart from constant, is

$$L_T(\theta) = T^{-1} \sum_{i=1}^T (\log h_i + \varepsilon_i^2 h_i^{-1})$$

Where

$$h_t = a_0 + \sum_{i=1}^q a_i y_{t-i}^2 + \sum_{j=1}^p b_j h_{t-j}$$

If $f(\cdot)$ denotes the probability density function of ε_t , generally, maximum likelihood estimators are derived by minimizing

$L_T(\theta) = T^{-1} \sum_{i=v}^T (\log \sqrt{h_i} - \log f(\varepsilon_i / \sqrt{h_i}))$ where h_i is the truncated version of h_t (Fan and Yao [3]. For heavy tailed error distribution, Peng and Yao (2003) proposed Least absolute deviations estimation (LADE), which minimizes, $\sum_{i=v}^T |\log \varepsilon_i^2 - \log(h_i)|$ where $v = p+1$, if $q=0$ and $v > p+1$, if $q > 0$. Fan and Yao [3] and Straumann and Mikosch [7] have given a good description of various estimation procedures for conditionally heteroscedastic time-series models.

Goodness of fit Statistics of Parametric models

In this present study, goodness of fit of a parametric model is assessed by computing the various diagnostic criterion namely: R^2 value, Root Mean Square Error (RMSE), Mean Absolute Percentage Error (MAPE), Mean Absolute Error (MAE), Akaike Information Criterion (AIC) and Bayesian information criterion (BIC) or Schwarz criterion (also SBC, SBIC). The Akaike information criterion (AIC) and Bayesian information criterion (BIC) values for GARCH model with Gaussian distributed errors are computed by

$$AIC = \sum_{i=v}^T (\log \tilde{h}_t - \varepsilon_t^2 \tilde{h}_t^{-1}) + 2(p + q + 1) \text{ and}$$

$$BIC = \sum_{i=v}^T (\log \tilde{h}_t - \varepsilon_t^2 \tilde{h}_t^{-1}) + 2(p + q + 1) \log(T - v + 1)$$

Where T is the total number of observations.

$$R^2 = 1 - \frac{\sum_{i=1}^n (Y_i - \hat{Y}_i)^2}{\sum_{i=1}^n (Y_i - \bar{Y})^2} \quad RMSE = \left[\frac{\sum_{i=1}^n (Y_i - \hat{Y}_i)^2}{n} \right]^{1/2}$$

$$MAE = \sum_{i=1}^n |Y_i - \hat{Y}_i| / n \quad MAPE = \frac{1}{n} \sum_{i=1}^n \left| \frac{Y_i - \hat{Y}_i}{Y_i} \right| \times 100 \%$$

RESULTS AND DISCUSSION

The, Kerala is the only state major contributor of pepper production in India followed by Karnataka (Table 1). There has been considerable expansion in area, production and productivity of pepper in Kerala, Karnataka and whole India during the study period. The maximum annual growth rate in area and production observed in Karnataka (315%) against 45 percent at national level.

In all the data series (area, production and productivity of pepper in India), non-linear patterns revealed that (Table 2) cubic model is fitted well. Thereby indicating more than one point of inflections in most of the cubic models, the coefficients of cubic time factor are positive in nature in almost all data series, representing the tendencies of the series to increase in recent past.

From the table 3, for area under pepper in Kerala, the ARIMA(1,1,3) found to be best ARIMA model. Likewise in Karnataka and whole India, the ARIMA(1,2,1) and ARIMA(1,1,1) models are fitted well. On the other hand, area under pepper in Kerala best fitted with GARCH(1,2) model, while in Karnataka and whole India, the GARCH(4) and GARCH(1) models are best fitted. For pepper production ARIMA(2,1,1), ARIMA(1,2,1) and ARIMA(1,1,2) are found to be best fitted ARIMA models in Kerala, Karnataka and whole India respectively. In the same way,

Table 1. Per se performance of pepper production in major states of India during the year of 1970–2012

| | Area ('000 ha) | | | Production ('000 t) | | | Productivity (kg/ha) | | |
|----------|----------------|-----------|--------|---------------------|-----------|-------|----------------------|-----------|--------|
| | Kerala | Karnataka | India | Kerala | Karnataka | India | Kerala | Karnataka | India |
| Mean | 154.12 | 6.28 | 166.95 | 42.36 | 1.89 | 45.78 | 270.67 | 237.73 | 272.69 |
| SE | 6.67 | 0.86 | 8.21 | 2.64 | 0.27 | 2.77 | 6.70 | 2.17 | 6.74 |
| Minimum | 80.00 | 2.00 | 84.57 | 17.00 | 0.70 | 18.00 | 164.00 | 164.00 | 167.00 |
| Maximum | 238.00 | 21.00 | 271.38 | 87.61 | 8.00 | 92.90 | 368.00 | 368.00 | 357.00 |
| Kurtosis | -1.39 | 0.95 | -1.22 | -0.71 | 4.61 | -0.70 | -0.47 | -1.20 | -0.66 |
| Skewness | 0.02 | 1.49 | 0.25 | 0.42 | 2.18 | 0.36 | -0.26 | -0.20 | -0.21 |
| SGR % | 1.06 | 22.09 | 1.57 | 15.00 | 315.00 | 45.00 | 0.99 | 0.30 | 1.02 |

Table 2. Trends in area, production and productivity of pepper in major states of India

| States | Equation | Model Summary | | | | Parameter Estimates | | | | |
|---------------------------------|----------|---------------|-------|-----|-----|---------------------|----------|--------|---------|--------|
| | | R Square | F | df1 | df2 | Sig. | Constant | b1 | b2 | b3 |
| Area ('000 ha) | | | | | | | | | | |
| Kerala | Cubic | 0.93 | 70.08 | 2 | 40 | 0 | 1941 | 0.373 | 0.050 | -0.002 |
| Karnataka | Cubic | 0.97 | 39.85 | 3 | 39 | 0 | 1958 | 10.937 | -0.825 | 0.021 |
| India | Cubic | 0.93 | 95.00 | 3 | 39 | 0 | 2027 | -1.180 | 0.008 | -0.002 |
| Production ('000 tonnes) | | | | | | | | | | |
| States | Equation | Model Summary | | | | Parameter Estimates | | | | |
| | | R Square | F | df1 | df2 | Sig. | Constant | b1 | b2 | b3 |
| Kerala | Cubic | 0.81 | 26.12 | 3 | 39 | 0 | 1931 | 2.898 | -0.041 | 0.003 |
| Karnataka | Cubic | 0.96 | 24.84 | 3 | 39 | 0 | 1950 | 45.394 | -11.977 | 1.070 |
| India | Cubic | 0.85 | 26.43 | 3 | 39 | 0 | 1945 | 1.678 | -0.015 | 0.004 |
| Productivity (kg/ha) | | | | | | | | | | |
| States | Equation | Model Summary | | | | Parameter Estimates | | | | |
| | | R Square | F | df1 | df2 | Sig. | Constant | b1 | b2 | b3 |
| Kerala | Cubic | 0.60 | 22.15 | 2 | 40 | 0 | 1955 | 0.601 | 0.001 | -0.005 |
| Karnataka | Cubic | 0.56 | 2.27 | 2 | 40 | 0.04 | 1126 | 5.507 | 0.002 | -0.003 |
| India | Cubic | 0.60 | 24.04 | 2 | 40 | 0 | 1941 | 0.156 | 0.006 | 0.003 |

among the various GARCH models, GARCH(1) for Kerala and GARCH(1,1) for whole India was best fitted GARCH models, whereas data series of pepper production for Karnataka is found not to have GARCH models. In case of

pepper productivity, ARIMA(1,1,2) for Kerala, ARIMA(1,1,1) for Karnataka and whole India respectively are found to be best fitted ARIMA models same reported Mishra *et. Al.* [5] Among the various GARCH models GARCH(1,2) found to be

Table 3. Best fitted ARIMA and GARCH models for area under pepper in India

| State | Model | Model Selection Criteria | | | | | | | | |
|-----------|----------------|--------------------------|--------|----------|----------|----------|----------|----------|----------|----------------|
| | | AIC | BIC | ME | RMSE | MAE | MPE | MAPE | MASE | R ² |
| Kerala | ARIMA (1,1,3)* | 323.6 | 325.29 | 1.637024 | 13.31331 | 8.905317 | 0.685472 | 5.920193 | 0.975925 | 0.91 |
| | GARCH (1,2) | 353.04 | 365.37 | 2.34 | 15.43 | 9.27 | 0.87 | 6.48 | 1.35 | 0.91 |
| Karnataka | ARIMA (1,2,1) | 106.18 | 111.17 | 0.130674 | 0.833939 | 0.545398 | 0.885657 | 10.4963 | 0.872637 | 0.968 |
| | GARCH (4)* | 103.69 | 108.78 | 0.11 | 0.39 | 0.00 | 0.58 | 0.00 | 0.34 | 0.97 |
| India | ARIMA (1,1,1)* | 313.38 | 318.44 | -0.07568 | 11.13294 | 8.446123 | -0.83452 | 5.562204 | 0.957068 | 0.96 |
| | GARCH (1) | 345.50 | 354.35 | -0.13 | 8.76 | 9.84 | -1.23 | 6.47 | 1.85 | 0.93 |

Table 3.1. Validation and forecasting of area under pepper in India on the basis of selected best model

| State | Model | 2010 | | 2011 | | 2012 | | 2016 | 2018 | 2020 |
|-----------|--------------|----------|-----------|----------|-----------|----------|-----------|-----------|-----------|-----------|
| | | Observed | Predicted | Observed | Predicted | Observed | Predicted | Predicted | Predicted | Predicted |
| Kerala | ARIMA(1,1,3) | 185 | 192 | 172 | 185 | 172 | 185 | 185 | 185 | 185 |
| Karnataka | GARCH (4) | 19 | 17 | 20 | 19 | 21 | 21 | 26 | 28 | 31 |
| India | ARIMA(1,1,1) | 243 | 273 | 201 | 235 | 201 | 236 | 270 | 276 | 283 |

Table 4. Best fitted ARIMA and GARCH models for production of pepper in India

| State | Model | Model Selection Criteria | | | | | | | | |
|-----------|----------------|--------------------------|--------|----------|----------|----------|----------|----------|----------|----------------|
| | | AIC | BIC | ME | RMSE | MAE | MPE | MAPE | MASE | R ² |
| Kerala | ARIMA (2,1,1)* | 295.33 | 297.02 | 0.537171 | 9.34958 | 6.48839 | -0.38836 | 14.26368 | 0.975698 | 0.75 |
| | GARCH (1) | 307.29 | 316.10 | 0.89 | 11.24 | 7.46 | -0.78 | 18.70 | 1.32 | 0.68 |
| Karnataka | ARIMA 1,2,1)* | 17.33 | 22.32 | 0.055611 | 0.267688 | 0.10874 | 1.7242 | 4.024148 | 1.087397 | 0.93 |
| | No GARCH | | | | | | | | | |
| India | ARIMA (1,1,2)* | 294.84 | 296.52 | 0.634756 | 9.292012 | 6.390854 | 0.035363 | 13.19543 | 0.975703 | 0.78 |
| | GARCH (1,1) | 313.16 | 323.72 | 1.03 | 12.34 | 6.42 | 0.05 | 14.18 | 1.54 | 0.78 |

Note: * indicates the best model and used further for forecasting purpose

Table 4.1. Validation and forecasting of production of pepper in India on the basis of selected best model

| State | Model | 2010 | | 2011 | | 2012 | | 2016 | 2018 | 2020 |
|-----------|---------------|----------|-----------|----------|-----------|----------|-----------|-----------|-----------|-----------|
| | | Observed | Predicted | Observed | Predicted | Observed | Predicted | Predicted | Predicted | Predicted |
| Kerala | ARIMA (2,1,1) | 46 | 44 | 42 | 46 | 42 | 46 | 46 | 46 | 46 |
| Karnataka | ARIMA (1,2,1) | 5 | 4 | 4 | 5 | 5 | 6 | 7 | 8 | 9 |
| India | ARIMA (1,1,2) | 51 | 51 | 48 | 51 | 41 | 51 | 51 | 51 | 51 |

Table 5. Best fitted ARIMA and GARCH models for productivity of pepper in India

| State | Model | Model Selection Criteria | | | | | | | | |
|-----------|----------------|--------------------------|--------|----------|----------|----------|----------|----------|----------|----------------|
| | | AIC | BIC | ME | RMSE | MAE | MPE | MAPE | MASE | R ² |
| Kerala | ARIMA (1,1,2)* | 389.57 | 392.95 | 3.691472 | 29.50145 | 22.25764 | 0.505496 | 8.584214 | 0.884996 | 0.63 |
| | GARCH (1,2) | 419.52 | 431.85 | 4.36 | 32.45 | 23.60 | 0.98 | 8.03 | 1.47 | 0.55 |
| Karnataka | ARIMA (1,1,1)* | 303.19 | 308.33 | 0.682159 | 8.965238 | 6.551727 | 0.149759 | 2.773228 | 1.035846 | 0.62 |
| | GARCH (1) | 313.02 | 322.20 | 0.84 | 10.33 | 6.64 | 0.39 | 2.77 | 1.39 | 0.57 |
| India | ARIMA (1,1,1) | 397.41 | 400.79 | 6.629741 | 32.4238 | 23.04134 | 1.309321 | 8.595542 | 0.84945 | 0.69 |
| | GARCH (1)* | 387.01 | 397.82 | 6.35 | 30.25 | 22.01 | 1.14 | 8.39 | 0.68 | 0.54 |

Note: * indicates the best model and used further for forecasting purpose

Table 5.1. Validation and forecasting of productivity of pepper in India on the basis of selected best model

| State | Model | 2010 | | 2011 | | 2012 | | 2016 | 2018 | 2020 |
|-----------|---------------|----------|-----------|----------|-----------|----------|-----------|-----------|-----------|-----------|
| | | Observed | Predicted | Observed | Predicted | Observed | Predicted | Predicted | Predicted | Predicted |
| Kerala | ARIMA (1,1,2) | 303 | 276 | 301 | 309 | 295 | 306 | 307 | 307 | 307 |
| Karnataka | ARIMA (1,1,1) | 239 | 242 | 239 | 238 | 240 | 238 | 237 | 236 | 236 |
| India | GARCH (1) | 313 | 300 | 311 | 304 | 305 | 304 | 304 | 304 | 304 |

best GARCH model for Kerala, GARCH(1) model found to be best fitted for Karnataka and whole India.

Best of ARIMA and GARCH models are selected based on the minimum value AIC, BIC, ME, RMSE, MAE, MPE, MAPE and maximum value of R^2 . These selected are again put under diagnostic checking through ACF and PACF graphs of residuals and found that the residuals of selected models are independent same kind of research reported by vishwajit *et al* [8], [9] and Yaziz *et al.* [10]. The selected best of the best models are validated by using recent three years data. The forecasted result (Table 5.1) revealed that, except the whole India productivity, remaining data series the ARIMA models fitted well. For whole India productivity data series GARCH(1) was fitted well. Using best fitted models forecasted value of pepper is estimated for 2020 as for Kerala 185 thousand hectares of area, 46 thousand tonnes production, 307 kg/ha of productivity. Likewise Karnataka 31 thousand hectares of area, 9 thousand tonnes of production, 236 kg/ha of productivity. In case of whole India 283 thousand hectares of area, 51 thousand tonnes of production, 304 kg/ha of productivity respectively.

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Biomass and Carbon Density in Relation to Altitude and Aspect in Moist-temperate Western Himalayan Ecosystem

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Abstract: Present investigation was carried out in Churdhar area of Sirmour district of Himachal Pradesh to assess the influence of aspect and altitude on the biomass and carbon density. Different aspects such as northern, western, southern and eastern with different altitudinal ranges such as 1500–1800, 1801–2100, 2101–2400, 2401–2700 and above 2700 m above mean sea level has been considered as treatment. The local volume equations have been used to calculate the biomass. The results of the experiment in moist-temperate western Himalayan ecosystem have revealed that maximum vegetation biomass and carbon density was recorded in northern aspect and minimum was in southern aspect. In the average effect of altitudinal ranges, maximum vegetation biomass and carbon density at A₄ altitudinal range whereas minimum was at A₅ altitudinal range. In the interaction effect among aspect and altitudinal ranges, maximum vegetation biomass as well as carbon density was recorded in northern aspect at the elevation range of 2101–2400 m above mean sea level.

Keywords: Altitude, Aspect, Biomass, Carbon density, Climate change, GHGs, Moist temperate north-western Himalaya

Climate change, more precisely global warming, is a reality and substantial uncertainty which is one of the most serious threats to the environment (Malhman, 1997; IPCC, 2001) due to increased concentration of GHGs to high level in the atmosphere (IPCC, 2001) causing rise in temperature, changes in patterns of precipitation, change in the distribution pattern of the species and the frequency and intensity of extreme climate events (Malhman, 1997; Watson *et al.*, 1998). The dominant gas of concern in this category is CO₂ (Health *et al.*, 1996; IPCC, 1996). Over the last century, the concentration of CO₂ and other GHGs has considerably increased in the atmosphere and is set to escalate further (Albrecht, 2003). Forest ecosystems helps in reducing the GHGs from the atmosphere (Lal, 2004; Miehle *et al.*, 2006; Mohanraj *et al.*, 2011) particularly by increasing carbon sequestration in the form of biomass in vegetation and organic matter in soil (Turner *et al.*, 2005; Nsabimana *et al.*, 2008) and continuously cycles between forests and the atmosphere through plant respiration and organic material decomposition (Alexandrov, 2007; Fonseca *et al.*, 2011).

Several other studies for the biomass and carbon estimation based on forest type (Chauhan *et al.*, 2004; Baral *et al.*, 2009), species specific plantation (Thakur and Singh, 2005; Fang *et al.*, 2007; Jana *et al.*, 2009), land use type (Sharma, 2009; Baishya *et al.*, 2009) have been done till date. But the studies relating the elevation, slope and aspect

with the biomass in the subtropical and temperate climate are very limited. The present study focuses on to fill the research gap which is quite important from the utilization, conservation and management point of view in the field of natural resource sciences. The hypothesis regarding the research work was that the slope and aspect affect the biomass production in moist temperate western Himalayan ecosystem. Based on the hypothesis research objective was to investigate the effects of elevation, aspect and their interaction on biomass of trees, herbs and shrubs in moist-temperate western Himalayan ecosystem along with the carbon density.

MATERIAL AND METHODS

Study area: The study was carried out in Sirmour district of Himachal Pradesh (Fig. 1) which is located between 30°52'22.9" N latitude and 77°28'82.5" E longitude, forms a transitional zone between the lesser and the greater Himalayas and presents a typical rugged mountainous terrain with moderate to high relief. The climate is temperate with moderate rainfall generally during the months of July, August, December and January. Altitude varies between 1500 m to over 2700 m above sea level with sandy loam and clay loam texture. The forest type of the area is mainly comprises of subtropical pine forests, Himalayan moist temperate forests, sub-alpine forests and moist alpine forest.

Experimental design and sampling: Aspects were

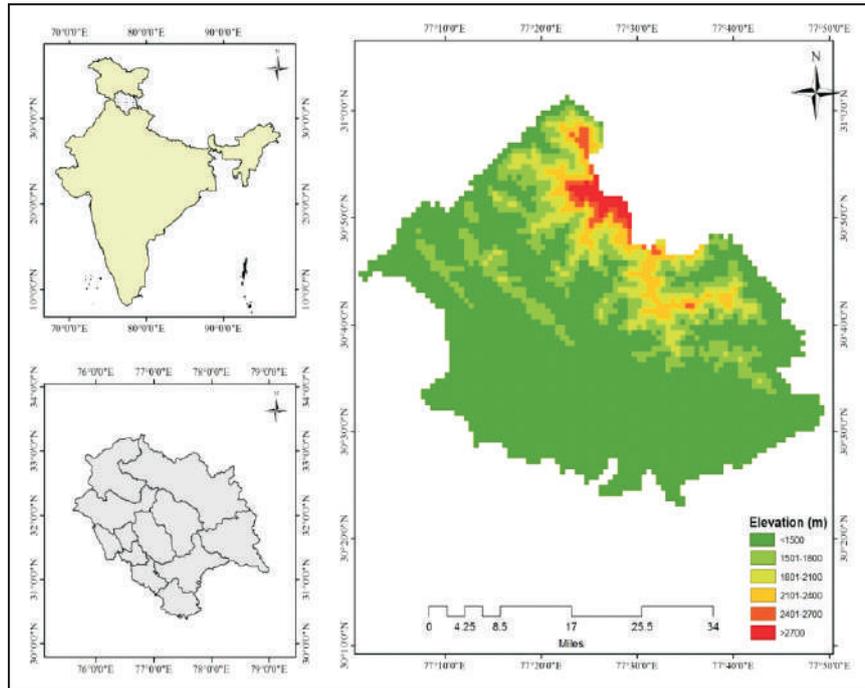


Fig. 1. Location map of the study area

considered as the treatment in this study along the altitudinal ranges. To distribute or to control the variability of the species distribution and biomass production, the five homogenous strata of the altitude i.e. 1500–1800 m, 1801–2100 m, 2101–2400 m, 2401–2700 m and above 2700 m in four different aspect i.e. northern, eastern, southern and western aspect. A Total of 20 treatments (5 altitudinal ranges \times 4 aspects) with four replications were considered to check the influence of the topographic variability in the biomass distribution and carbon density (Table 1). Factorial Randomised block design was used for observations regarding biomass estimation i.e. girth at breast height (GBH), height and density of the plant cover etc. Across the aspect, four random sample plots of 0.1 ha (31.62 \times 31.62 m²) were established at different altitude. First, laid a plot of 0.1 ha (31.62 \times 31.62 m²) for taking observations of tree, than laid two plots of 5 \times 5 m² for shrub and five plot of 1 \times 1 m for grasses and herbs in the same plot. The plots of 1 \times 1 m² for litter were laid randomly as suitable in the plot of 0.1 ha laid for trees. The systematic representation of the plot designs and their positions are represented in the figure 2. A total of 80 sample plots were established to estimate the biomass of trees and 160, 400 sample plots for shrub and grass, respectively. The observations viz. tree biomass (stem, branch and leaves), shrub biomass, herbage biomass and surface leaf litter with twigs, comprising total above ground biomass and below ground biomass were recorded. Below ground biomass was estimated as per the

equation of Crains (1997) and IPCC guidelines for trees and woody vegetation, and uprooting technique were used for herbs.

Above ground biomass estimation: All the trees in the sample plot (31.62 \times 31.62 m²) were enumerated for biomass estimation (Fig. 2). Tree biomass was estimated with the help of local volume equation (Table 2) developed for specific tree species (FSI, 1996). Pressler's formula (1865) was used to estimate volume where the volume equations for concerned species were not available. The stem volumes multiplied with the specific gravity to estimate the biomass of the stem.

$$V = f \times h \times g$$

where V = volume, f = form factor, h = total height of tree, g = Basal area

$$f = 2h_i / 3h$$

where f = form factor, h_i = height at which diameter is half of dbh, h = total height of tree

The biomass of the branch of forest trees were estimated using sample trees. Total number of branches irrespective of size were counted on each of the sampled tree, then these were categorized on the basis of basal diameter into three groups, viz., <6 cm, 6–10 cm and >10 cm. Fresh weight of two sampled branches from each group was recorded separately. The following formula (Chidumayo, 1990) was used to determine the dry weight of branches:

$$B_{dwi} = \frac{B_{twi}}{1 + M_{cbdi}}$$

where B_{dwi} - oven dry weight of branch, B_{twi} - fresh/green

weight of branches, M_{cbd} —moisture content of branch on dry weight basis

Total branch biomass (Fresh/dry) per sample tree was estimated using the following formula:

$$B_{bt} = n_1 b_{w1} + n_2 b_{w2} + n_3 b_{w3} - \sum n_i b_{wi}$$

where B_{bt} —branch biomass (fresh/dry) per tree, N_i —number of branches in the i^{th} branch group, B_{wi} —average weight of branch of i^{th} group and 1, 2, 3 refers to branch group

Leaf biomass of the forest tree species was estimated using the table 3 given by Jenkins *et al.* (2003).

The total tree biomass was the sum of stem biomass, branch biomass and leaf biomass.

$$TT_b = S_b + B_b + L_b$$

Where TT_b = total tree biomass, S_b = stem biomass, B_b = branch biomass and L_b = leaf biomass

Shrub biomass was estimated using 5×5 m² quadrates (Fig. 2). All the shrubs occurring within the borders of the quadrates were enumerated. The diameter of all tillers was measured at base with the help of calliper according to the method given by Chaturvedi and Khanna (1982). The length of tiller was measured with the help of measuring tape. Local volume equation developed for specific shrub species were used for calculating the volume of the forest shrubs of the

sample plots.

Grass biomass and surface litter was estimated using 1×1 m² quadrates (Fig. 2). The total grass biomass occurring within the borders of the quadrate were cut at ground level and collected samples were weighed, sub sampled and oven dried at 65±5°C to a constant weight.

Above ground biomass for the plot were estimated by adding the biomass of all components.

$$AGB = S_b + B_b + L_b + SR_b + H_b + LI_b$$

where AGB = above ground biomass, SR_b = shrub biomass, H_b = herb biomass and LI_b = litter biomass. Others are same as given above.

Below ground biomass: Below ground biomass of trees was calculated using the guidelines of IPCC (1996) and Cairns *et al.* (1997). Below ground biomass of the herbs and grasses was measured using root-shoot ratio given by Mokany *et al.* (2006).

Total biomass was the sum of above ground biomass and below ground biomass estimated for each plot in elevation strata at a particular aspect had been averaged.

Carbon density assessment: Carbon density was estimated using following formula:

$$\text{Carbon} = \text{Biomass} \times 0.5 \text{ (IPCC default value)}$$

$$\text{Carbon density} = \text{Carbon divided by area (t ha}^{-1}\text{)}$$

Table 1. Tree characteristics at different aspect and altitudinal range in moist-temperate western Himalayan ecosystem

| Treatment | Altitude (m) | Stem density (ha ⁻¹) | Average DBH (cm) | Average volume (M ³ ha ⁻¹) | Specific gravity (g cm ⁻³) | Dominant tree species |
|-----------------------------------|--------------|----------------------------------|------------------|---|--|-----------------------|
| Northern Aspect (T ₁) | 1500-1800 | 560 | 49.36 | 126.09 | 0.46 | Deodar |
| | 1801-2100 | 530 | 55.20 | 173.99 | 0.46 | Deodar |
| | 2101-2400 | 530 | 58.26 | 202.71 | 0.46 | Deodar |
| | 2401-2700 | 430 | 55.99 | 106.33 | 0.46 | Deodar |
| | >2700 | 340 | 48.96 | 68.99 | 0.46 | Deodar |
| Western Aspect (T ₂) | 1500-1800 | 410 | 46.23 | 86.57 | 0.75 | Ban oak |
| | 1801-2100 | 400 | 56.56 | 140.57 | 0.35 | Blue pine |
| | 2101-2400 | 410 | 49.54 | 97.40 | 0.46 | Deodar |
| | 2401-2700 | 330 | 71.83 | 169.94 | 0.46 | Deodar |
| | >2700 | 290 | 76.33 | 132.48 | 0.37 | Fir |
| Southern Aspect (T ₃) | 1500-1800 | 380 | 42.34 | 46.11 | 0.47 | Chir pine |
| | 1801-2100 | 300 | 46.24 | 52.41 | 0.47 | Chir pine |
| | 2101-2400 | 310 | 43.02 | 55.88 | 0.46 | Deodar |
| | 2401-2700 | 390 | 48.61 | 84.64 | 0.88 | Kharsu oak |
| | >2700 | 330 | 50.00 | 73.06 | 0.37 | Fir |
| Eastern Aspect (T ₄) | 1500-1800 | 530 | 52.36 | 161.96 | 0.46 | Deodar |
| | 1801-2100 | 410 | 45.06 | 87.22 | 0.46 | Deodar |
| | 2101-2400 | 360 | 53.48 | 114.05 | 0.46 | Deodar |
| | 2401-2700 | 330 | 49.83 | 75.78 | 0.46 | Deodar |
| | >2700 | 360 | 49.16 | 75.81 | 0.37 | Fir |

Vegetation carbon density (t ha⁻¹) = Tree carbon (t ha⁻¹) + Shrub carbon(t ha⁻¹) + Herb and grass carbon (t ha⁻¹)

RESULTS AND DISCUSSION

Vegetation composition: In the northern aspect, the dominant species was *Cedrus deodara* (*deodar*) in the all altitudinal ranges with considerable variability among the associates. Similarly the southern aspect dominated by the *Pinus roxburghii* (*chir pine*) and *Quercus semicarpifolia* (*kharsu*). Western aspect having heterogynous species composition distributed along the altitudinal ranges. *Quercus leucotricophora* (*banj oak*) dominated at lower elevation (1501-1800 m) followed by *Pinus wallichiana* (blue pine) at 1801-2100 m, *Cedrus deodara* at 2101-2700 m and *Abies pindrow* (*fir*) at above 2700 m altitude, whereas the eastern aspect was dominated by *Cedrus deodara* and *Abies pindrow* in the all altitudinal ranges (Table 4).

Vegetation biomass: The different aspects and altitudinal ranges significantly influences the above ground biomass (AGB) and below ground biomass (BGB). The maximum AGB and BGB (842.64 t ha⁻¹ and 179.52 t ha⁻¹ respectively) was at northern aspect, was significantly higher than all other aspects (Table 5). In the average effect of altitudinal ranges, the maximum AGB and BGB (766.88 t ha⁻¹ and 175.3 t ha⁻¹ respectively) at A₄ altitudinal range, and minimum (544.38 t ha⁻¹ and 118 t ha⁻¹ respectively) was observed at A₅ altitudinal range. In the interaction effect maximum tree AGB and BGB (1192 t ha⁻¹ and 238.4 t ha⁻¹ respectively) in northern aspect at altitudinal range of 2101-2400 m above sea level, whereas minimum in the southern aspect at the same elevation range. Total tree biomass was the sum of above ground biomass and below ground biomass of the trees. Maximum total tree biomass (1021.98 t ha⁻¹) was in northern aspect which was significantly different from other. In the average effect of altitudinal ranges, maximum total tree biomass (942.18t ha⁻¹) at A₄ altitudinal range, and minimum tree biomass was observed at A₅ altitudinal range (Table 5). There was no consistent trend at any of the aspect in relation to the increasing altitudinal ranges. Shrub biomass was also significantly influence by aspects as well as altitudinal ranges. Among the different aspects, maximum shrub biomass (1.59 t ha⁻¹) was recorded at western aspect, which was higher than entire aspects. Minimum shrub biomass (0.85 t ha⁻¹) was recorded in northern aspect. In the average effect of altitudinal ranges, the shrub biomass augmented significantly from A₁ to A₄ and then declined at A₅. Interaction effect were showing decline trend in the shrub biomass from A₁ to A₅ in the northern aspect whereas increased from A₁ to A₄ and decline at A₅ in the southern and western aspect and

Table 2. Volume equation for biomass estimation of different forest tree species

| Species Name | Volume equation |
|--------------------------------|---|
| <i>Pinus roxburghii</i> | V=0.034529+0.284662xD ² H (R ² =0.9478) |
| <i>Pinus wallichiana</i> | V=0.251311-2.683081xD+13.484565xD ² |
| <i>Cedrus deodara</i> | V=0.167174-1.735312xD+12.039017xD ² |
| <i>Picea smithiana</i> | V=0.28318+0.0337/D ² H |
| <i>Abies pindrow</i> | V=0.293884-3.441808xD+15.922114xD ² |
| <i>Quercus leucotricophora</i> | V=0.682380+5.049937D-2.770924 D (R ² =0.9392) |
| <i>Quercus semicarpifolia</i> | V/D ² =0.1358/D ² 1.84908/D+10.8234-0.6276D |
| <i>Rhododendron arboreum</i> | V=0.06007-0.21874 D+3.63428D ² (R ² =0.91132) |

Table 3. Proportion of biomass (%) in tree foliage (Jenkins et al., 2003)

| | DBH (cm) | | | | | | | | | |
|-----------------|----------|----|----|----|----|----|----|----|----|------|
| | 10 | 20 | 30 | 40 | 50 | 60 | 70 | 80 | 90 | > 90 |
| Hardwoodfoliage | 3 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 |
| Softwoodfoliage | 8 | 6 | 6 | 6 | 6 | 6 | 5 | 5 | 5 | 5 |

increased from A₁ to A₃ and decline at A₄ to A₅ in the eastern aspect. However, maximum (3.06 t ha⁻¹) and minimum (0.27 t ha⁻¹) biomass was in the treatment combination of T₃A₄ and T₁A₅, respectively (Table 5).

The maximum herb and grass biomass (4.35 t ha⁻¹) was in western aspect, which was significantly higher than southern, eastern and northern aspects, respectively in the descending order (Table 5). Minimum herb and grass biomass (2.88 t ha⁻¹) was at northern aspect. In the average effect of altitudinal ranges, maximum herb and grass biomass (5.82 t ha⁻¹) at A₁ altitudinal range, which was significantly higher than entire altitudinal ranges, and minimum (2.44 t ha⁻¹) was observed at A₄ altitudinal range. In the interaction effect, maximum herb and grass biomass was recorded in the northern aspect at the altitudinal range of A₅, whereas minimum (1.98 t ha⁻¹) in eastern aspect at 2101-2400 m altitude (Table 5). Total vegetation biomass was estimated by adding the total tree biomass, shrub biomass, and herb and grass biomass. Maximum vegetation biomass (1025.58 t ha⁻¹) was in northern aspect, which was significantly different from western, eastern and southern aspects (Table 5). Minimum was in southern aspect. In the average effect of altitudinal ranges, maximum vegetation biomass (946.35 t ha⁻¹) at A₄ altitudinal range, which was significantly highest vegetation biomass than entire

altitudinal ranges, and minimum vegetation biomass (668.08 t ha⁻¹) was at A₅ altitudinal range (Table 5). In the interaction effect among aspect and altitudinal ranges, maximum vegetation biomass (1433 t ha⁻¹) was recorded in northern aspect at the elevation range of 2101–2400 m above mean sea level, whereas minimum biomass was in the southern

Table 4. Vegetation composition at different aspect and altitudinal range in moist-temperate western Himalayan ecosystem

| Treatment | Altitude (m) | Tree species, Shrub species, Herb and Grasses |
|-----------------------------------|--------------|--|
| Northern Aspect (T ₁) | 1500–1800 | <i>Cedrus deodara</i> , <i>Quercus leucotrichophora</i> , <i>Pinus roxburghii</i> , <i>Pinus wallichiana</i> , <i>Daphne papyracea</i> , <i>Rubus ellipticus</i> , <i>Indigofera heterantha</i> , <i>Pyracantha crenulata</i> , <i>Viola odorata</i> , <i>Geranium wallichianum</i> and <i>Cymbopogon distans</i> |
| | 1801–2100 | <i>Cedrus deodara</i> , <i>Salix wallichiana</i> , <i>Daphne papyracea</i> , <i>Indigofera heterantha</i> , <i>Viola odorata</i> and <i>Cymbopogon distans</i> |
| | 2101–2400 | <i>Cedrus deodara</i> , <i>Rhododendron arboretum</i> , <i>Daphne papyracea</i> , <i>Indigofera heterantha</i> , <i>Salix wallichiana</i> , <i>Rosa macrophylla</i> , <i>Rubus ellipticus</i> , <i>Bergenia ciliate</i> and <i>Corex nubigena</i> |
| | 2401–2700 | <i>Cedrus deodara</i> , <i>Rhododendron arboretum</i> , <i>Quercus dilatata</i> , <i>Abies pindrow</i> , <i>Piceas mithiana</i> , <i>Sorbaria tomentosa</i> , <i>Salix wallichiana</i> , <i>Daphne papyracea</i> , <i>Bergenia ciliate</i> and <i>Corex nubigena</i> |
| | >2700 | <i>Cedrus deodara</i> , <i>Rhododendron campanulatum</i> , <i>Quercus semicarpifolia</i> , <i>Abies pindrow</i> , <i>Piceas mithiana</i> , <i>Sorbaria tomentosa</i> , <i>Salix wallichiana</i> , <i>Daphne papyracea</i> , <i>Wickstroemia canescens</i> , <i>Calamagrostis</i> sp. and <i>Ansaema</i> sp. |
| Western Aspect (T ₂) | 1500–1800 | <i>Quercus leucotrichophora</i> , <i>Pinus roxburghii</i> , <i>Pinus wallichiana</i> , <i>Berberis aristata</i> , <i>Woodfordia fruticosa</i> , <i>Rubus ellipticus</i> , <i>Arundinella benghalensis</i> , <i>Asparagus racemes</i> and <i>Phyllanthus</i> sp. |
| | 1801–2100 | <i>Cedrus deodara</i> , <i>Quercus leucotrichophora</i> , <i>Pinus roxburghii</i> , <i>Pinus wallichiana</i> , <i>Berberis aristata</i> , <i>Woodfordia fruticosa</i> , <i>Rubus ellipticus</i> , <i>Apluda mutica</i> and <i>Chrysopogon gongryllus</i> |
| | 2101–2400 | <i>Cedrus deodara</i> , <i>Rhododendron arboretum</i> , <i>Quercus leucotrichophora</i> , <i>Pinus wallichiana</i> , <i>Daphne papyracea</i> , <i>Berberis aristata</i> , <i>Rubus ellipticus</i> , <i>Wickstroemia canescens</i> , <i>Cerexinanis</i> , <i>Chrysopogon gryllus</i> and <i>Epipactis latifolia</i> |
| | 2401–2700 | <i>Cedrus deodara</i> , <i>Rhododendron arboretum</i> , <i>Quercus dilatata</i> , <i>Abies pindrow</i> , <i>Piceas mithiana</i> , <i>Daphne papyracea</i> , <i>Berberis aristata</i> , <i>Rubus ellipticus</i> , <i>Wickstroemia canescens</i> , <i>Cerexinanisa</i> and <i>Chrysopogon gryllus</i> |
| | >2700 | <i>Cedrus deodara</i> , <i>Rhododendron campanulatum</i> , <i>Quercus semicarpifolia</i> , <i>Abies pindrow</i> , <i>Piceas mithiana</i> , <i>Daphne papyracea</i> , <i>Rubus ellipticus</i> , <i>Wickstroemia canescens</i> , <i>Salix denticulate</i> , <i>Canbamogrotis</i> sp. and <i>Arisaema</i> sp. |
| Southern Aspect (T ₃) | 1500–1800 | <i>Quercus leucotrichophora</i> , <i>Pinus roxburghii</i> , <i>Pinus wallichiana</i> , <i>Berberis aristata</i> , <i>Woodfordia fruticosa</i> , <i>Princepiautalis</i> , <i>Lantana camera</i> , <i>Chrysopogon</i> sp. and <i>Arundinella benghalensis</i> |
| | 1801–2100 | <i>Quercus leucotrichophora</i> , <i>Pinus roxburghii</i> , <i>Pinus wallichiana</i> , <i>Berberis aristata</i> , <i>Woodfordia fruticosa</i> , <i>Princepiautalis</i> , <i>Rubus ellipticus</i> , <i>Arundinella benghalensis</i> and <i>Geranium</i> sp. |
| | 2101–2400 | <i>Cedrus deodara</i> , <i>Quercus leucotrichophora</i> , <i>Pinus roxburghii</i> , <i>Pinus wallichiana</i> , <i>Berberis aristata</i> , <i>Hypericumelodii</i> , <i>Cotoneaster</i> spp., <i>Rubus ellipticus</i> , <i>Aster thomsonii</i> and <i>Heteropogon</i> sp. |
| | 2401–2700 | <i>Cedrus deodara</i> , <i>Rhododendron arboretum</i> , <i>Quercus dilatata</i> , <i>Abies pindrow</i> , <i>Piceas mithiana</i> , <i>Berberis aristata</i> , <i>Zanthoxylum</i> sp., <i>Rhamnus</i> spp., <i>Rubus wallichianum</i> , <i>Viola odorata</i> , <i>Apludamutica</i> and <i>Ranunculus lactus</i> . |
| | >2700 | <i>Cedrus deodara</i> , <i>Rhododendron campanulatum</i> , <i>Quercus semicarpifolia</i> , <i>Abies pindrow</i> , <i>Piceas mithiana</i> , <i>Sorbaria tomentosa</i> , <i>Jasminum</i> sp., <i>Chrysopogon</i> sp. and <i>Dactylis glomerata</i> . |
| Eastern Aspect (T ₄) | 1500–1800 | <i>Cedrus deodara</i> , <i>Quercus leucotrichophora</i> , <i>Pinus roxburghii</i> , <i>Pinus wallichiana</i> , <i>Berberis aristata</i> , <i>Woodfordia fruticosa</i> , <i>Princepiautalis</i> , <i>Lantana camera</i> , <i>Chrysopogon</i> sp. and <i>Arundinella benghalensis</i> . |
| | 1801–2100 | <i>Cedrus deodara</i> , <i>Quercus leucotrichophora</i> , <i>Pinus wallichiana</i> , <i>Berberis aristata</i> , <i>Woodfordia fruticosa</i> , <i>Princepiautalis</i> , <i>Rubus ellipticus</i> , <i>Arundinella benghalensis</i> , <i>Geranium</i> sp. and <i>Chrysopogon</i> sp. |
| | 2101–2400 | <i>Cedrus deodara</i> , <i>Rhododendron arboretum</i> , <i>Daphne papyracea</i> , <i>Berberis aristata</i> , <i>Rubus ellipticus</i> , <i>Salix wallichiana</i> , <i>Viola odorata</i> , <i>Geranium</i> sp. and <i>Cymbopogon</i> sp. |
| | 2401–2700 | <i>Cedrus deodara</i> , <i>Rhododendron arboretum</i> , <i>Quercus dilatata</i> , <i>Abies pindrow</i> , <i>Piceas mithiana</i> , <i>Daphne papyracea</i> , <i>Indigofera heterantha</i> , <i>Rosa</i> sp., <i>Rubus ellipticus</i> , <i>Bergenia ciliate</i> and <i>Heteropogon</i> sp. |
| | >2700 | <i>Cedrus deodara</i> , <i>Rhododendron campanulatum</i> , <i>Quercus semicarpifolia</i> , <i>Abies pindrow</i> , <i>Piceas mithiana</i> , <i>Daphne papyracea</i> , <i>Rubus ellipticus</i> , <i>Sorbaria</i> sp., <i>Bergenia ciliate</i> and <i>Heteropogon</i> sp. |

Table 5. Effect of aspect, altitude and their interaction on total vegetation biomass ($t\ ha^{-1}$) in moist-temperate western Himalayan ecosystem

| Aspect | Altitudinal range (m) | | | | | Mean |
|--|-----------------------|----------------|----------------|----------------|----------------|---------|
| | A ₁ | A ₂ | A ₃ | A ₄ | A ₅ | |
| Tree above ground biomass ($t\ ha^{-1}$) | | | | | | |
| T ₁ (Northern) | 827.20 | 1025.00 | 1192.00 | 697.10 | 471.90 | 842.64 |
| T ₂ (Western) | 707.00 | 716.20 | 673.20 | 1096.00 | 675.10 | 773.50 |
| T ₃ (Southern) | 307.90 | 316.00 | 257.90 | 759.20 | 519.30 | 432.06 |
| T ₄ (Eastern) | 1068.00 | 547.40 | 669.20 | 515.20 | 511.20 | 662.20 |
| Mean | 727.53 | 651.15 | 698.08 | 766.88 | 544.38 | |
| | T | A | T×A | | | |
| SE _i | 1.520 | 1.699 | 3.400 | | | |
| CD (p=0.05) | 3.044 | 3.404 | 6.807 | | | |
| Tree below ground biomass ($t\ ha^{-1}$) | | | | | | |
| T ₁ (Northern) | 174.70 | 203.70 | 238.40 | 175.30 | 105.50 | 179.52 |
| T ₂ (Western) | 168.30 | 150.60 | 148.20 | 233.90 | 133.70 | 166.94 |
| T ₃ (Southern) | 66.66 | 71.42 | 54.38 | 180.10 | 116.70 | 97.85 |
| T ₄ (Eastern) | 230.10 | 115.40 | 130.40 | 111.90 | 116.10 | 140.78 |
| Mean | 159.94 | 135.28 | 142.85 | 175.30 | 118.00 | |
| | T | A | T×A | | | |
| CD (p=0.05) | 1.959 | 2.189 | 4.189 | | | |
| Total tree biomass ($t\ ha^{-1}$) | | | | | | |
| T ₁ (Northern) | 1002.00 | 1228.00 | 1430.00 | 872.40 | 577.50 | 1021.98 |
| T ₂ (Western) | 875.40 | 866.80 | 821.30 | 1330.00 | 808.80 | 940.46 |
| T ₃ (Southern) | 374.40 | 387.40 | 312.30 | 939.30 | 635.90 | 529.86 |
| T ₄ (Eastern) | 1298.00 | 662.80 | 799.60 | 627.00 | 627.30 | 802.94 |
| Mean | 887.45 | 786.25 | 840.8 | 942.18 | 662.38 | |
| | T | A | T×A | | | |
| CD (p=0.05) | 3.633 | 4.062 | 8.122 | | | |
| Shrub biomass ($t\ ha^{-1}$) | | | | | | |
| T ₁ (Northern) | 1.765 | 1.055 | 0.815 | 0.358 | 0.268 | 0.852 |
| T ₂ (Western) | 0.895 | 1.047 | 2.090 | 2.140 | 1.820 | 1.598 |
| T ₃ (Southern) | 0.573 | 0.755 | 1.555 | 3.062 | 0.510 | 1.291 |
| T ₄ (Eastern) | 0.488 | 1.622 | 1.762 | 1.140 | 1.250 | 1.252 |
| Mean | 0.930 | 1.119 | 1.555 | 1.675 | 0.962 | |
| | T | A | T×A | | | |
| CD (p=0.05) | 0.014 | 0.016 | 0.032 | | | |
| Herb and grass biomass ($t\ ha^{-1}$) | | | | | | |
| T ₁ (Northern) | 1.77 | 1.82 | 2.33 | 2.52 | 5.95 | 2.88 |
| T ₂ (Western) | 8.40 | 1.84 | 3.09 | 2.57 | 5.84 | 4.35 |
| T ₃ (Southern) | 6.06 | 5.47 | 2.95 | 2.38 | 4.65 | 4.30 |
| T ₄ (Eastern) | 7.07 | 5.75 | 1.98 | 2.27 | 2.44 | 3.90 |
| Mean | 5.82 | 3.72 | 2.59 | 2.44 | 4.72 | |
| | T | A | T×A | | | |
| CD (p=0.05) | 0.015 | 0.016 | 0.033 | | | |
| Total vegetation biomass ($t\ ha^{-1}$) | | | | | | |
| T ₁ (Northern) | 1005.00 | 1231.00 | 1433.00 | 875.20 | 583.70 | 1025.58 |
| T ₂ (Western) | 884.70 | 869.70 | 826.50 | 1335.00 | 816.50 | 946.48 |

Cont...

| | | | | | | |
|--|---------|--------|--------|--------|--------|--------|
| T ₃ (Southern) | 381.20 | 393.70 | 316.80 | 944.80 | 641.10 | 535.52 |
| T ₄ (Eastern) | 1306.00 | 670.20 | 803.30 | 630.40 | 631.00 | 808.18 |
| Mean | 894.23 | 791.15 | 844.9 | 946.35 | 668.08 | |
| | T | A | T×A | | | |
| SE _t | 1.815 | 2.029 | 4.059 | | | |
| CD (p=0.05) | 3.635 | 4.064 | 8.126 | | | |
| Total vegetation carbon density (t ha⁻¹) | | | | | | |
| T ₁ (Northern) | 502.70 | 615.60 | 716.60 | 437.60 | 291.80 | 512.86 |
| T ₂ (Western) | 442.30 | 434.80 | 413.30 | 667.40 | 408.30 | 473.22 |
| T ₃ (Southern) | 190.60 | 196.80 | 158.40 | 472.40 | 320.50 | 267.74 |
| T ₄ (Eastern) | 653.00 | 335.10 | 401.70 | 315.20 | 315.50 | 404.10 |
| Mean | 447.15 | 395.58 | 422.50 | 473.15 | 334.03 | |
| | T | A | T×A | | | |
| SE _t | 0.908 | 1.015 | 2.029 | | | |
| CD (p=0.05) | 1.817 | 2.032 | 4.062 | | | |

aspect at same altitude (Fig. 3a, 3b and 3c). In the moist temperate western Himalayan ecosystem, northern aspect and altitudinal range 2401-2700 m exhibited significantly higher values of above, below and total tree biomass than all other aspect and altitudinal ranges. The results of study indicate that biomass components viz. above ground biomass, below ground biomass and total biomass produced by particular aspects and altitudinal ranges is influenced by the age/diameter of the components, type of the forest vegetation growing therein; structure nature and number of woody components and soil type, etc. The variation in the biomass level and biomass carbon density at different altitude can be explained on the basis of age and density of woody species, variation in soil organic carbon percentage, and human population density as well as change in the pattern of temperature and rainfall with the changes in the

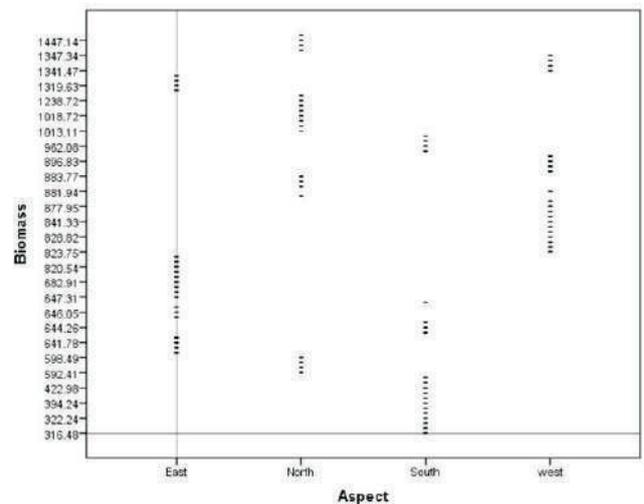


Fig. 3a. Vegetation biomass variability with respect to aspect

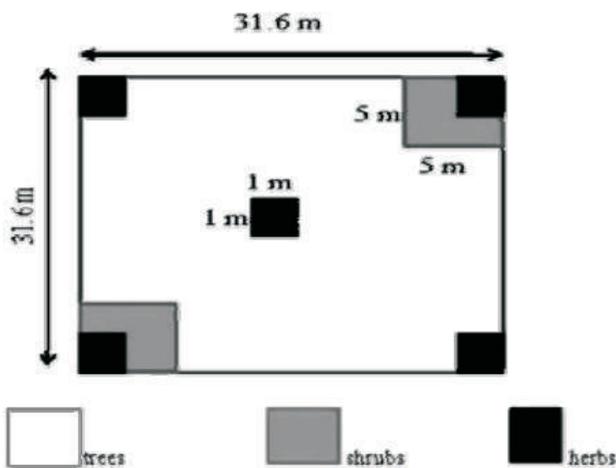


Fig. 2. Plot design for sampling plot of biomass

altitudinal ranges. In the present study, tree density was observed highest at lower altitude, and subsequently decreases with increasing altitude, is also reason for decreasing the average total vegetation biomass and carbon density with increasing elevation did not extend higher than 2400 m above sea level because tree density also plays an important role behind the tree biomass (Nagar *et al.*, 2015). Other studies reported that biomass production in tropical mountain forests of Asia (Kitayama and Aiba, 2002) and the Andes (Girardin *et al.*, 2010; Moser *et al.*, 2011) decrease with elevation rather than a unimodal pattern, or even an increase in wet temperate north western Himalaya (Senneh, 2007) and Shiwalik chir pine forest (Sharma, 2009). The result reveals that the major contributor of biomass at the different altitudinal ranges was woody perennials, and also observed that the average age of the tree species increased

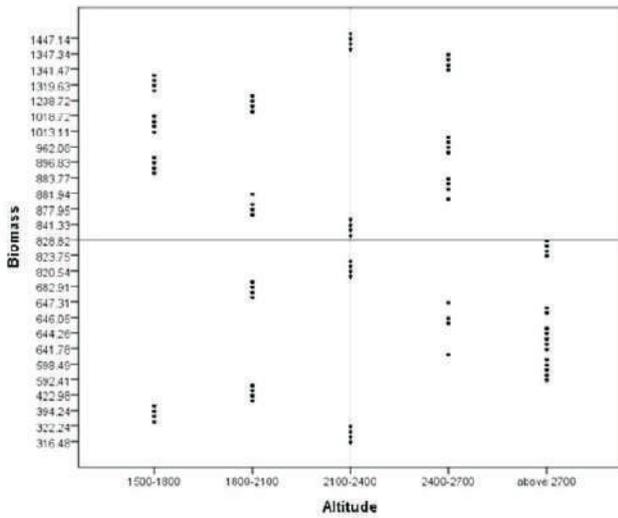


Fig. 3b. Vegetation biomass variability with respect to altitude

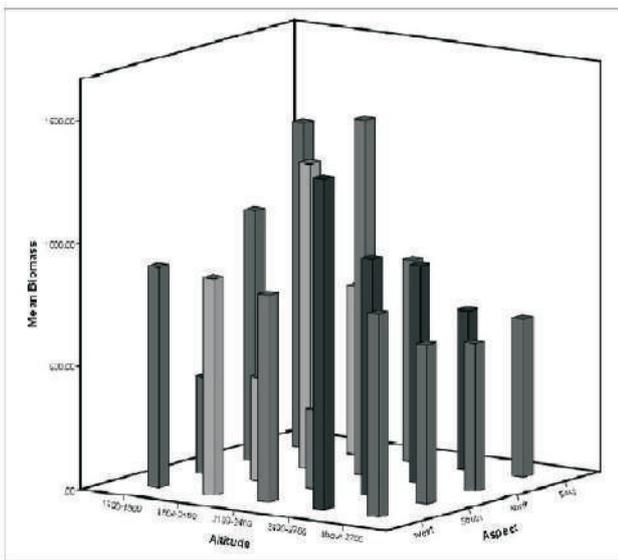


Fig. 3c. Vegetation biomass variability with respect to interaction of aspect and altitude

with the increasing altitudinal ranges. This may be one of the major reasons for biomass variation at different altitudinal ranges. Vegetation age, soil organic carbon, less human interference and high rainfall intensity are the possible cause of the high biomass at the medium range elevation. The results are in the line with the findings of Kumar *et al.* (2001) and Senneh (2007).

Vegetation carbon density: Maximum vegetation carbon density (512.86 t ha⁻¹) was demonstrated by northern aspect, which was significantly higher than western, eastern and southern aspects, respectively in the descending order (Table 5). In the average effect of altitudinal ranges,

maximum vegetation carbon density (473.15 t ha⁻¹) at A₂ altitudinal range, which was significantly higher than other altitudinal ranges, and minimum was at A₅ altitudinal range. In the interaction effect of different treatment combinations, the maximum vegetation carbon density (716.6 t ha⁻¹) was in the northern aspect at the elevation range of 2101-2400 m above mean sea level, whereas minimum was also in the same elevation range in southern aspect. The lower productivity on the higher altitudinal range (>2700) was observed. The possible cause of this would be the lower temperature which is the limiting factor in the photosynthetic activity. The interaction effect of the aspect and altitude on biomass production and its carbon density varies considerably. The variation in the biomass level and biomass carbon density at different altitude can be explained on the basis of density of woody species, variation in soil organic carbon percentage and change in the pattern of temperature and rainfall (Ensslin *et al.*, 2015) with the changes in the altitudinal ranges.

CONCLUSION

The biomass and carbon density were significantly affected by the slope, aspect and their interactions. This study will facilitate for precise estimation as well as establishing functional relationship between various constants for precise estimation of carbon sequestration potential of forest trees as input in the climate change modeling, in addition would facilitate to the decision making for effective C led forest management in terms of regeneration, plantation, protection and conservation of forest resource etc.

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Assessment of Human Essential Trace Elements in Soil and Ground Water of Gonda District, Uttar Pradesh, India

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Abstract: The present study has been carried out to determine the occurrence, prevalence and contributing factors to the incidence of goitre in *tarai* region Gonda district, Uttar Pradesh. To achieve these objectives, cultivated soil and ground water samples were collected from thirty five reference locations, in order to determine their physico-chemical properties of soil, ionic concentrations of ground water, iodine and selenium concentrations in both the soil and water samples. The soil mean value of hot water extractable iodine and selenium was estimated as 3.33 and 0.109 mg kg⁻¹, with range of 1.81-4.46 and 0.012-0.287 mg kg⁻¹, respectively. The iodine and selenium concentration in ground water varied from 1.21-26.71 and 12.39 to 63.36 µg L⁻¹ with mean of 15.52 and 35.26 µg L⁻¹, respectively. The pH, EC, Cl⁻, SO₄²⁻, NO₃⁻, PO₄³⁻, Ca²⁺, Mg²⁺, Na⁺, K⁺, and NH₄⁺ of ground water were within the desirable limit of WHO for drinking purpose, except HCO₃⁻ and CO₃²⁻ ions concentration. Higher concentrations of HCO₃⁻ and CO₃²⁻ in ground water enhanced the pH of the water. In view of the quality of ground water, the water under study was good quality for drinking purpose, as most of the pH was within the range of 6.5 to 9.2 and EC was also below 2 dSm⁻¹.

Keywords: Environmental strategy, Iodine, Selenium, Iodine deficiency, Gonda district

Essential trace elements such as iodine and selenium are essential to human health and other animal health in small doses and insufficient intake of trace minerals can cause symptoms of nutritional deficiency. Iodine (I) forms an important constituent of the thyroid hormones thyroxine [3,5,3',5'-tetraiodothyronine (T₄)] and 3,5,3'-triiodothyronine (T₃) and play a fundamental biological role controlling growth and development. Selenium (Se) is an important trace element found in most of the soils and selenium concentrations in aquifer and surface water systems has emerged as a serious concern during the last half-century (Zhang *et al.*, 2008). In recent years, it has been suggested that Se deficiency may be an important factor in the onset of iodine deficiency disorder (IDD). Iodine and selenium deficiency is in almost all part of the developed and developing world due to its irregular distribution over the earth crusts. Its deficiency in the Indian soils is generally confined to the Himalayan mountain areas over the lower plain. In present study attempt is made for systematic data on iodine and selenium status in cultivated soil and drinking water in the *tarai* region of Uttar Pradesh.

MATERIAL AND METHODS

Site description: Geographically the district Gonda is situated between 26° 47' and 27° 20' North latitude and 81° 30' and 82° 46' East longitude and at an altitude of 120 m

above the mean sea level and rivers Saryu and Ghaghara pass through the district (Fig. 1). The soils of the district are composed of the fluvial deposits of these two rivers, making it one of the most productive soils in the *tarai* region. The average summer temperature is nearly 34 °C. Average annual precipitation varies from 1500 mm to 2000 mm. and annual devastating floods during monsoons is very common because of heavy precipitation and flowing currents from the Shivalik mountains.

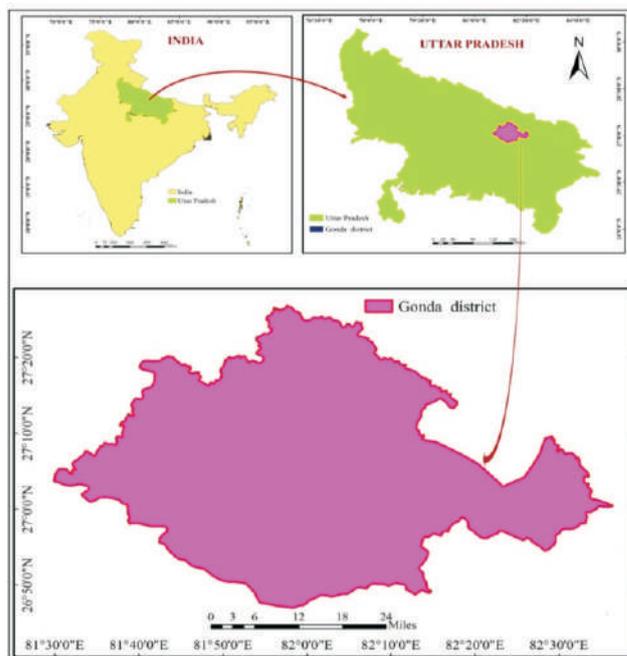
Collection and analysis: Thirty five cultivated soil and ground water samples were collected from Gonda district, Uttar Pradesh (Table 1). The surface soil samples (0-15 cm depth) were air-dried, ground and passed through 2 mm stainless steel sieve for laboratory analysis and their properties *viz.*, bulk density, particle distribution, water holding capacity (WHC), pH, electrical conductivity (EC), organic carbon and cation exchange capacity (CEC) was determined by following the standard procedures (Black, 1965; Jackson, 1973; Bouyoucos, 1962; Walkley and Black, 1934; and Chapman, 1965). The ground water samples were collected (from wells, bore wells and hand pump) and preserved by the addition of toluene (2 drops in one litre water) after immediate analysis of pH and EC for further chemical analysis. The collection, preservation, transportation, and analysis of the samples were done in accordance to the procedures in the standard methods (APHA, 2005).

Table 1. Location of soil samples of Gonda district

| Location | Global positions | Cropping system |
|----------------|------------------------|---------------------|
| Madhepur | N27°05.787'E82°17.030' | Sugarcane |
| Siswon | N27°05.951'E82°10.105' | Sugarcane |
| Chatura Bheti | N26°59.619'E82°31.142' | Rice-Wheat |
| Bakhrauli | N26°59.648'E82°24.130' | Vegetable-vegetable |
| Pipra Mahim | N27°05.729'E82°24.159' | Rice-Wheat |
| Rupaidih | N27°18.153'E81°56.218' | Sugarcane |
| Bichuri | N27°18.124'E81°49.817' | Sugarcane |
| Chauhatta | N27°24.234'E81°56.392' | Vegetable-vegetable |
| Parsa Sohausa | N27°11.967'E82°03.222' | Sugarcane |
| Ayah | N27°17.921'E82°03.288' | Orchard |
| Khiraura Mohan | N27°11.113'E81°56.151' | Sugarcane |
| Bisunpur Mafi | N27°17.921'E82°10.280' | Sugarcane |
| Dulhapur | N27°11.926'E82°03.105' | Sugarcane |
| Chakrad | N27°05.997'E82°03.105' | Sugarcane |
| Shirgar | N27°24.176'E82°03.405' | Sugarcane |
| Rehra Bazar | N27°10.866'E82°16.547' | Orchard |
| Raipur | N27°18.328'E81°42.281' | Rice-Wheat |
| Tilka | N27°12.201'E81°42.285' | Rice-Wheat |
| Saraikhas | N27°12.316'E81°42.265' | Sugarcane |
| Duda | N27°06.317'E81°35.254' | Sugarcane |
| Gogia | N27°06.113'E81°49.162' | Sugarcane |
| Pandeychaura | N27°06.317'E81°42.208' | Sugarcane |
| Dulhapur | N27°06.084'E81°56.047' | Sugarcane |
| Dehras | N27°0.123'E81°49.028' | Rice-Wheat |
| Udwatpur | N27°0.010'E81°55.866' | Rice-Wheat |
| Mohammadpur | N26°53.923'E81°48.970' | Rice-Wheat |
| Bahadurkhas | N26°47.992'E81°55.604' | Rice-Wheat |
| Charsadi | N27°01.061'E81°41.975' | Sugarcane |
| Sonbezar | N26°59.950'E82°02.994' | Rice-Wheat |
| Bhopatpur | N26°53.753'E82°02.936' | Rice-Wheat |
| Ramaipur | N26°59.793'E82°10.047' | Sugarcane |
| Chaubepur | N26°53.608'E82°09.931' | Sugarcane |
| Daulatpur | N27°05.528'E82°31.229' | Sugarcane |
| Margupur | N26°53.811'E81°55.749' | Rice-Wheat |
| Manipurgrint | N26°59.677'E82°16.914' | Rice-Wheat |

RESULTS AND DISCUSSION

Physico-Chemical properties of cultivated soil: Mean bulk density of the collected soil samples of Gonda district was 1.30 Mg m⁻³. The calculated mean value of water holding capacity (WHC) of cultivated soils was 37.31 percent. The average values of sand, silt and clay content observed 66.21, 10.78 and 22.98 percent respectively. The pH and electrical conductivity (EC) of the soil recorded 6.84 and 0.15 dSm⁻¹, respectively. The pH of the soils of Gonda district was mostly

**Fig. 1.** Location map of the study area

neutral (57%) to acidic range (28.5%), only 14.3% was mildly alkaline in reaction due to different physiography of the locations. The category of the soils of *tarai* region with respect to electrical conductivity (total soluble salts) is normal, as the EC of all the soils are below 1.0 dSm⁻¹. Average organic carbon content in cereal, sugarcane, fruits and vegetable cultivated soils of Gonda district was 7.08 g kg⁻¹. On an average, all the soil samples are content medium category of organic carbon. Thus, organic matter content in Gonda district in *tarai* region of Uttar Pradesh was comparatively medium to high. Cation exchange capacity (CEC) of the soils obtained 42.50 cmol (p⁺) kg⁻¹. The soils with very high CEC (greater than 40) was invariably rich in organic matter

Chemical composition of ground water: The ground water falls in alkaline range with mean pH of 8.57. The electrical conductivity of the ground water of Gonda district was 0.46 dSm⁻¹. In view of the quality of ground water, the water under study was good quality for drinking purpose, as pH is within the range of 6.5 to 9.2 and EC in ground water also below 2 dSm⁻¹. The CO₃²⁻, HCO₃⁻, Cl⁻, NO₃⁻, SO₄²⁻, PO₄²⁻, Ca²⁺, Mg²⁺, Na⁺, K⁺ and NH₄⁺ were present in all the ground water samples in each location except CO₃²⁻. The anions in ground water were 1.65 meL⁻¹ of CO₃²⁻, 10.71 meL⁻¹ of HCO₃⁻, 1.35 meL⁻¹ of Cl⁻, 0.30 meL⁻¹ of SO₄²⁻, 0.12 meL⁻¹ of NO₃⁻, and 0.003 meL⁻¹ of PO₄³⁻. The order of mean acidic anions in drinking water was as follows in order of Cl⁻ > SO₄²⁻ > NO₃⁻ > PO₄³⁻, whereas the order of basic anions was HCO₃⁻ > CO₃²⁻. High amount of HCO₃⁻ and

Table 2. Physico-chemical properties of the soils of Gonda district

| Parameters | Unit | Mean±SD |
|----------------|--|-------------|
| Bulk density | Mg m ³ | 1.30±0.06 |
| WHC | % | 37.31±3.87 |
| Sand | % | 66.21±6.51 |
| Silt | % | 10.78±4.07 |
| Clay | % | 22.98±3.99 |
| pH | – | 6.84±0.66 |
| EC | dSm ⁻¹ | 0.15±0.04 |
| Organic carbon | g kg ⁻¹ | 7.08±1.36 |
| CEC | [cmol (p ⁺) kg ⁻¹] | 42.50±16.79 |

Table 3. Electrochemical properties of the ground waters of Gonda district

| Parameters | Unit | Mean±SD | WHO limit |
|------------|-------------------|-----------|-----------|
| pH | – | 8.57±0.39 | 6.5-9.2 |
| EC | dSm ⁻¹ | 0.46±0.16 | – |

CO₃²⁻ in ground water enhanced the pH of the water (mean pH 8.5). The Ca²⁺ and Mg²⁺ in the ground water were 1.40 me L⁻¹ and 3.33 me L⁻¹, respectively. Thus, Mg²⁺ concentration was comparatively higher than Ca²⁺. The Na⁺ in ground water was estimated as 0.48 me L⁻¹ and K⁺ was 0.21 me L⁻¹. The order of mean alkali metals content in drinking water were Mg²⁺ > Ca²⁺ > Na⁺ > K⁺. The NH₄⁺ was recorded 0.006 me L⁻¹. Considering the permissible limit of different electrochemical parameters (pH, EC), anionic and cationic concentrations in the ground water of Gonda district, all the parameters *viz.* pH, EC, Cl⁻, SO₄²⁻, NO₃⁻, PO₄³⁻, Ca²⁺, Mg²⁺, Na⁺, K⁺, and NH₄⁺ were within the desirable limit of WHO (2008) for drinking purpose, except HCO₃⁻ and CO₃²⁻ ions concentration. Alkalinity in drinking water (mean pH 8.5) was due to presence of bicarbonates, carbonates or hydroxides (Kumar and Puri, 2012).

Iodine content in soils and ground water: The mean content of hot water extractable iodine in the soils of 35 different locations of Gonda district was estimated as 3.33 mg kg⁻¹ with wide range of iodine content in the soils. Its content in the surface soil of Patnagar, Bilaspur, Kaladungi and Varanasi earlier documented in range of 3.65–7.54, 5.45–9.82, 4.23–8.08 and 1.14–2.54 mg kg⁻¹, respectively (Singh *et al.*, 2002; Nath *et al.*, 2010). As the district Gonda is the part of north-eastern *tarai* areas of Uttar Pradesh and situated far away from sea/ocean, maximum part of soil mineral iodine is lost away towards the sea through run-off and the possibility of iodine deposition through precipitation is negligible. Thus, it is expected that plant available iodine content in this region would not be sufficient for accumulation in the edible part of

Table 4. Ionic concentration in the ground waters of Gonda district

| Parameters (meL ⁻¹) | Mean±SD | WHO limit |
|---------------------------------|-------------|-----------|
| CO ₃ ²⁻ | 1.65±1.32 | 2.50 |
| HCO ₃ ⁻ | 10.71±7.20 | 5.55 |
| Cl ⁻ | 1.35±0.35 | 7.00 |
| NO ₃ ⁻ | 0.12±0.27 | 0.72 |
| SO ₄ ²⁻ | 0.30±0.17 | 5.20 |
| PO ₄ ³⁻ | 0.003±0.001 | – |
| Ca ²⁺ | 1.40±0.71 | 10.0 |
| Mg ²⁺ | 3.33±1.23 | 10.2 |
| Na ⁺ | 0.48±0.28 | 8.70 |
| K ⁺ | 0.21±0.01 | 0.30 |
| NH ₄ ⁺ | 0.006±0.014 | 0.01 |

Table 5. Iodine and selenium content of Gonda district

| Parameters | Mean±SD |
|---|-------------|
| Hot water extractable iodine in soil(mg kg ⁻¹) | 3.33±0.61 |
| Hot water extractable selenium in soil (mg kg ⁻¹) | 0.109±0.053 |
| Iodine in ground water's (µg L ⁻¹) | 15.52±6.64 |
| Selenium in ground water's (µg L ⁻¹) | 35.26±12.35 |

the crop. The iodine content in ground water was 15.52 µg L⁻¹. Iodine concentrations in ground water largely lie in the range of 0.01–70 µg L⁻¹ depending on the geographical location, local geology and soils. The principal sources of iodine in ground water are aquifers, soils and the atmosphere. Iodine deficiency (goiter prevalence) has often been noted in people inhabiting limestone areas. In such areas iodine deficiency may also be induced by fixation of iodine by calcium in the soils, yielding low concentrations in ground water and decreased efficiency of uptake by plants. Deficiency in dietary iodine can lead to a number of iodine deficiency disorders (IDD) in humans. But no regulations or recommendations are placed on concentrations of iodine in drinking water; even there is no WHO guideline value for iodine content in potable ground water. Thus, considering critical iodine concentration in drinking water as 10 µg L⁻¹ as in the case of Sri Lanka, 20% tested ground water samples are found below critical limit prone to the incidence of IDD, particularly goitre.

Selenium content in soils and ground water: The mean content of hot water extractable selenium in the soils was estimated as 0.109 mg kg⁻¹. Browsing of all the data on hot water extractable selenium in soils of different locations of Gonda district, revealed that Se content in soil was below the world average value *i.e.* 0.4 mg kg⁻¹. Similar results were obtained by Yadav *et al.* (2005) in Indian different states, *viz.*

Himachal Pradesh (0.274-0.343 mg kg⁻¹), Rajasthan (0.503-0.516 mg kg⁻¹), Punjab (0.224-0.288 mg kg⁻¹) and Haryana (0.207-0.552 mg kg⁻¹). Further, in nearly 60% study areas of Gonda district, Se content in soil was below 0.1 mg kg⁻¹. Thus, the low content of Se in soils would be risk of selenium deficiency disease (Ermakov and Jovanovic, 2010) and the negative health effects are the serious concern in Gonda district. Selenium naturally enters the food chain through water. The selenium content in ground water of Gonda district was 35.26 µg L⁻¹ within the limit of WHO (35.2 µg L⁻¹).

CONCLUSION

The soil reaction (pH) of the soils vary from slightly acidic to mildly alkaline and medium to high soil organic carbon. Considering the permissible limit of different chemical parameters of ground water of Gonda district, were within the desirable limit of WHO for drinking purpose, except HCO₃⁻ and CO₃²⁻ ions concentrations. In comparison to the other parts of the world as well as of India, I and Se content (hot water extractable) in this *tarai* region are low. The selenium content in the drinking water of Gonda district found optimum level. While, 20% tested ground water samples in Gonda district were found below the critical limit, i.e. prone to the incidence of IDD, particularly goitre.

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Spatio-Temporal Analysis of Habitat Change in and Around Lala Bustard Sanctuary-Gujarat, India

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Abstract: Lala Bustard Sanctuary is a pristine patch of grassland that is one of the few remaining habitats of the critically endangered Great Indian Bustard (*Ardeotis nigriceps*) of Kachchh District in Gujarat state of India. The sanctuary covers a protected area of about 2 sq. kms. and is one of the smallest sanctuary in the country. A series of factors such as expanding agricultural landscapes, unplanned installation of windmills/power grids, industrialization, and other construction activities in the surrounding regions endanger this fragile ecosystem in recent times. The anthropogenic infringement in the fragile landscape has been a death knell for the species and the ecosystem. Quantifying these changes in the habitat and surrounding areas, and understanding them in context of such threats can help the stakeholders to plan out effective management strategies for effective conservation of the species. The current study used satellite images for approx 30 year period to assess the land use land cover changes on a spatio-temporal scale using maximum likelihood classification on data procured from coarse resolution sensors. Our study reveals that there was a significant increase in all the land use classes except barren land which are generally common land property resource and are inter converted by anthropogenic interferences. However, constant threat of installation of new power grids, windmills or electric lines loom large over the landscape. This requires cooperation between different government departments as well as stringent monitoring. Availability of water, improving grassland integrity, and isolation from human activities will be the key factors require for comprehensive habitat restoration of the species. Strict monitoring and seasonal assessment of the grassland is of utmost importance for sustainable conservation of bustard populations in the sanctuary. A time-specific management plan is required for phase wise restoration of the grassland to increase the habitat of the bustards as well as decrease the varied anthropogenic pressures that threaten the existence of the species.

Keywords: Great Indian Bustard, Lala Bustard Sanctuary, Kachchh, Spatio-temporal changes, Land use land cover, Anthropogenic infringement

Grasslands are one of the world's most extensive terrestrial ecosystems (Ali *et al.*, 2016). It is considered as a playground for crucial interplay of complex ecological interactions. The unique grassland ecosystem is critical for survival of primary trophic levels of ecosystem and plays an important role in conservation and management of wildlife. These habitats are widely studied for various issues, including biodiversity, biomass assessment, and carrying capacity among other factors (Lele *et al.*, 2015). The loss of biodiversity in grasslands and semi-deserts is many times more than that of the forested areas due to the change in the land use practices. Hence, grasslands and semi-deserts with a number of threatened species are rapidly disappearing ecosystems (Bawa *et al.*, 2004). Out of 25 species of bustards found globally, four inhabit the Indian subcontinent viz. the Great Indian Bustard (*Ardeotis nigriceps*), the Lesser Florican (*Sypheotides indica*), the Bengal Florican (*Houbaropsis bengalensis*) and the Houbara Bustard (*Chlamydotis undulate*) & are majorly found in grassland

habitats of India. The Great Indian Bustard (GIB) was once widespread on the Kathiawar Peninsula spanning the Saurashtra and Kachchh districts and was also found in all areas except the Gir National Park, Girnar and the Barda hills (Dharmakumarsinhji, 1957). Bustards are cryptic and vagile bird species occupying large landscapes without distinct boundaries that make complete enumeration of population impractical and unreliable. Estimation of their population status requires robust sampling techniques that are replicable, not biased by imperfect detection, and allow statistical extrapolation of estimates to non-sampled areas (Dutta *et al.*, 2014). However, at the beginning of 21st century a population of mere 25-30 GIBs was recorded in the Kachchh district, Gujarat (Singh, 2001). Due to hunting, overgrazing, energy and irrigation projects, agricultural intensification and human interference, the spread of GIB reduced to 10% of its former range. The total population was estimated to be around 1,260 individuals in 1969 (Dharmakumarsinhji, 1971) which reduced drastically to 745

by 1978 (Dharmakumarsinhji, 1978) and 600 by 2001 (Birdlife International, 2001). The census repeated in 2008 set the count to about 300 individuals (Rahmani, 2006); following this, in 2011 the International Union for Conservation of Nature (IUCN) declared the GIB as '*critically endangered*' species (IUCN 2017). In 2014 a survey of the Thar Desert, Rajasthan, estimated the species was present at a density of 0.61 ± 0.36 individuals/100 km², yielding abundance estimates of 103 ± 62 in the sampled area (16.9 km²) and 155 ± 94 individuals in the Thar landscape (25,488 km²). During the survey, 38 individuals were detected (Dutta *et al.*, 2014). The bird species is endemic to Indian subcontinent and has been categorized as a Schedule 1 animal (highest protection status) under India's Wildlife Protection Act (1972) and is listed as '*endangered*' on Appendix I of the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES). The current study is a spatio-temporal analysis of the land use land cover changes in and around the Lala Bustard Sanctuary with the application of geospatial techniques to investigate the status condition of habitats of the Great Indian Bustard population.

MATERIAL AND METHODS

Study area: Kachchh Great Indian Bustard Sanctuary, also known as Lala Bustard Sanctuary is located near Jakhau village in *Naliya taluka*, Kachchh District, Gujarat, India. It is one of the smallest Indian sanctuary covers an area of about 2.03 km². It is located between 23°11'22"N to 23°11'26"N latitude and 68°43'39"E to 68°44'33"E longitude near *Abdasa (Naliya) taluka* of Kachchh. It also encompasses the forest area of *Jakhau* and *Budia* villages. The location map is shown in (Figure 1a and 1b). The study area was differentiated into six different Land-use/cover classes such as Agriculture, Barren land, Forest, Grassland, Saline Soil and Water. Three cropping seasons were observed in the study area, namely Kharif (June/July to September/October), Rabi (November/December to February/March) and Zaid (April-May) for study purpose and clarification of area in all seasons. Non-agricultural degraded land that was deteriorating for the lack of water and appropriate soil management was classified as Barren Land.

The sanctuary is bounded on the north by the *Jakhau* creeks along the coast of Kachchh; this area is particularly rich in water fowls and large flocks. On the southern and western sides, the sanctuary joins with the Gulf of Kachchh while the agriculture fields are on the eastern side. A buffer zone of 10 km diameter around the core sanctuary area was included since GIB uses the countryside area surrounding the sanctuary as well (Fig. 1b).

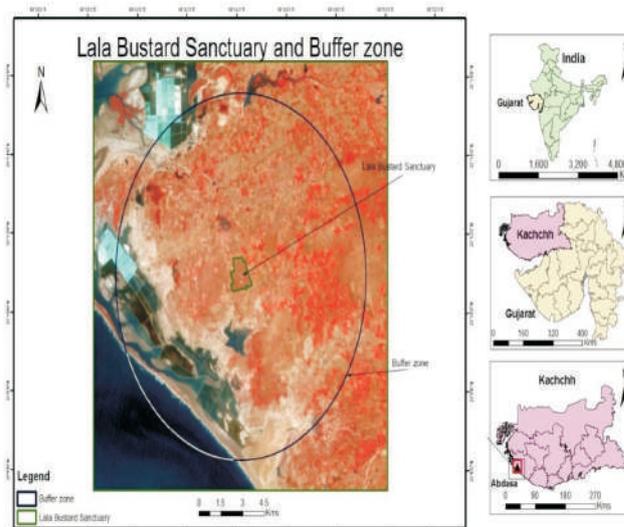


Fig. 1. Study area map: the Lala Bustard Sanctuary and Buffer zone (10kms)

Methodology: Four types of satellite sensor images used in the study are LANDSAT 5 TM (1989), LANDSAT 7 ETM+ (1999), RESOURCESAT-1 LISS III (2009) and LANDSAT-8 Thermal Infrared Sensor (TIRS) (2016) (Table 1). The LANDSAT images were acquired from the Global Land Cover Facility (GLCF; <http://www.glcg.org>) through Earth Science Data Interface (ESDI) & earth explorer platform and Resourcesat-1 data was acquired from Bhuvan platform of ISRO (<http://bhuvannoeda.nrsc.gov.in>). Prior to analysis the satellite images were processed in order to enhance the efficiency, harmonize data and reduce noise (Jensen, 1996).

Table 1. Details of the satellite imageries procured for classification

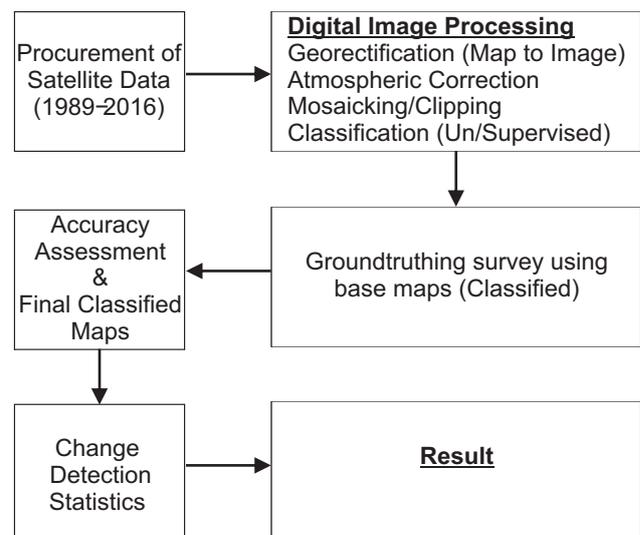
| Satellite | Year | Month | Sensor | Bands | Pixel resolution |
|-----------|------|------------------|------------------|-------|--|
| Landsat-5 | 1989 | October/November | Landsat-5 (TM) | 7 | 30m |
| Landsat-7 | 1999 | October | Landsat-7 (ETM+) | 7 | 30m |
| IRS-1D | 2009 | October | LISS-III | 3 | 30m (recoded) (original resolution: 23.5m) |
| Landsat-8 | 2016 | October | Landsat-8 (TIRS) | 7 | 30m |

Data was procured from three platforms, and map to image geo-rectification was made with the help of toposheets of particular area having a scale of 1:50000 with image processing software ERDAS 9.3. We brought these under Universal Transverse Mercator (UTM) projection with spheroid and datum named WGS-84 in UTM Zone 42 North. After geo-referencing all images, layer stacking operation was done in ERDAS Imagine 9.3 with various useful bands of different imageries. The satellite images were stacked to produce a multi-spectral (MSS) image from each of the spectral bands provided per image. Unfortunately, few images did not cover the entire study area as one image, so adjacent images of different dates were stacked independently and merged to cover the study area by mosaic operation. To avoid seasonal variations and enable unbiased comparison of changes in habitat types, we took each dataset from the same time/month of year just after the monsoon. The post monsoon data was considered because it would give the exact idea of land use land cover changes in the area and all the classes could be covered for better understanding of the landscape of particular species. As GIB is predominantly a grassland bird, we should know all the classes covered or occupied of earth surface of its landscape. The images were then clipped or subset and buffer to represent only the study areas by using the vector file of study area and were subsequently used for visual interpretation and classification purpose.

Supervised Classification (Maximum Likelihood Classifier) was carried out for the four independent images which is the established technique to deal for better classification with collected training samples from the ground with further change detection (Singh 1989, Krishnakumar P., 2011). Visual interpretation of the images was done by selecting reference training areas (for the supervised classification) to understand the features of the different land-use patterns. Differences were revealed by comparing image values of the Landsat 1989 data set with those of the corresponding layers of the other data sets, Landsat (1999), IRS (2009) & Landsat (2016). The final images reveal the changes that have occurred over 27 years in Lala Bustard Sanctuary and surrounding area (Table 3 and Figure 4). Primary and secondary training samples were collected from

the field and were input into the system for Maximum Likelihood Supervised Classification (Asmala, 2012) for the year 1989, 1999, 2009 as well as 2016 to get better classification outputs (Figure 4). Maximum Likelihood is a technique for which a fixed set of data and underlying statistical model, the method of maximum likelihood selects values of the model parameters that produce a distribution that gives the observed data the greatest probability (i.e., parameters that maximize the likelihood function) (Mehta *et al.* 2012). In comparison to other techniques dealing with supervised classification, maximum likelihood classification is more efficient for this particular objective. Accuracy assessment was done by ERDAS Imagine software to get accurate result of ground truthing data of particular study with the help of previously classified imageries.

Accuracy Assessment: The accuracy of the classification and the output of land cover mapping were assessed using representative samples taken during field observations and groundtruthing of the current year data. For every class we had collected at least 8–10 samples or training class from the field for 2016. Secondary data were also collected from the local sources for the past years on the seasonal variations

**Fig. 2.** Flowchart showing approach to data analysis for the 30 year period

base. Garmin e-Trex 10 was used to collect GCP (Ground Control Points) from the field and imported into the satellite imageries for accuracy assessment purpose to compare Producer and User's accuracy in ERDAS Imagine 9.3 software. For the 1989-99 data The accuracy statistics provides objective information about the quality of the LULC classification and are shown in (Table 2).

The overall accuracy and the Kappa value of field data versus automated classification results were 87.18% and 0.8211 for 1989; 86.00% and 0.821 for 1999; 87.50% and 0.8408 for year 2009; 91.89% and 0.8980 for the year 2016. The accuracy level of each true LC category is indicated (Table 2).

After accuracy assessment, the classified images were subjected to the change detection process with PCA (Principal Component Analysis) technique to quantify the change that had occurred over the 27-year period. Change detection can be used by so many techniques like Difference Image, PCA, Classification comparison and change vector analysis (Mehta *et al.*2012). We have used here Principal Component Analysis technique to make it simple and accurate result.

RESULTS AND DISCUSSION

The analysis undertaken in this study has shown that during the period within 1989 to 1999 grassland area has increased around 25 Km² and water area has also decreased by 21 Km² respectively, whereas between 1999 and 2009 grassland area has decreased by 22.15 Km² and water areas have increased by 16.46 Km² respectively. Overall grassland (14% of total area-2016) have marginally increased in more than two decades and water area (22% of total area-2016) have also increased during the latest decade (Table 3 and Figure 3) and this increase in breeding area, food and water availability may have led to the increase in the population of GIB in past years which may be one of the reason in inclining population from the land cover point of view. The agricultural

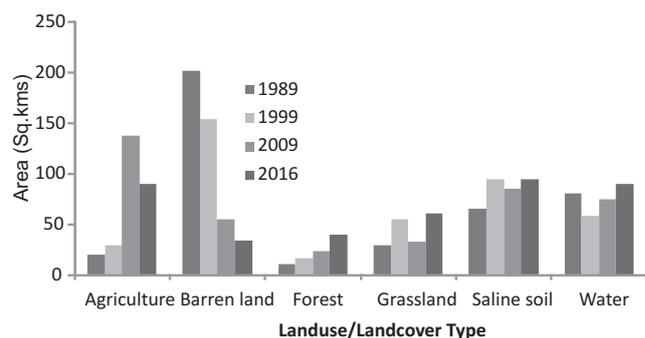


Fig. 3. Graphical representation of time series analysis

area and saline soil area have increased considerably over the last two decades in comparison to 1989. This study clearly identifies that grassland has doubled its potential due to continuous efforts of Forest Department and barren land have decreased in much larger extent respectively between 1989 and 2016. The increase in area of grassland and the steep increase in agriculture may help to explain the habitat changes for the survival of the populations of Great Indian Bustard surrounding these areas. But there are other several anthropogenic factors which can also count in for their declining population and one cannot ignore about them even though supporting land cover changes is in favor. In some sanctuaries, for example *Ghatigaon*, the Great Indian Bustard population might be lost within 2 or 3 years unless urgent action is taken. They have already disappeared from *Karera*, *Sorsan* and *Rannibennur* reserves (Rahmani, 2006). In the case of the *Gaga* Sanctuary the local people from surrounding villages depend on the area for grazing of their livestock. It is thought that the disappearance of the Great Indian Bustard here by 2010 was due to changes in habitat (Dutta, 2010; Munjpara, 2011). The principle factors are the invasion of *Prosopis juliflora* in the sanctuary area and overgrazing. This has lead to serious decline in the number of indigenous species in the grassland area which in turn contributed to the habitat degradation and decline in the

Table 2. Accuracy assessment for 1989-2016 satellite imageries

| Class | 1989 | | 1999 | | 2009 | | 2016 | |
|--------------------------|---------|---------|---------|---------|---------|---------|---------|---------|
| | PA | UA | PA | UA | PA | UA | PA | UA |
| Agriculture | 66.67% | 80.00% | 100.00% | 66.67% | 80.00% | 92.31% | 100.00% | 100.00% |
| Barren land | 94.44% | 89.47% | 87.50% | 82.35% | 100.00% | 66.67% | 100.00% | 66.67% |
| Forest | 66.67% | 100.00% | 75.00% | 85.71% | 66.67% | 66.67% | 100.00% | 100.00% |
| Grassland | 66.67% | 50.00% | 83.33% | 83.33% | 75.00% | 75.00% | 66.67% | 80.00% |
| Saline soil | 100.00% | 100.00% | 85.71% | 100.00% | 100.00% | 100.00% | 91.67% | 91.67% |
| Water | 100.00% | 100.00% | 100.00% | 100.00% | 100.00% | 100.00% | 100.00% | 100.00% |
| Overall accuracy | 87.18% | | 86.00% | | 87.50% | | 91.89% | |
| Overall Kappa Statistics | 0.8211 | | 0.8210 | | 0.8408 | | 0.8980 | |

PA =Producer's accuracy, UA = User's accuracy

Table 3. Spatio-temporal changes for the sanctuary and buffer zones combined (27 year period)

| Class (Km ²) | 1989 | 1999 | 2009 | 2016 |
|--------------------------|-------|--------|--------|-------|
| Agriculture | 19.51 | 29.04 | 137.28 | 89.71 |
| Barren land | 202.2 | 154.23 | 54.6 | 33.37 |
| Forest | 10.1 | 16.25 | 23.24 | 39.14 |
| Grassland | 29.15 | 54.61 | 32.46 | 60.62 |
| Saline soil | 66 | 94.64 | 84.73 | 95.16 |
| Water | 80.41 | 58.6 | 75.06 | 89.37 |

Analysis of images with temporal variations is very important to draw meaningful inferences (Krishnakumar, 2011). Afforestation has been highlighted as a problem at four sites used by the species: *Naliya* (Gujarat), *Nannaj* (Maharashtra), *Ranibennur* (Karnataka) and *Rollapadu* (Andhra Pradesh) (Anon. 2015). Spatio-temporal analysis of land use land cover changes is of specific importance to analyze the effects of such changes. Antagonism towards the species by local people is a major threat with local extinctions recorded (Anon. 2015).

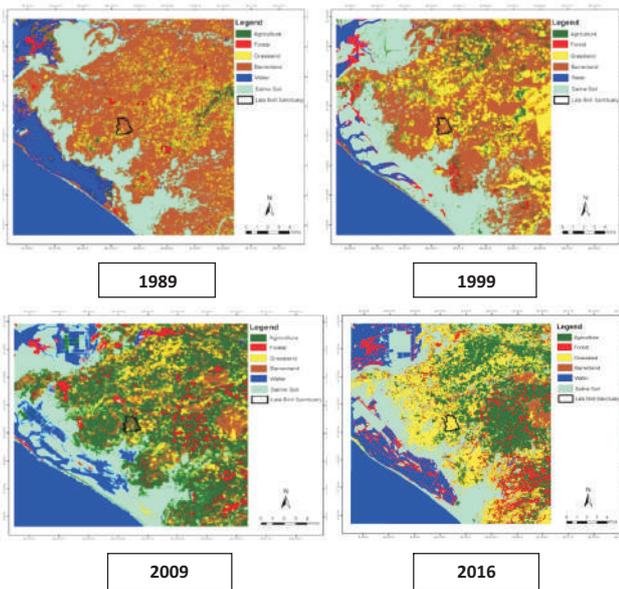


Fig. 4. Supervised classification map in and around Lala Bustard Sanctuary (1989–2016)

quality and quantity of foraging species of GIB ultimately leading to its heavy mortality and migration. Besides these causes of gradual degradation, the Lala Sanctuary and surrounding areas are facing some additional problems too such as erratic climate conditions, frequent droughts, acute water scarcity, and salinity ingress as well as the development of windmills as well as power-grids. The natural as well as anthropogenic causes when combined would have similar far reaching consequences. The present sanctuary consists of only about 202 hectares and the birds are not constrained within this but move freely in and out of the sanctuary. The identification of the areas where the males stay during the post breeding season has implications for conservation of Great Indian Bustards. Habitat requirements for the GIB are areas of grass, scrub and barren land which are particularly associated with open areas (Yedage et. al., 2011). For this reason the study encompasses areas within and around the sanctuary. Satellite data has the unique capability to detect the changes in land cover with precision.

CONCLUSIONS

The current study is an attempt to investigate variations in Great Indian Bustard population in Lala Bustard Sanctuary of Kachchh, Gujarat. Spatio-temporal analysis of a thirty year timescale reveals the fluctuations in populations correlated with land use land cover changes. Similar study is to be repeated for other sites with GIB to see if the proposed correlation between habitat change and population dynamics can be substantiated with better classification technique and high data resolution. The future change in land use land cover is to be monitored after specific time gap. For example when 2019 data becomes available or maybe we can shorten the time span of study period to see rapid changes of landscape (on yearly or seasonal basis). High resolution data could not be used in the current study as it is not freely available and financial constraints prevent us from purchasing the necessary data. The designated areas are to be protected by the forest department by declaring it as an eco-sensitive zone with good buffer range and public access to these areas should be banned. These small steps would ensure sustainability in management and long term conservation of Great Indian Bustard.

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Remediation of Heavy Metal Contaminated Soil using Different Techniques

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Abstract: Heavy metal contamination of soil by human activities has gradually increased with the development of global economy which is highly hazardous to the environment and results in its deterioration. In this study, textile effluent contaminated soil is remediated for the available heavy metals which were above their permissible limits. Various heavy metals were detected using the X-Ray Analyzer (XRF) and their level was tested with the Atomic Absorption Spectroscopy (AAS). Cr, Pb, Zn and Cu were in excess that required removal for the soil clean up. Soil washing is done with addition of varying proportions of citric, tartaric, oxalic acids and EDTA with the soil to determine the effective removal of the above heavy metals. The removal of these metals increased with increase in percentage addition of the acids used. Oxalic acid is more effective for removal of Pb, Zn and Cu whereas EDTA was more effective on Cr. Immobilization is carried out using cement and lime each with different percentage addition to determine the optimum percentage for stabilization and leaching activity, of which cement was more effective than lime. In phytoremediation technique, *Helianthus annuus*, *Brassica juncea* and *Canna indica* plants were grown to determine the metal extraction tolerability, of which *B. juncea* has higher extraction ability on Cr and Zn with percentage removal of 47% and 40% respectively whereas *C. indica* helped in greater removal of Cr as high as 48%. Physical barriers of soil-bentonite, cement-bentonite and soil-cement-bentonite were modeled to prevent the metal mobility, in which soil-cement-bentonite barrier had proved effective than the other two barriers. Earthworms were cultivated in the contaminated soil as animal remediation upto a period of 50 days and it was observed that the percentage removal of Zn, Cu, and Cr was 52, 46 and 48% respectively.

Keywords: Textile effluent, Contaminated soil, Heavy metal removal, Remediation technologies, AAS, XRF

Heavy metal contamination refers to the excessive deposition of toxic heavy metals in the soil by human activities. Many heavy metals are accumulated in the soil due to contamination which also include metals of biological toxicity, such as Mercury (Hg), Cadmium (Cd), Lead (Pb), Chromium (Cr), Arsenic (As), Zinc (Zn), Copper (Cu), etc. In recent years, with the development of the global economy, both the type and content of heavy metals in the soil have gradually increased, resulting in the deterioration of the environment and have turned highly hazardous to living organisms (Mulligan *et al.*, 2001). Heavy metal contamination of soil may pose risks and hazards to humans and the ecosystem through contact with contaminated soil, the food chain (soil-plant-human or soil-plant-animal human), consumption of contaminated ground water, reduction in food quality via phytotoxicity, reduction in land usability for agricultural and land tenure problems (Chao Su and Wen Jun Zhang, 2014). If the soil is subjected to heavy metal contamination, it is difficult to be remediated. In the past, soil contamination was not considered as important as air and water pollution, as soil contamination was difficult to be controlled and governed than the others (Raymond and Felix, 2011). However, in recent years the soil contamination in developed countries has become a serious issue and

became a concern with regard to environmental protection worldwide. The presence of toxic metals in soil can severely inhibit the biodegradation of organic contaminants. The adequate protection and restoration of soils contaminated by heavy metals require their characterization and remediation (Audrone and Saulius, 2005). Land contamination is not only harmful for the subsurface water aquifers but for also the structures existing on it. Any changes in engineering properties and behaviour of soil strata may lead to loss of bearing capacity, an increase in total or differential settlement of foundation system leading to failure of structures thereby causing loss of property and life (Arpita Patel, 2014). The objective of the present work is to determine the presence and concentration of heavy metals in the textile effluent contaminated soil and remediate the contaminated soil using different remediation techniques.

MATERIAL AND METHODS

Soil collection and preparation: The contaminated soil sample for the current study was collected from the Banks of Noyyal river, Andipalayam, Tirupur district with geographical coordinates 11.0925°N, 77.3123°E at the depth varying from 0 to 10cm. This soil was contaminated by the discharge of effluents from the textile industries. Control soil was also

collected from the nearby area which was not affected by the textile effluent.

Heavy metal detection: The collected textile effluent contaminated soil and control soil was tested for the presence of heavy metals using the X-Ray Fluorescence (XRF) Analyzer which showed positive results and detected the presence of Chromium (Cr), Lead (Pb), Zinc (Zn), Copper (Cu), Nickel (Ni), Iron (Fe), Antimony (Sb) and Tin (Sn). For more accuracy in the determination of the levels of the detected heavy metals in the soil, the collected soil sample was tested using Atomic Absorption Spectrophotometer (AAS) and the concentrations were obtained for contaminated and control soil. The harmfulness of the heavy metals can be classified based on the pollution index (Hong *et al.*, 2014). The procedure given by Lacatusu, (2000) was used to find the contamination / pollution index (MPI) of contaminated soil which is defined as metal concentration of contaminated soil / metal concentration of reference soil (Table 1). The soil sample to be tested using AAS was prepared by collecting the sample, air drying and sieving into coarse and fine fractions. Well mixed samples of 3g each were taken in 250ml glass beaker and digested with 20ml of aqua regia (1:3 of Conc. HNO₃ and dil. HCl) on a sand bath for 2 hours. After evaporation to near dryness, the samples were cooled, filtered and diluted to 100ml with distilled water (Pavithrapriya *et al.*, 2015). The heavy metal concentrations are then analyzed using AAS. After detection and brief study, it was found that Cr, Pb, Zn and Cu were beyond permissible limits and required removal (Table 2).

Heavy metal removal techniques: Several technologies exist for the remediation of metal contaminated soil such as isolation and containment, solidification/stabilization, soil washing, electrokinetics and phytoremediation (Audrone and Saulius, 2005). The techniques can be adopted both in-situ and ex-situ. Selection of the most appropriate soil remediation method depends on site characteristics, concentration, types of pollutants to be removed and the final use of contaminated medium. In the present work all the above techniques were employed to find the percentage removal of contaminants from soil.

Soil washing: Soil washing is a waste minimization treatment process done both ex-situ and in-situ. Soil washing adopted in this work refers to ex-situ technique that employs chemical procedures to extract metal contaminants from soils. Several classes of chemicals used for soil washing include surfactants, cosolvents, cyclodextrins, chelating agents, and organic acids. Acid and chelator soil washing are the two most prevalent removal methods (Raymond and Felix, 2011). The contaminated soil collected is first sieved in 2.36 mm sieve and rinsed with distilled water and left on filter

Table 1. Significance of MPI

| MPI | Significance of MPI | Remark |
|------------|---------------------------|--|
| < 0.1 | Very slight contamination | Will not pose negative effect on soil, plant, animal and environment |
| 0.10 –0.25 | Slight contamination | |
| 0.26 –0.5 | Moderate contamination | |
| 0.5 –0.75 | Severe contamination | |
| 0.76 –1.00 | Very severe contamination | Will pose negative effect on soil, plant, animal and environment |
| 1.1 –2.0 | Slight pollution | |
| 2.1 –4.0 | Moderate pollution | |
| 4.1 –8.0 | Severe pollution | |
| 8.1 –16.0 | Very severe pollution | |
| > 16.0 | Excessive pollution | |

Table 2. Detection of heavy metals in the contaminated soil

| Heavy metals detected | Concentration (ppm) | | MPI | Remarks |
|-----------------------|---------------------|----------------|-------|---------------------------|
| | Contaminated soil | Reference soil | | |
| Cr | 789 | 0 | | Requires removal |
| Pb | 1451 | 7 | 207.3 | |
| Zn | 250 | 13 | 19.2 | |
| Cu | 445 | 51 | 8.7 | |
| Ni | 73 | 72 | 1.01 | Does not requires removal |
| Fe | 22670 | 21740 | 1.04 | |
| Sb | 146 | 134 | 1.09 | |
| Sn | 91 | 85 | 1.07 | |

paper to drain out the excess water for 24 hours at room temperature and then dried in oven at 600°C for two hours (Ping Wang *et al.*, 2013). The acids and chelators used are citric acid, oxalic acid, tartaric acid and EDTA at 10 to 60% with each at 10% increment. About 250g of cleaned and dried soil sample is taken and added with the above chemicals each with respective percentages and mixed well. The sample mixed with chemicals is placed on a filter cloth with a mesh and distilled water is added to wash the sample. The chemicals are kept in contact with the soil sample for about 90 minutes which is considered as the effective contact time for soil washing (Mansour Baziar *et al.*, 2013). After washing, the soil sample is drained out for excess water and oven dried. This dried sample is tested using AAS to determine the concentration of heavy metals in the remediated soil. The same procedure is followed for all the above chemicals at each percentage addition to determine their effectiveness in removal of heavy metals.

Immobilization technique: Ex-situ and in-situ immobilization techniques are practical approaches employed in metal contaminated soils. This technique uses organic and inorganic amendments to accelerate the attenuation of metal mobility and toxicity in soils. The primary

role of immobilizing amendments is to alter the original soil metals to geochemically stable forms via sorption, precipitation and complexation (Ganjidoust and Rajabpour, 2009). The commonly applied amendments include clay, cement, minerals, lime, phosphates, zeolites, organic composts and microbes which are injected or mixed with the contaminated soil (Raymond and Felix, 2011). In this study, immobilization technique is adopted to stabilize the heavy metals and control their mobility otherwise it leads to pollution of the underneath soil and ground water. Stabilization of heavy metals and its leachate control was carried out by mixing the contaminated soil with cement and lime each at 1, 2 and 3% addition. About 5kg of contaminated soil was taken and sieved in 4.75mm sieve, washed with distilled water and dried. The dried sample is mixed with the above agents separately at their respective percentages. Seven rectangular tanks were chosen to study stabilization and leaching of heavy metals. About 10kg of the control (non contaminated) soil was also sieved, washed and dried to get rid of impurities. In each tank, the dried control soil was filled to about a depth of 6cm. One of the tanks was filled with the contaminated soil, three with contaminated soil mixed with 1, 2 and 3% of cement and the other three with contaminated soil mixed with 1, 2 and 3% of lime to a depth of 3cm above the control soil. The stabilization and leaching of heavy metals was studied for incubation period of 7, 14, 30 and 60 days (Noha Abdel-Kader *et al.*, 2013). The leachate of the metals increased with increase in incubation period (Nanthi Bolan *et al.*, 2014). Water is added at a rate of 2.1ml/sec which is determined by checking the permeability of the soil to cause leaching of heavy metals in the soil. The number of days for which water is added upto the incubation period depends on the rainfall conditions. After the required incubation period, soil sample is collected from the surface to check the removal of heavy metals using AAS which refers to the stabilization of heavy metals. For the same incubation period, soil sample is also collected from the bottom of the tank to determine the presence of heavy metals in the control soil to study the leaching of heavy metals. The collected soil samples are tested using AAS to determine the levels of various heavy metals.

Isolation and containment: Isolation and containment technique is adopted in order to prevent the mobility of the contaminants and preventing the soil from further contamination. This technique involves construction of a physical barrier in between the contaminated and the reference zone of a region (Jeff Fahrenholz, 1999). These physical barriers make the contaminants immobile but leave them in the same state without treatment. For the remediation of contaminated soil, this technique can be used

in combination with other techniques to achieve desired results (Mulligan, 2001). Physical barriers can be constructed both horizontally and vertically of various materials like steel, bentonite, soil, cement and other grouts (Audrone and Saulius, 2005). The efficiency of these materials depends on the type of contamination of the region and hence it is a site-specific technology. A comparative study was done with four models, three with different barriers and one without a barrier. The collected contaminated and reference soils were placed in tanks with / without barrier in between to study the prevention of mobility of the heavy metals with barriers. Three barriers were of cement-bentonite, soil-bentonite and cement-soil-bentonite. Cement-bentonite barrier was made with a ratio of 1:0.3 with a required water content of 55 – 70% to make a cement-bentonite slurry. In a similar manner, soil-bentonite barrier with 2% of bentonite by weight of soil and 25 – 35% of water, soil-cement-bentonite barrier with 25% cement, 2% bentonite by weight of soil with 55% of water was made. After the construction of the above barriers in model tanks, the samples were collected from the reference zone to determine the spread of contaminants to the reference zone from the contaminated zone at incubation period of 7, 14, 30 and 60 days. The samples were tested for the concentration of the heavy metals using AAS. The models were sprinkled with water of 2.1ml/sec based on the seasonal changes. The reduction in percentage transfer of heavy metals was also calculated in comparison to the metal mobility without a barrier.

Phytoremediation: Phytoremediation, also called green remediation is an emerging technology to remove contaminants from soil using different plant mechanisms (Meriem and Hassan, 2015). It is an easily adoptable in-situ remediation technique which is environment friendly and also cost effective. Various metals like Pb, Cr, As, Cd, Cu, Ni, Zn, Hg etc. can be extracted or stabilized using this technique. Plants of different species under families Brassicaceae, Fabaceae, Euphorbiaceae, Laminaceae are helpful in accumulating heavy metals (Raymond and Felix, 2011). Plant species differ in their ability to accumulate heavy metals due to various factors (Sonil and Jayanthi, 2013). They take up the metals by various mechanisms like phytoextraction, phytostabilization, phytovolatilization and rhizofiltration and accumulate them either in the shoot or root systems (Meriem and Hassan, 2015). The selection of the appropriate plants depends on soil properties, heavy metal concentration, climatic conditions and their availability. As these plants cannot be used by human and animal life after remediation, they have to be disposed off by incineration, pyrolysis or any other technique. It is mostly suitable for soils

at shallow depth (Rajendra and Abhilasha, 2014). For the present study, *Brassica juncea* (Indian mustard), *Helianthus annuus* (Sunflower) and *Canna indica* (Indian shot) were chosen based on the availability. Seeds of *B.juncea* and *H.annuus* were sown in the contaminated soil. For *C.indica*, root of the plant was used for its growth in contaminated soil. Germination was observed in seeds of *B.juncea* within five days after the seeds are sown and the plant was grown till its life span (period of 85 days). *H.annuus* plant showed germination but the seed did not continue to grow to a plant which showed that the plant did not get sufficient nutrients from the contaminated soil for its growth. *C.indica*, survived a good life in the contaminated soil. The samples were tested using AAS for the removal of heavy metals after 3 months of their growth.

Vermiremediation: Earthworms help in reducing the heavy metals by accumulating in their tissues and detoxifying them by binding and storage (Surindra *et al.*, 2014). Earthworm species such as *Eisenia fetida*, *Aporrectodea tuberculata*, *Lumbricus terrestris*, *Lumbricus rubellus*, *Eiseniella tetraedra* are reported to remove heavy metals, pesticides and other organic pollutants from the soil (Suneet Dabke,

2013). Earthworms also help in increasing the growth of microbes providing good soil aeration which also contributes to the contaminant stabilization. Previous studies showed that there is significant reduction in heavy metals concentration using earthworms. The culture of *E.fetida* was procured and cultivated in the contaminated soil. Feed in form of dry leaves and other decayed organic matter was provided and moisture was maintained in the soil for their growth. Soil samples were collected with proper mixing after 25 and 50 days to check the efficiency of heavy metal removal using AAS.

RESULTS AND DISCUSSION

Effect of soil washing: The soil washing technique adopted with organic acids and chelators proves to be good to dissolve the heavy metals in the contaminated soil and wash them out with distilled water (Fig. 1). The washed soil samples showed tremendous percentage increase in the removal of heavy metals proportional to the amount of applied chemicals (Naghipoor *et al.*, 2006). For all the selected chemicals, percentage removal of Cr was very high compared to other heavy metals and the removal efficiency

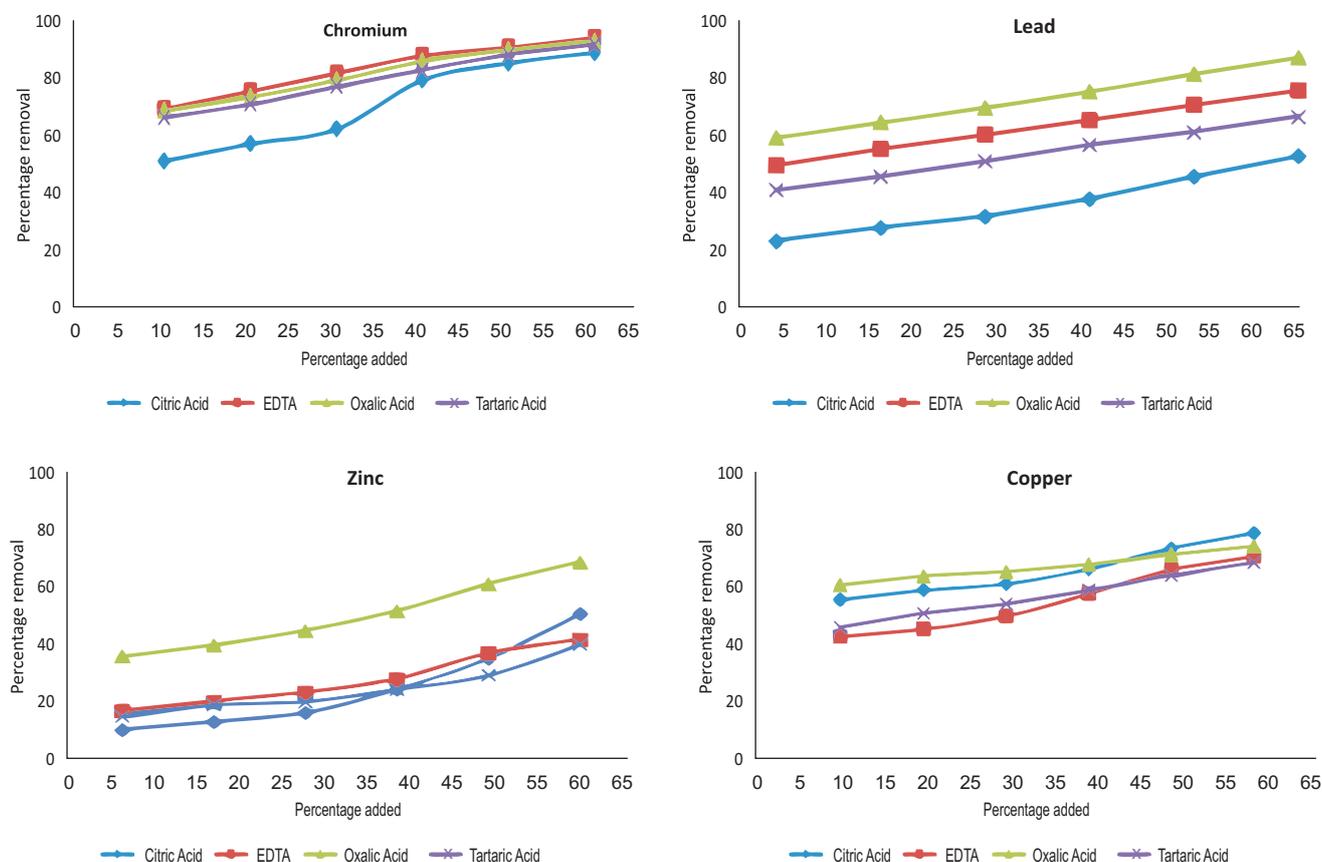


Fig. 1. Effect of soil washing on heavy metals with addition of different chemicals

at 60% addition of acids gave as close as 90% removal of Cr. Removal of Pb from soil with the use of chelating agents was 54, 77, 89 and 68% respectively for Citric acid, EDTA, Oxalic acid and Tartaric acid. Cu showed removal efficiency of 83% when citric acid is used. Zn was less reactive with all chemicals and the percentage removal of this metal was low compared to all other metals. It is also observed that each chemical has different removal efficiency on different metals.

Effect of immobilization technique on stabilization of heavy metals: The results of cement stabilization for heavy metals showed that the percentage removal is increased with increase in incubation periods (Fig. 2). Pb was stabilized upto 54% in 60 days which was achieved with 1% addition of cement. For the same percentage addition of cement, the removal efficiency of other metals Cu, Cr and Zn was 47, 44 and 20% respectively. With further increase in percentage of cement, the removal efficiency varied to a marginal level only. Lime stabilization results showed that Cr had the same effect as that of cement but the removal percentage for 60 days is comparatively lesser to that of cement (Fig. 3). Addition of lime of 2% to soil showed 50% removal of Pb at 60 days. For other metals, the removal efficiency was 44, 39 and 15% respectively for Cu, Cr and Zn. With further increase in addition of lime, the removal efficiency of all the metals were only marginal and hence it was reported that 1% cement and

2% lime by weight of soil was the optimum stabilizing agents in immobilization technique.

Effect of immobilization technique in leaching of heavy metals: In leaching study, for the same incubation period as that of the stabilization process, with the aid of cement and lime stabilizers, there is very large reduction in the percentage of contaminants with increase in incubation periods. On adding 1% cement to soil and at an incubation period of 60 days, the percentage removal of the metals was 13, 17, 16 and 23% respectively for Cr, Pb, Zn and Cu which was originally found in soils at concentrations of 43% Cr, 51% Pb, 80% Zn and 65% Cu (Fig. 4) whereas with 2% lime to soil the maximum reduction in the concentrations of Cr, Pb, Zn and Cu was observed as 16, 20, 19 and 27% respectively (Fig. 5).

Effect of isolation and containment on heavy metal mobility: The percentage transfer of the metals was about 50-60% without barrier for an observation period of 2 months. With cement-bentonite barrier, the mobility of Cr was much reduced followed by Pb. Soil-bentonite was effective on Pb than the cement-bentonite barrier whose transfer was only 19% at 60 days. Though cement-bentonite barrier was effective on Cr, Zn and Cu and the soil-bentonite barrier on Pb, the soil-cement-bentonite barrier was very effective on all the four metals due to the combined effect of soil and cement.

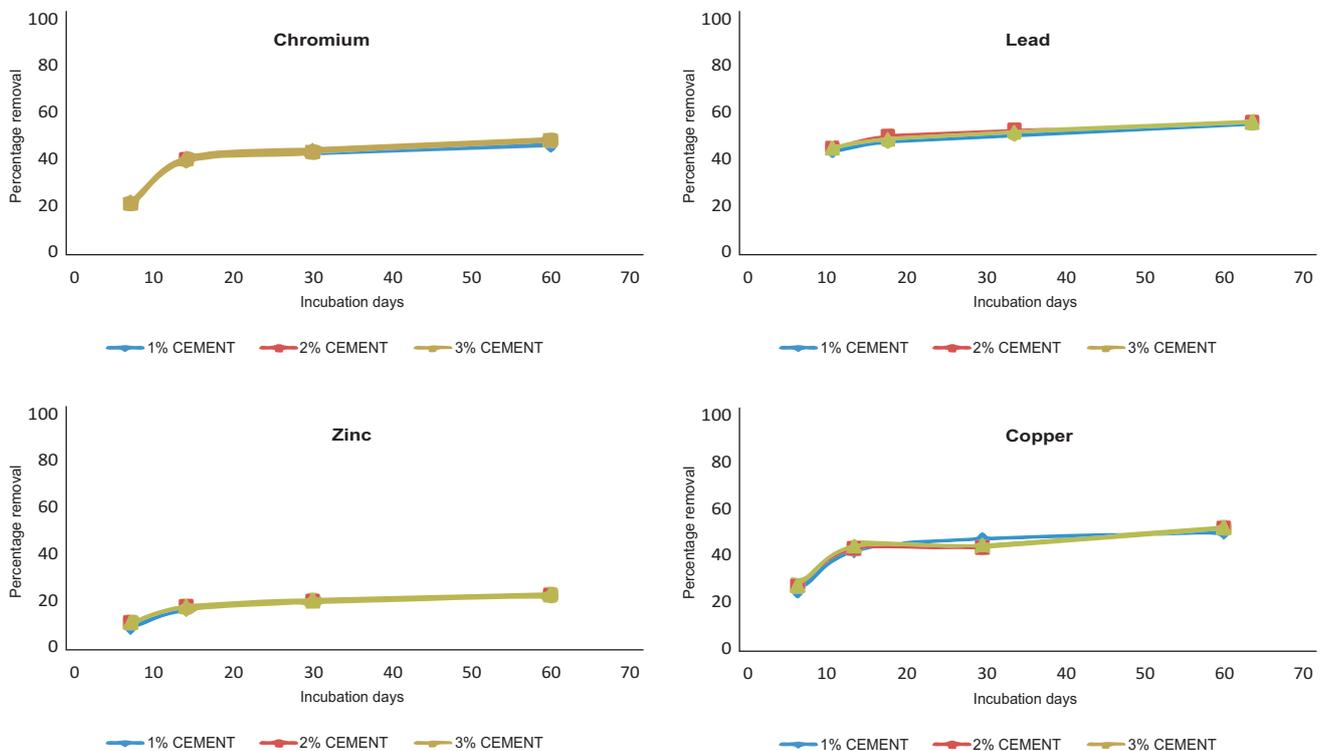


Fig. 2. Effect of cement stabilization on immobilization of heavy metals

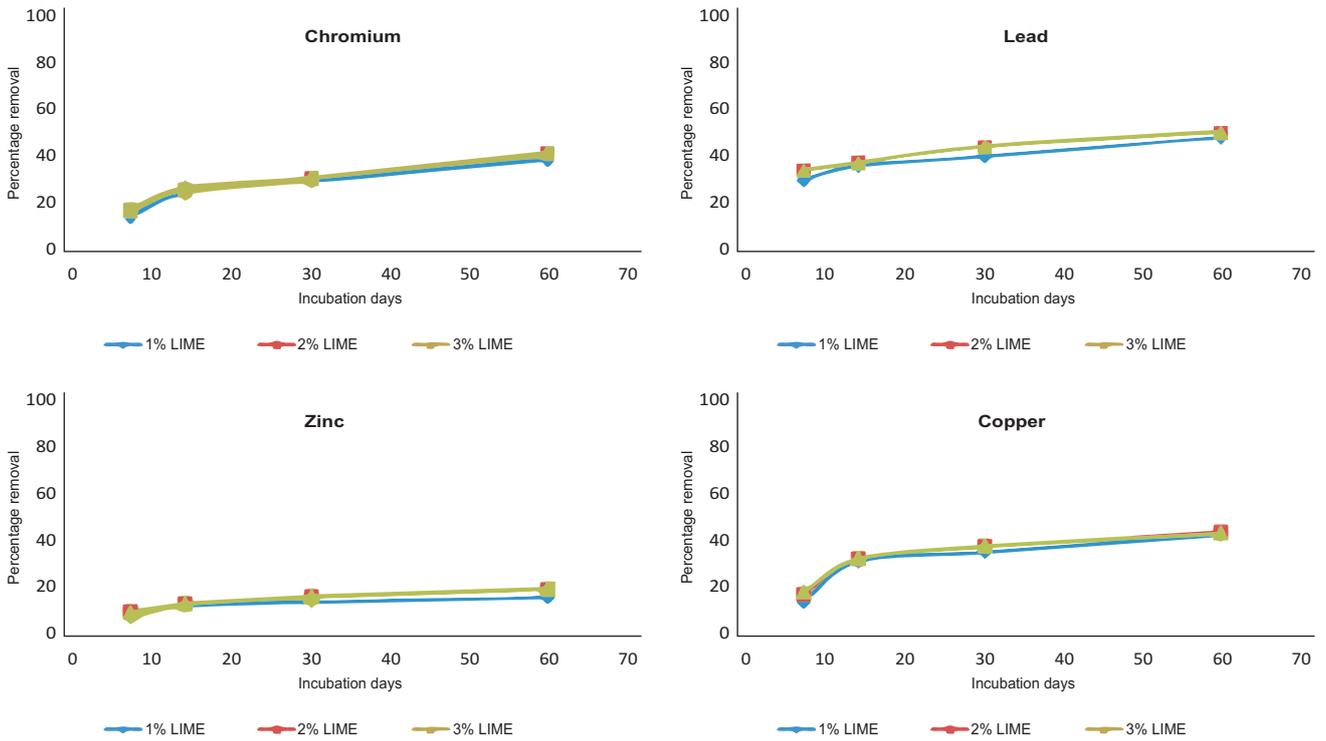


Fig. 3. Effect of lime stabilization on immobilization of heavy metals

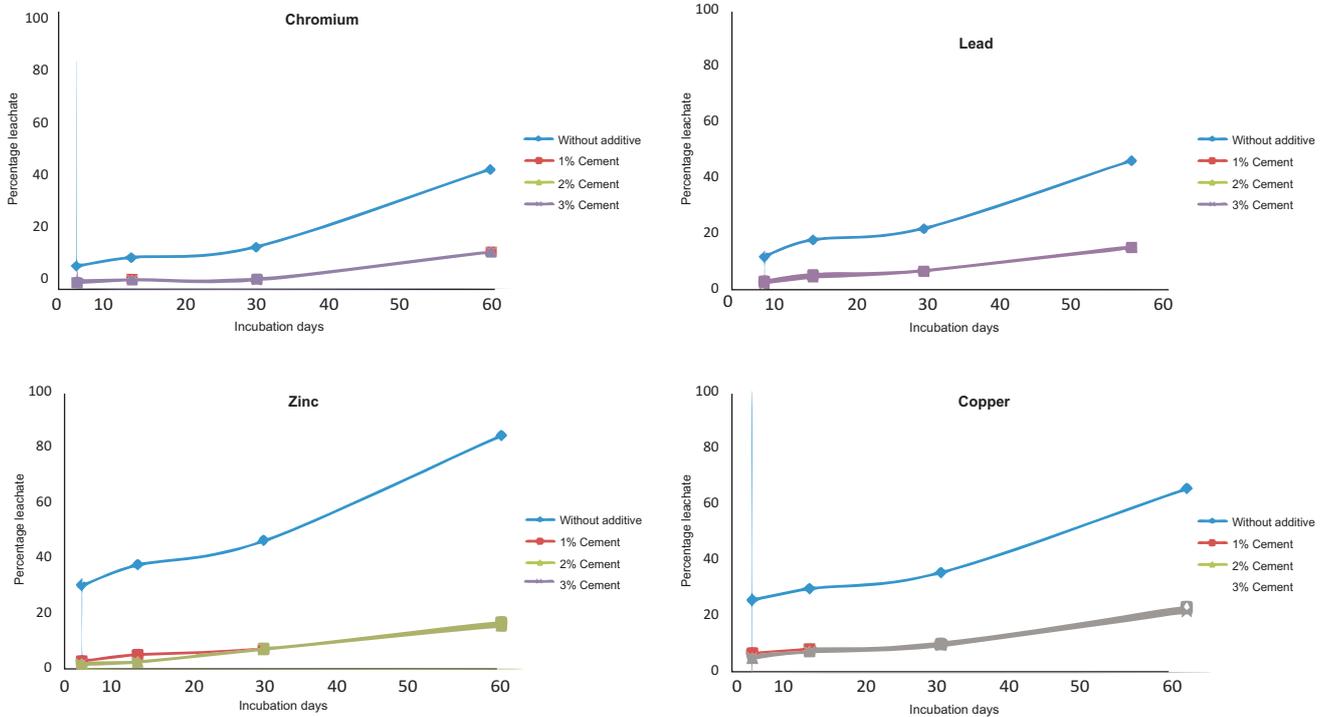


Fig. 4. Effect of cement on leaching of heavy metals

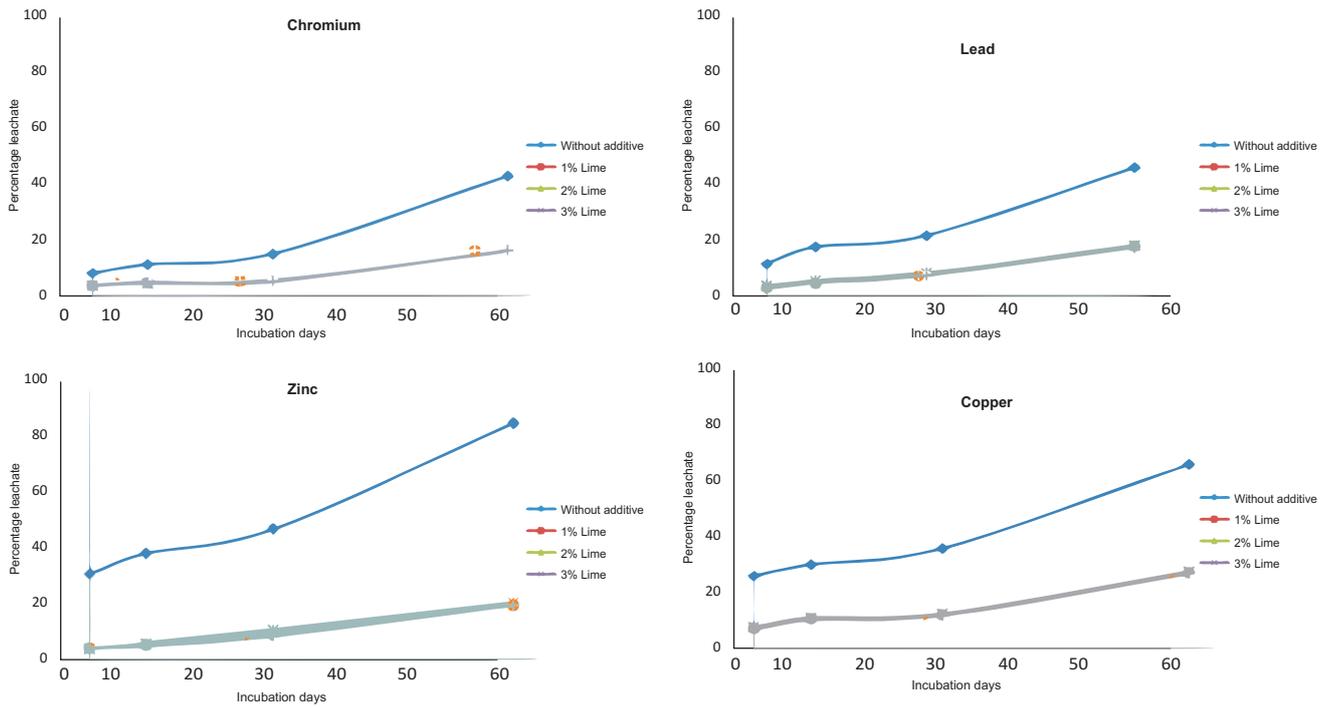


Fig. 5. Effect of lime on leaching of heavy metals

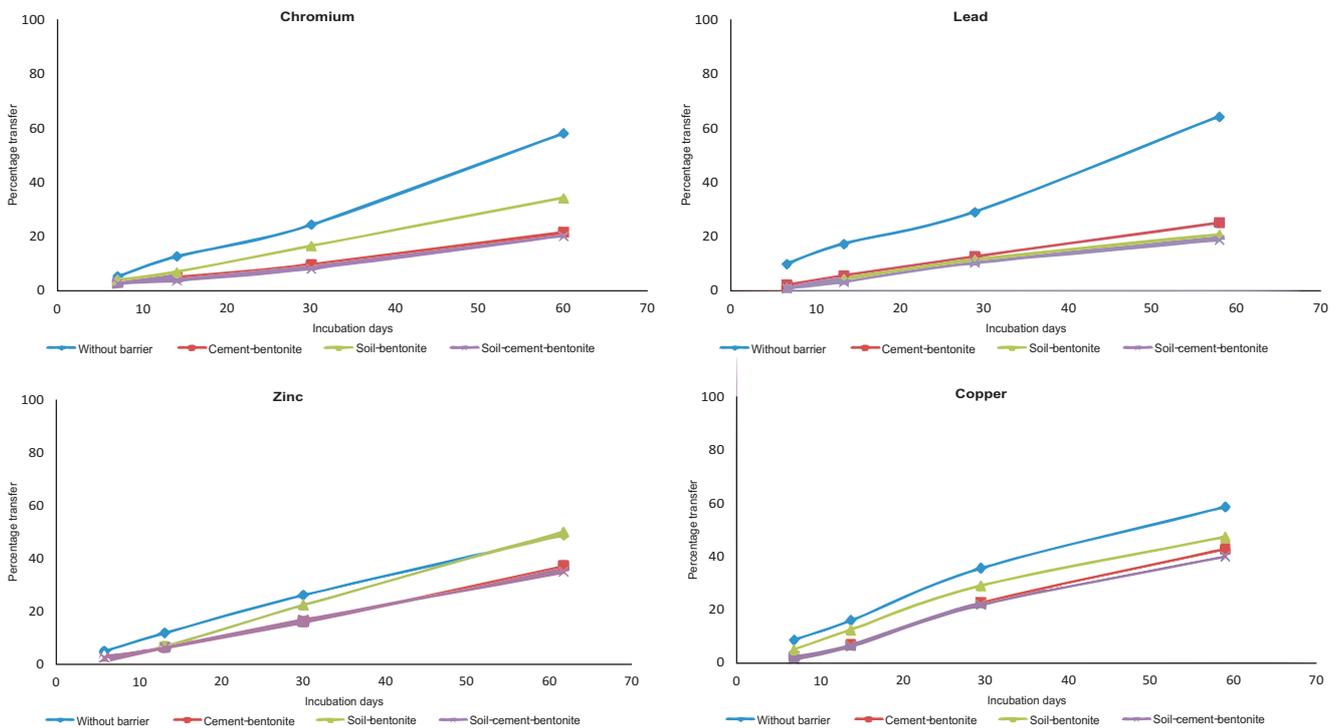


Fig. 6. Effect of isolation and containment on heavy metal mobility

The spread of heavy metals decreased to the range of 20–30% with soil-cement-bentonite barrier. This proved that the heavy metal transfer can be reduced to 50% with some cost effective barriers (Fig. 6).

Phytoremediation on heavy metal extraction: The

phytoextraction mechanism is adopted by *B.juncea* and *C.indica* in which these plants extract metals and accumulate in their shoot system. As the growth of *H.annus* was not observed, it proved inappropriate for the extraction of heavy metals. The results of phytoextraction by *B.juncea* showed

maximum reduction of Cr upto 47% whereas the removal efficiency (%) for Pb, Zn and Cu, was observed as 33, 40 and 17, respectively. The percent removal by *C.indica* was 48, 28, 21 and 9 for Cr, Cu, Zn and Pb, respectively (Fig. 7).

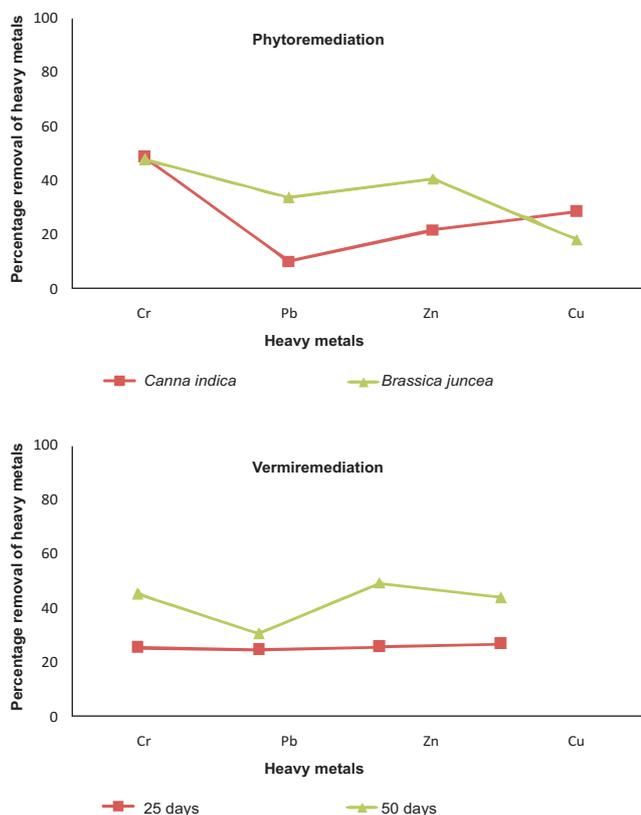


Fig. 7. Percentage removal of heavy metals by phytoremediation and vermiremediation

Vermiremediation for heavy metal removal: For Pb, a rapid loss was observed upto 25 days, after which the removal rate slowed down. In Cr, straight trend of loss was observed which were 25% and 48% removal at 25 and 50 days respectively. Zn showed a maximum loss of 52% in 50 days followed by Cr. Cu also showed its loss with 46% removal in 50 days (Fig. 7). Metal reduction in contaminated soil could be due to bio-accumulation mechanisms where the earthworms help in reducing the concentration of heavy metals by accumulating in their tissues and detoxifying them by binding and storage.

CONCLUSION

In soil washing, the removal of heavy metals increased with increase in percentages of the applied chemicals at an effective contact time of 90 minutes. Chemicals help in increasing the solubility of heavy metals in soil which are washed away with distilled water. Of the applied chemicals,

oxalic acid more effective on removal of Pb, Zn and Cu whereas EDTA was more effective on Cr compared to citric acid, EDTA, tartaric acid and oxalic acid. Soil washing can thus be used as an effective and quick method for remediation of heavy metal contaminated soil. The 1% cement and 2% lime are optimum in immobilization technique. In controlling the mobility of heavy metals, soil-cement-bentonite barrier served to be more effective than soil-bentonite and cement-bentonite barriers. *Brassica juncea* is effective in removal of Cr and Zn and *Canna indica* was effective on Cr and Cu. The plant species can be used on large scale considering appropriate factors. In vermiremediation, the concentration of all the four heavy metals greatly reduced at a treatment period of 50 days.

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Soil Quality and Heavy Metal Contamination of Soils in Mindi Industrial Area, Visakhapatnam, Andhra Pradesh, India

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Abstract: Agricultural land near to industries, often un-noticed, accumulates lot of harmful chemicals and heavy metals. A study was done to assess the soil quality (chemical and biological) near Hindustan Zinc Limited (HZL) in Mindi area, for paddy fields (major crop) and corresponding adjacent fallow area with and without exposure to effluents. Soil samples were collected from paddy growing site exposed to effluents (PGSEE), paddy growing site without exposure to effluents (PGSWE), fallow land without exposure to effluents (FWE) and fallow land exposed to effluents (FEE). Fallow fields with effluents release (FEE) were high in Cu (7.8 mg kg^{-1}), Zn (15.5 mg kg^{-1}), Pb (87.8 mg kg^{-1}) and Cd (1.8 mg kg^{-1}) in comparison to paddy cultivated fields. The chemical and biological soil quality index and relative soil quality index shows that PGSWE is having better chemical soil quality index (CSQI): 14.29, biological soil quality index (BSQI): 2.00 soil health condition than PGSEE (CSQI: 10.20 and BSQI: 0.69).

Keywords: Heavy metal, Soil Quality, Soil health, Industrial effluent

Soil is an important system of terrestrial ecosystem. There is a direct impact of pollutants on minerals, organic matter and microbial community of soil (Nagaraju *et al.*, 2007). The discharge of industrial effluents especially without treatment may have profound influence on physico-chemical and biological properties of soil related to soil fertility. Rapid industrialization and ever increasing population, there has been a substantial increase in the generation of industrial wastes leading contamination of water, air and land resources. Increased inputs of metals and synthetic chemicals in the terrestrial environment due to rapid industrialization coupled with inadequate environmental management in the developing country like India, has led to large-scale pollution of the environment (Adriano, 1995; Hooda *et al.*, 2004). Many metals such as Zn, Cu, and Se are essential elements for normal growth of plants and living organisms, however, high concentrations of these metals become toxic, other metals, which are not included in the group of essential elements, such as Pb or Cr, may be tolerated by the ecosystem in low concentration, but become harmful in higher concentrations. The availability of metal compounds in soil is influenced by the pH, temperature, redox potential, cation exchange capacity of the solid phase, competition with other metal ions, ligation by anions and composition and quality of the soil solution (Mapanda *et al.*,

2005; Skordas *et al.*, 2005)

The contamination of soils by heavy metals is a significant problem as it negatively influences soil characteristics that potentially influence productivity and food quality, and environmental quality. The fate of heavy metals in soil is controlled by the effects of various chemical, physical and biological processes and their interactions on the soil. With accumulation of heavy metals in soil beyond its holding capacity makes them available to plants growing on them, leading to contamination of food, which potentially could be a health hazard (Muchuweti *et al.*, 2006). Many field studies of metal contaminated soils have demonstrated that the elevated metal loadings can result in decreased microbial community size and decrease in activities such as organic matter mineralization and leaf litter decomposition. Industries are the major sources of soil pollution with the heavy metals Zinc (Zn) and Cadmium (Cd). Elevated levels have toxic effects on micro-organisms, which play an important role in soils.

Visakhapatnam attracted for establishment of major industries like M/s. Hindustan Petroleum Corporation Ltd., (Formerly M/s. CALTEX – Refinery), M/s. Hindustan Zinc Ltd., (Zinc & Lead Smelter), M/s. Coromandel Fertilisers Ltd., (Complex Fertiliser Plant) etc., due to close proximity to a natural harbor and sea port. Mindi area has been identified

as one of the most polluted industrial area of Vishakhapatnam; AP (A.P. Pollution Control Board, 2010). The present work was undertaken at Mindi industrial area with an objective to study the impact of industrial pollution on soil quality and heavy metal contamination to cropped field near to the industry.

MATERIAL AND METHODS

Mindi, Vishakhapatnam lies between 17° 40' 30" and 17° 40' 45" North latitude and 83° 16' 15" and 83° 21' 30" East longitude is identified as critically polluted area in Vishakhapatnam. The industries dispose wastes into soil or water which changes the chemical and biological parameters of the soils. In order to analyse soil quality (chemical and biological), thirty two soil samples were collected from three different locations (paddy growing site exposed to effluent (PGSEE) and not exposure to effluent (PGSWE), fallow lands exposed to effluents (FEE)) in Mindi area of Visakhapatnam. The composite samples were air dried, crushed lightly, and then passed through a 2-mm sieve. All subsequent analyses were performed on the <2-mm fraction using standard methods. The soil pH and electrical conductivity was measured in a 1:2.5 soil water suspension using a glass electrode and conductivity meter (Elico, India), respectively. Organic carbon was determined by wet digestion method (Walkley and Black, 1934) and cation exchange capacity by ammonium acetate method (Jackson, 1973). Available heavy metals in the soil were determined by extracting the soil with 0.01 M DTPA as described by Lindsay and Norvell (1978). Soil samples were digested in HNO₃-HClO₄ acid mixture (6:3) as described by Jackson (1973) and analysed for Cd, Cr, Ni and Pb contents with an atomic absorption spectrophotometer. Particle size distribution determined by the hydrometer method (Bouyoucos, 1962), Available nitrogen, potassium and phosphorus were estimated by Kjeldahl method, flame photometer method and Olsen method, respectively. Micronutrients like Na, Ca, Mg, Fe, Cu, Zn and Mn estimated by DTPA method. Calculation of soil microbial biomass carbon was done by Fumigation extraction method.

Soil quality: The chemical soil quality index (CSQI), biological soil quality index (BSQI) and overall soil quality index (SQI) were estimated by using linear scoring technique following 'more is better' and 'less is better' approach depending upon the importance and nature of the parameters. To assign the scores, these parameters were arranged in order depending on whether a higher value was considered "good" or "bad" in terms of soil quality and function. In case of 'more is better' indicators (pH, EC, OC, N, P, K, Ca, Mg, Carbon fractions, CEC, DHA, MBC and Mn),

each observation was divided by the highest observed value such that the highest observed value received a score of 1. For 'less is better' indicators (Na, Pb, Cr, Cd, Ni, Fe, Zn, Cu), the lowest observed value (in the numerator) was divided by each observation (in the denominator) such that the lowest observed value received a score of 1. After performing these steps, to obtain soil quality index (SQI), the soil quality indicator scores for each observation were summed up using the following relation:

$$SOI = \sum_{i=1}^n (Si)$$

Where S_i is the score for the subscripted variable based on the assumption is that higher index scores meant better soil quality or greater performance of soil function. The SQI values for chemical and biological indicators were computed separately. Finally the overall SQI were computed to understand the performance of the soil quality indicators by pooling CSQI and BSQI. For better understanding and relative comparison of the performance of treatment type/situations, the SQI values were reduced to a scale of 0-1 by dividing all the SQI values with the highest SQI value. The numerical values so obtained clearly reflect the relative performance of the management treatments, hence were termed as the relative soil quality indices (RSQI).

RESULTS AND DISCUSSION

Physico-chemical properties: The bulk density of soils varied between 1.1 to 1.09 Mg m⁻³ and was slightly higher in the cultivated land than in fallow may be because lands are under continuous paddy cultivation. Soil texture for PGSEE is mainly sandy loam while texture of PGSWE varied from sandy clay loam to clay loam while fallow lands had clay loam texture. The percentage of clay is relatively higher in PGSWE than PGSEE thus better soil health. The pH of the test soil ranged from 6.37 to 7.45. In PGSEE, the soil is slightly acidic (6.37) while in PGSWE soil is mildly alkaline (7.45). Fallow lands without exposure to effluents (FWE) and fallow lands exposed to effluents (FEE) were near to neutral. The salt content of soils, measured in terms of EC, ranged from 0.217–1.08 dS m⁻¹ (Table 1). The EC value was slightly more in cultivated area than fallow plots. Soil organic carbon was remarkably high in this area, even in fallow lands there was good amount of organic carbon build-up. The organic carbon ranged in between 0.18 to 0.46 g kg⁻¹. The area affected by industries effluent had more organic carbon because of some organic material present in the effluent. Available nitrogen was significantly low in all the sites in comparison with PGSWE. The CEC ranged from 21.38 to 31.08 cmol (p⁺) kg⁻¹. In PGSEE and FEE soils, its concentration was 22.88 and 21.38 cmol (p⁺) kg⁻¹, respectively while in soils of PGSWE and

FEW; the value was 31.08 and 29.60 $\text{cmol (p}^+) \text{ kg}^{-1}$ respectively, indicating better nutrient storage capacity of these soils. The calcium ranged in the soil between 3.66 to 9.21 cmol kg^{-1} . The soils of paddy growing site exposed to effluent (PGSEE) and FWE, recorded was 3.66 and 4.99 cmol kg^{-1} , whereas, in soils of PGSWE and FEE was 9.09 and 9.21 cmol kg^{-1} , respectively. The Magnesium ranged between 1.53 to 2.69 cmol kg^{-1} , PGSEE and FWE were 1.76 and 1.53 cmol kg^{-1} . In soils of PGSWE and FEE values were 2.69 and 2.16 cmol kg^{-1} respectively. In soils of PGSEE, the Sodium concentration was 1.71 cmol kg^{-1} , while PGSWE having high level of sodium concentrations (2.31 cmol kg^{-1}). In soils of FEW and FEE, concentration was 0.72 and 0.54 cmol kg^{-1} , respectively indicating very low levels of sodium in soil.

Biological properties: The Dehydrogenase activity is very high in soils of PGSWE followed by PGSEE showing 2.31 mg and 1.71 mg, while for fallow land, values were very low showing 0.72 mg in FWE and 0.54 mg in FEE. The SMBC values were in the range of 145.26 to 194.51 $\mu\text{g g}^{-1}$ being very high in soils of PGSWE. The SMBC value was 145.26

indicating low in soils of FEW followed by 139.46 in soils of PGSEE. This shows that effluent from industries affect the microbial population especially in agricultural fields. The lowest SMBC in the PGSEE proves how badly the effluent from industries reduces the microbial population in cultivated area nearby to industry.

Heavy metal concentration: The concentration of heavy metals (Cd, Ni, Cu, Zn, Cr, Pb and Mn) in soils varied from 1.0 to 967 mg kg^{-1} and, the values for most of the metals were within the critical limits for Indian soils. The concentration of Cr was low compared to other heavy metals and ranged from 0.03 to 0.04 mg kg^{-1} . The Fe and Cu concentration was more in PGSWE than PGSEE soils. The zinc concentration was higher (11.70 mg kg^{-1}) in PGSEE than PGSWE (11.16 mg kg^{-1}), this may be because of the effluents of zinc metal industry added to soil. Pb concentration was between 3.80 to 87.77 mg kg^{-1} . The heavy metals from the industries effluent is not showing huge accumulation in the cultivated area may be because of constant uptake by the crop. Thus, it is severely affecting the quality of crops grown in this area.

Soil quality: The chemical and biological soil quality index

Table 1. Primary properties of soils of Mindi area

| Location | pH | EC | OC | CEC | OC (%) | | | Available N | Available P | Available K |
|-------------|------|------|------|-------|-------------|--------|-------------|-------------|-------------|-------------|
| | | | | | Very labile | Labile | Less labile | | | |
| PGSEE | 6.37 | 0.46 | 0.40 | 22.88 | 0.18 | 0.11 | 0.13 | 108.71 | 16.70 | 184.46 |
| PGSWE | 7.45 | 1.08 | 0.46 | 31.08 | 0.22 | 0.28 | 0.11 | 154.71 | 24.10 | 251.63 |
| FWE | 7.41 | 0.21 | 0.18 | 29.60 | 0.10 | 0.12 | 0.05 | 39.38 | 12.48 | 179.42 |
| FEE | 7.32 | 0.33 | 0.27 | 21.38 | 0.10 | 0.09 | 0.18 | 105.92 | 18.85 | 196.94 |
| CD (p=0.05) | 0.34 | 0.15 | 0.66 | 4.32 | 0.07 | 0.07 | NS | 35.51 | 3.03 | 55.09 |

Paddy growing site exposed to effluents (PGSEE), Paddy growing site without exposure to effluents (PGSWE)
Fallow land without exposure to effluents (FWE) and Fallow land exposed to effluents (FEE)

Table 2. Secondary micronutrient and heavy metal concentration in study area

| Location | Na | Ca | Mg | Fe | Cu | Zn | Mn | Pb | Cr | Cd | Ni |
|-------------|-----------------------|------|------|---------------------|------|-------|-------|-------|------|------|------|
| | cmol kg^{-1} | | | mg kg^{-1} | | | | | | | |
| PGSEE | 1.71 | 3.66 | 1.76 | 82.79 | 3.73 | 11.70 | 4.61 | 30.17 | 0.04 | 0.37 | 0.63 |
| PGSWE | 2.31 | 9.09 | 2.69 | 88.30 | 4.90 | 11.16 | 11.04 | 46.04 | 0.04 | 0.29 | 0.86 |
| FWE | 0.72 | 4.99 | 1.53 | 6.26 | 0.89 | 2.49 | 6.57 | 3.80 | 0.04 | 0.03 | 0.20 |
| FEE | 0.54 | 9.21 | 2.16 | 7.94 | 7.85 | 15.51 | 7.09 | 87.77 | 0.03 | 1.81 | 0.03 |
| CD (p=0.05) | 1.13 | 1.18 | 0.34 | 32.04 | 1.61 | 3.54 | 3.85 | 4.52 | NS | 0.05 | 0.23 |
| Mean | 1.32 | 6.74 | 2.04 | 46.32 | 4.34 | 10.22 | 7.33 | 41.95 | 0.04 | 0.63 | 0.43 |

Table 4. Chemical and biological soil quality index and relative soil quality index

| Location | CSQI | RSQI (Chemical) | BSQI | RSQI (Biological) | Overall SQI | Overall SQI |
|----------|-------|-----------------|------|-------------------|-------------|-------------|
| PGSEE | 10.20 | 0.71 | 1.16 | 0.69 | 11.36 | 0.70 |
| PGSWE | 14.29 | 1.00 | 2.00 | 1.20 | 16.29 | 1.00 |
| FWE | 13.89 | 0.97 | 0.84 | 0.50 | 14.73 | 0.90 |
| FEE | 13.32 | 0.93 | 0.86 | 0.52 | 14.18 | 0.87 |

and relative soil quality index shows that PGSWE is better (CSQI: 14.29 and BSQI: 2.00) soil health than PGSEE (CSQI: 10.20 and BSQI: 0.69), (Table 4). This indicate that effluents from the industry are affecting the agricultural field.

Table 3. Dehydrogenase activity and microbial biomass carbon status

| Location | Soil enzymes– dehydrogenase (DHA) mg TPF 24/h/g | Soil microbial biomass carbon (SMBC) µg/g |
|---------------------------|--|--|
| Effluent effected area | 1.71 | 139.46 |
| Non-effected area | 2.31 | 194.51 |
| Fallow land-far industry | 0.72 | 145.26 |
| Fallow land-near industry | 0.54 | 160.25 |
| CD (p=0.05) | 0.99 | 17.22 |

CONCLUSION

Soil environments of the study that effluent coming out of HZL affecting indicate better nutrient storage capacity of these soils may have become polluted by a large variety of toxic compounds. Many of these compounds at high concentrations or following prolonged exposure have the potential to produce adverse effects in human and other organisms. These include the danger of acute toxicity, mutagenesis (genetic changes), carcinogenesis, and teratogenesis (birth defects) for humans and other organisms. Some of these man-made toxic compounds are also resistant to physical, chemical, or biological degradation and thus represent an environmental burden of considerable magnitude. The study area *i.e.* Mindi in Visakhapatnam is also worst affected by the industrial growth. Our investigation shows that the soil quality of both fallow and agriculture land near Hindustan Zinc limited are severely affected by the effluent coming out of the industry and require immediate attention from the people and farmers living in this

area. It was concluded from the study that effluent coming out of HZL affect nutrient storage capacity of these soils. The paddy growing site having exposure to effluent from the industry shows drastic reduction in soil quality as compared to fallow land nearby.

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Statistical Model for Profit Maximization of Homesteads in Southern Laterite Agro-Ecological Unit

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Abstract: The present study of "Statistical model for profit maximization of homesteads in southern laterite agro-ecological unit was undertaken to examine and develop statistical model for the homestead farming system and to suggest suitable farming system model that maximize farm income by the optimal use of available resources. Linear programming (LP) technique was used to develop optimum plans for the homesteads of the study area. The developed optimum model for average homestead with 27 enterprises had non-binding solution for coconut and banana and as compared to the existing model this provided 13.31 per cent increase in net return. The results of the study brought out that there was sub-optimal allocation of resources in the existing plans. The optimal plans indicated the possibilities of increasing income even under existing constraints like total area, intercropped area, investment amount and population of each enterprise. The income was increased further through increasing cropping intensity and by removing the most uneconomical and less important enterprises in the existing plan with due importance to food security. Sensitivity analysis of the optimum model revealed that enhancement of net return in agro-ecological region could be achieved by increasing the investment amount, cropping intensity in the underutilized intercropped area and changing the binding enterprises.

Keywords: Homestead farming, Optimum allocation, Optimum model, Linear programming, Sensitivity analysis

Homestead farming has been the backbone agricultural economy of Kerala, owing to its direct and indirect benefits to the social and economic well being of the state over the years, both in the micro and macro levels. John (1997) comprehensively defined homestead/ home garden as a functional/operative and self-sustaining farm unit which consists of a conglomeration of crops and multipurpose trees, planted arbitrarily, with or without animals/poultry/apiculture, owned and primarily managed by the dwelling farm family, with the objectives of satisfying the basic family needs (food, fuel, timber) and producing marketable surplus for the purchase of non-producible items. Mixed cropping, a feature of homesteads, allows for intensive forms of cultivation in small landholdings. The major crops grown in homesteads are perennials and annuals, such as coconut, areca nut, pepper, cashew, banana, and vegetables. Moreover, the share of land under homestead farming in Kerala has grown, and the share of area under garden land has declined, owing to rapid urbanization. Over the years, many small holdings have fragmented into smaller homesteads. Farmers depending on farming alone were in distress with low and fluctuating income. The only way to meet increasing demand of food, fibre and fuel for the ever increasing population is by increasing production per unit area which is possible by more scientific utilization of the

resources and their optimal allocation to achieve maximum returns (Hassan *et al.* 2015). Mathematical programming tools have been employed to model mixed farming, horticultural crops, and livestock alone, various breeds and varieties, and all sorts of combinations of different activities in homesteads. Linear Programming (LP) is one such tool applied to farm activities to determine mathematically the optimum plan for the choice and combination of farm enterprises, so as to maximize the income or minimize costs within the limits of available farm resources in present scenario, LPP is used for all sorts of decision making problems regarding production, distribution, marketing and policy decision making since it is perhaps the most important and best-studied optimization problem.

The present study is an attempt to examine and develop statistical model for the homestead farming system in the southern laterite agro-ecological units and to suggest a suitable farming system model that maximizes farm income by the optimal use of available resources.

MATERIAL AND METHODS

Three stage sampling technique was used for drawing samples for the present study. Trivandrum district was selected purposively for the present study, as it is one of the agriculturally advanced districts of Kerala. From the district

southern laterite agro-ecological units (AEU 8) was purposively selected for the study and two panchayaths with maximum number of homesteads purposively identified from selected agro-ecological unit. At the third stage 20 homesteads having similar type of cropping systems and holding size between 0.1-0.3 ha was selected at random from each of the selected panchayaths. Therefore, the total sample size for the present study was forty. The study was conducted in the year 2016-2017. The benefit-cost analysis worked out for average farm size by considering, different costs and returns incurred in cultivation of crop as well as rearing livestock and poultry. Cost of cultivation is taken into account in the case of annuals and biennials, whereas only maintenance cost is considered for perennials, livestock and poultry. Linear programming is the most widely and best understood optimization method which can effectively handle number of linear constraints and variables (activities) simultaneously. Hence, the simplex method of LP was employed to develop optimized homestead models. The simplex method involves formulation of set of inequalities subject to which an objective function is to be maximized.

Mathematical formulation of the model

$$\text{Maximize } z = \sum_{j=1}^n c_j x_j$$

$j = 1$ to n activities

Subject to following constraints,

$$\sum_{j=1}^n a_{ij} x_j \leq or = or \geq b_i$$

$x_j, b_j \geq 0$ (Non negativity constraint)

Where,

z = Objective function is to be maximized

c_j = Unit net return from j^{th} activity/ enterprise

x_j = Real number of j^{th} production activity/ enterprise to be determined

a_{ij}, b_i = Fixed real constants

With the help of above model, optimum plan (model) were developed for the farming system comprised of crops, poultry, goat and cattle and Sensitivity analysis is done to find information about what happens when net return and constraints/available resources value are changed. The constraints included in the analysis were,

Total area: The model is developed for a 0.18 ha homestead (average homestead size in AEU 8) which includes area of house and permanent structures, net cropped area and uncultivated land.

Intercropped area: The interspace accessible was assessed after excluding the area occupied by the house and permanent structures and the area occupied by the basins of coconut and other tree components.

Investment amount : All the activities are financed internally and the farmer is not dependent upon external financing in the form of credit. The third quartile value of the investment was considered while developing the model rather going for higher value of the investment by the homestead farmers of each system.

Population of each enterprise: The constraints with respect to the population of different enterprises included in the model were decided so as to meet the multiple demand of the farm family by enterprise diversification, optimize the available resources and maximize the gross returns. Modal value, the tastes and preferences of the farmer and his constraints in increasing or decreasing the population of each enterprise was considered for developing constraints on population of each enterprise. Coconut is the base crop in the model, as all homesteads are coconut-based in southern Kerala, adequate number of coconut palms maintained in the model based on farmer's preferences for this enterprise. The optimum model was developed by giving more emphasis to safe to eat vegetable cultivation by at least doubling the area under vegetable cultivation over the existing plan.

Objective Function: The role of objective function in this study was to maximize the net income from the homesteads subjected to the specified constraints in the model. The net returns were measured by deducting operative expenses from gross return. The various items of operative expenses were input cost (cost of seeds, manures, fertilizers and plant protection chemicals), labour cost (both family and hired labour) and miscellaneous expenses. Valuation of family and hired labour done at rates paid out on the villages during the period of study. In this model, the value of objective function in the optimal solution was to be maximized included the sum of the year's net returns.

RESULTS AND DISCUSSION

Selected farming system in AEU 8 comprised of crops+poultry+goat+cattle with the average homestead size of 45 cents (1800 m²). The average area under house and permanent structures was 438.69 m², with 1361.31 m² area as net cropping area. Coconut, tapioca and banana together constituted 39.74 per cent of the total cultivated area. Fruit trees/crops like jack (1), mango (3), gooseberry (1), banana (56), sapota (1), guava (1), annona (1), pineapple (30) and papaya (5) were cultivated which were sufficient enough to meet the fruit requirement of the family, in addition to generation of farm income. Tapioca was observed as the most predominant crop in the homestead (164) and other tuber crops cultivated were colocasia, amorphophallus and dioscorea. Around 46.5 m² area in the kitchen yard was employed for vegetable cultivation. Tamarind, pepper,

ginger, nutmeg, turmeric and curry leaf met spice requirement. Cashew (1), the export oriented crop was grown in the homesteads and arecanut palm (3) was noticed as the main masticatory nut. The livestock/poultry components comprised of three cattle unit, one goat and ten poultry units. The livestock system not only ensured enterprise diversification, but also augmented farm income by the sale of surplus milk and eggs. The interaction between the crop and livestock system of the model facilitated a high degree of organic recycling between the systems. The total investment worked out was ₹168905/-out of which 27.03 per cent was used to meet labour charge (both family and hired labour) and 71.57 per cent for meeting input materials cost. It is evident from the table that 73.09 per cent of the total

expenditure was used for cattle rearing which contributed 70.8 per cent of the total net income. The gross and net returns from the average homestead of S₂ were estimated as ₹341150 and ₹341150 respectively contributing a benefit: cost ratio of 2.02 (Table1).

Optimum Model for Homestead Farming System: In selected homesteads, a minimum of 15 adult bearing coconut palms was required for the farm family but the solution of LP problem with the objective of maximization of farm income was found feasible without incorporating more coconut palm, subjected to unit net income and other constraints for coconut palm, failed to give a best feasible solution. However, in view of socially acceptable nature of homesteads, LP problem formulated a solution viz;

Table 1. Economic analysis-AEU 8, average farm size of 0.18 ha

| Enterprise | Population | Input cost (₹) | Labour cost (₹) | Other expenses (₹) | Total expenditure (₹) | Gross return (₹) | Net return (₹) | B:C ratio |
|----------------|------------|----------------|-----------------|--------------------|-----------------------|------------------|----------------|-----------|
| Coconut | 17 nos. | 1108.79 | 1637.8 | 147.74 | 2894.33 | 5656.73 | 2762.4 | 1.95 |
| Jack | 1 no. | - | 352.56 | - | 352.56 | 1075.38 | 722.82 | 3.05 |
| Mango | 3 nos. | 12.6 | 727.39 | 97.99 | 837.98 | 2085.53 | 1247.55 | 2.49 |
| Gooseberry | 1 no. | - | 102.91 | 0 | 102.91 | 388.94 | 286.03 | 3.78 |
| Tamarind | 1 no. | - | 97.99 | 30.15 | 128.14 | 509.55 | 381.41 | 3.98 |
| Bread Fruit | 1 no. | - | 153.53 | 37.69 | 191.22 | 481.21 | 289.99 | 2.52 |
| Cashew | 1 no. | - | 252.51 | 67.84 | 320.35 | 643.72 | 323.37 | 2.01 |
| Arecanut | 2 nos. | 37.84 | 156.41 | 52.76 | 247.01 | 672.36 | 425.35 | 2.72 |
| Tapioca | 164 nos. | 2493.02 | 2555.28 | 505.03 | 5553.32 | 12143.22 | 6589.89 | 2.19 |
| Banana | 56 nos. | 3013.86 | 6007.54 | 595.48 | 9616.88 | 18936.53 | 9319.65 | 1.97 |
| Nutmeg | 2 nos. | 72.65 | 950.77 | 75.38 | 1098.79 | 3165.83 | 2067.04 | 2.88 |
| Pepper | 3 nos. | 19.24 | 399.5 | 101.38 | 520.12 | 1317.59 | 797.47 | 2.53 |
| Ginger | 6 nos. | 20.39 | - | - | 20.39 | 58.34 | 37.95 | 2.86 |
| Turmeric | 5 nos. | 32.94 | - | - | 32.94 | 56.98 | 24.05 | 1.73 |
| Curry Leaf | 1 no. | - | 32.91 | - | 32.91 | 89.4 | 56.5 | 2.72 |
| Papaya | 5 nos. | 219.47 | 124.37 | - | 343.84 | 874.37 | 530.53 | 2.54 |
| Moringa | 1no. | - | 17.88 | - | 17.88 | 77.45 | 59.57 | 4.33 |
| Colocasia | 4 nos. | 39.3 | 27.75 | - | 67.05 | 135.68 | 68.63 | 2.02 |
| Dioscorea | 2nos. | 16.03 | 42.75 | - | 58.78 | 135.68 | 76.89 | 2.31 |
| Amorphophallus | 1 no. | 15.83 | 31.43 | - | 47.26 | 131.91 | 84.65 | 2.79 |
| Sapota | 1 no. | 7.61 | 173.37 | - | 180.98 | 320.35 | 139.37 | 1.77 |
| Annona | 1 no. | 5.44 | 286.15 | - | 291.59 | 731.16 | 439.57 | 2.51 |
| Bilimbi | 1 no. | - | 37.74 | - | 37.74 | 86.16 | 48.42 | 2.28 |
| Guava | 1 no. | 11.76 | 248.74 | - | 260.5 | 678.39 | 417.89 | 2.6 |
| Pineapple | 30 nos. | 165.52 | 113.07 | 75.38 | 353.96 | 753.77 | 399.81 | 2.13 |
| Vegetables | 1 unit. | 1410.82 | 2241.93 | 198.99 | 3851.75 | 8730.99 | 4879.24 | 2.27 |
| Cattle | 3 nos. | 97987.58 | 25100 | 368.33 | 123455.91 | 245400 | 121944.09 | 1.99 |
| Goat | 1 no. | 6061.74 | 1985.6 | - | 8047.34 | 17000 | 8952.66 | 2.11 |
| Poultry | 10 nos. | 8139.73 | 1801.23 | - | 9940.96 | 18813.67 | 8872.71 | 1.89 |
| Total | | 120892.16 | 45659.11 | 2354.14 | 168905.4 | 341150.89 | 172245.49 | 2.02 |

investment amount and area needed for 15 coconut palms was subtracted from total available number of palms and LP problem was solved with resources kept for rest of the enterprises. Crops like banana, sapota, turmeric and poultry did not reach the suggested limit, even though the land area was abundant, because of the constraint, lack of capital for investing on the homesteads. For all other enterprises, optimum model had binding solution. The prospect of further enhancing the income by incorporating all enterprises in the suggested limit with an additional capital investment is discussed in the upcoming sections. The practical difficulty in

variety of the components preferentially opted by the farmers, gives much significance to the family requirement, taste, interest and market demand of the enterprises. The livestock/poultry components of the model comprised of 3 cattle, 4 goats and 10 poultry (Fig. 1). The livestock integration with crops was provide a high degree of organic recycling between the systems, which further helps to maintain soil health and sustainable productivity.

The optimum model for average homestead in AEU 8 was developed by investing an amount of ₹188331.05. The farmer would obtain a net profit of ₹195182 (Table 2) which

Table 2. Optimum model for homesteads in AEU-8

| Enterprise | Value | Space (M2) | | Expendiure (Rs) | | Gross Return (Rs) | | Net Return (Rs) | Constraints |
|--------------------|---------|------------|--------|-----------------|-----------|-------------------|-----------|-----------------|-------------|
| | | Unit | Total | Unit | Total | Unit | Total | | |
| Main Area | | | | | | | | | |
| Coconut | 15 nos. | 8.04 | 120.58 | 170.2549 | 2553.82 | 332.749 | 4991.24 | 2437.41 | 15 35 |
| Jack | 1 no. | 4.67 | 4.67 | 352.563 | 352.56 | 1075.38 | 1075.38 | 722.82 | 1 2 |
| Mango | 3 nos. | 5.89 | 17.68 | 279.3256 | 837.98 | 695.1759 | 2085.53 | 1247.55 | 3 |
| Gooseberry | 2 nos. | 3.14 | 6.28 | 102.91 | 205.82 | 388.9447 | 777.89 | 572.07 | 2 |
| Tamarind | 1 no. | 11.04 | 11.04 | 128.1407 | 128.14 | 509.5477 | 509.55 | 381.41 | 1 |
| Bread Fruit | 2 nos. | 21.23 | 42.45 | 191.2184 | 382.44 | 481.21 | 962.42 | 579.98 | 2 |
| Cashew | 2 nos. | 30.18 | 60.35 | 320.3518 | 640.7 | 643.7186 | 1287.44 | 646.73 | 3 |
| Cow | 3 nos. | 12 | 12 | 41151.97 | 123455.91 | 81800 | 245400 | 121944.09 | 3 |
| Goat | 4 nos. | 5 | 5 | 8047.34 | 32189.36 | 17000 | 68000 | 35810.64 | 4 |
| Poultry | 10 nos. | 3.5 | 3.5 | 994.0961 | 9940.96 | 1881.367 | 18813.67 | 8872.71 | 15 |
| House & | 1 | 438.69 | 438.69 | 0 | 0 | — | 0 | | 1 |
| Interspaces | | | | | | | | | |
| Tapioca | 80 nos. | 0.58059 | 46.45 | 33.86 | 2708.94 | 74.044 | 5923.52 | 3214.58 | 80 |
| Banana | 21 nos. | 2.5434 | 53.41 | 171.73 | 3606.33 | 338.1523 | 7101.2 | 3494.87 | 20 45 |
| Pepper | 8 nos. | 0.5024 | 4.02 | 173.37 | 1386.99 | 439.1967 | 3513.57 | 2126.58 | 2 8 |
| Ginger | 8 nos. | 0.66442 | 5.32 | 3.4 | 27.19 | 9.723618 | 77.79 | 50.6 | 8 |
| Turmeric | 8 nos. | 0.72346 | 5.79 | 6.59 | 52.7 | 11.39698 | 91.18 | 38.47 | 10 |
| Curry Leaf | 2 nos. | 1.02019 | 2.04 | 32.91 | 65.81 | 89.4 | 178.8 | 112.99 | 2 |
| Papaya | 10 nos. | 1.62778 | 16.28 | 68.77 | 687.68 | 174.8744 | 1748.74 | 1061.06 | 10 |
| Moringa | 1 no. | 4.5216 | 4.52 | 17.88 | 17.88 | 77.45 | 77.45 | 59.57 | 1 |
| Colocasia | 12 nos. | 0.88203 | 10.58 | 16.76 | 201.15 | 33.9196 | 407.04 | 205.89 | 12 |
| Dioscorea | 9 nos. | 0.63585 | 5.72 | 29.39 | 264.53 | 67.8392 | 610.55 | 346.02 | 9 |
| Amorphophallus | 7 nos. | 0.75391 | 5.28 | 47.26 | 330.81 | 131.9095 | 923.37 | 592.55 | 7 |
| Sapota | — | 4.5216 | 0 | 180.98 | 0 | 320.3518 | 0 | 0 | 1 |
| Annona | 1 no. | 3.20311 | 3.2 | 291.59 | 291.59 | 731.1558 | 731.16 | 439.57 | 1 |
| Bilimbi | 1 no. | 1.32665 | 1.33 | 37.74 | 37.74 | 86.16 | 86.16 | 48.42 | 1 |
| Guava | 1 no. | 9.72646 | 9.73 | 260.5037 | 260.5 | 678.39 | 678.39 | 417.89 | 1 |
| Vegetables | 2 unit | 46.5 | 93 | 3851.754 | 7703.51 | 8730.99 | 17461.99 | 9758.48 | 2 |
| Interspace Total | | | 266.66 | | | | | | 1043.61 |
| Main Area Total | | | 722.24 | | | | | | 1800.00 |
| Grand Total | | | 988.9 | | 188331.05 | | 383514.01 | 195182.96 | |

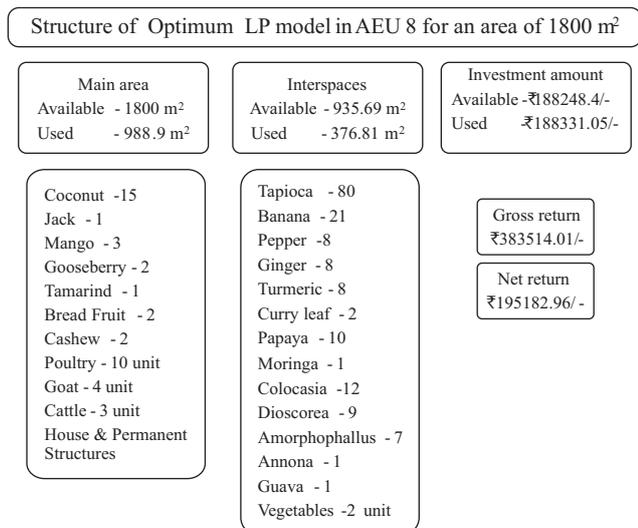


Fig. 1. Optimization model for homesteads in AEU 8

shows an enhancement of 13.31 per cent in net return as compared to the net return from the existing plan (Fig. 2). The optimum model worked out for in AEU 8 was binding solution for almost all the enterprises except some enterprises like banana, poultry and turmeric with B: C ratio of 2.04.

Sensitivity Analysis: Sensitivity analysis of the model of AEU 8 revealed a minimum and maximum range of net income for each enterprise, within which, the optimal LP solution will remain unchanged (Table 3). It is more important to look for maximum range of objective coefficient/unit net return for the enterprises having non binding solution and minimum range for enterprises with binding solutions to come across the reliability of model. It is evident from the results of sensitivity analysis on the objective function coefficient that the coconut palm can be included in the model only if the unit net income reaches ₹1319 but purposefully, 15 palms were added in the model. The non binding enterprises like banana and poultry may become binding enterprises if the unit net income reach above ₹169. and ₹963 respectively. The value of binding enterprises like gooseberry and

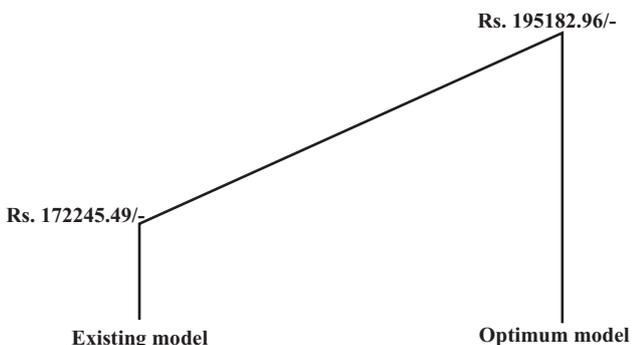


Fig. 2. Net income from existing and optimum model-AEU 8

Table 3. Sensitivity analysis on objective function coefficients

| Name | Final value | Objective coefficient | Maximum range | Minimum range |
|----------------|-------------|-----------------------|---------------|---------------|
| Coconut | 15 | 162.49 | 1319.02 | - |
| Jack | 1 | 722.82 | - | 341.67 |
| Mango | 3 | 415.85 | - | 270.69 |
| Gooseberry | 2 | 286.03 | - | 99.72 |
| Tamarind | 1 | 381.41 | - | 124.18 |
| Bread Fruit | 2 | 289.99 | - | 185.31 |
| Cashew | 2 | 323.37 | - | 310.45 |
| Tapioca | 80 | 40.18 | - | 32.81 |
| Banana | 21 | 166.42 | 169.62 | 153.27 |
| Pepper | 8 | 265.82 | - | 168.01 |
| Ginger | 8 | 6.33 | - | 3.3 |
| Turmeric | 8 | 4.81 | 6.39 | - |
| Curry Leaf | 2 | 56.5 | - | 31.89 |
| Papaya | 10 | 106.11 | - | 66.65 |
| Moringa | 1 | 59.57 | - | 17.33 |
| Colocasia | 12 | 17.16 | - | 16.25 |
| Dioscorea | 9 | 38.45 | - | 28.49 |
| Amorphophallus | 7 | 84.65 | - | 45.8 |
| Sapota | 0 | 139.37 | 175.38 | - |
| Annona | 1 | 439.57 | - | 282.58 |
| Bilimbi | 1 | 48.42 | - | 36.57 |
| Guava | 1 | 417.89 | - | 252.45 |
| Vegetables | 2 | 4879.24 | - | 3732.71 |
| Cow | 3 | 40648.03 | - | 39880.12 |
| Goat | 4 | 8952.66 | - | 7798.63 |
| Poultry | 10 | 887.27 | 963.37 | - |
| Home | 1 | 0 | - | - |

tamarind will remain the same until the unit net return reaches a minimum of ₹99 and ₹124 respectively.

Sensitivity analysis on available resources of suggests several changes that would help to increase the farm income, if some of the constraints are removed/ changed (Table 4) The shadow price values (dual price) indicate the increase or decrease in the gross returns of the model for unit change in value of the constraint within the given range of minimum and maximum of RHS. In the case of expenditure, third quartile of the investment amount (₹1,85,695) is considered for LP modeling and the sensitivity analysis indicated that if the farmer is willing to invest more amount, up to ₹1,89,899, for which he would receive ₹0.97 /- on every additional rupee invested. The enterprise banana in the optimum model has a value which was minimum of the feasibility range with a shadow price zero suggested no further increase in the population of this enterprise in the model. Shadow price was highest for vegetables (₹1154) in one cent among the enterprises indicating the need of expanding area under

Table 4. Sensitivity analysis of available resources

| Name | Final value | Constraint right hand side | Maximum right hand side | Minimum right hand side | Shadow price |
|----------------|-------------|----------------------------|-------------------------|-------------------------|--------------|
| Expenditure | 185695 | 185695 | 189899 | 185606 | 0.97 |
| Total Area | 940.6 | 1800 | - | 940.6 | 0 |
| Interspace | 265.44 | 1043.61 | - | 265.44 | 0 |
| Home | 1 | 1 | 2.96 | 0 | 0 |
| Coconut | 15 | 35 | - | 0 | 0 |
| Mango | 3 | 3 | 3.32 | 0 | 145.16 |
| Gooseberry | 2 | 2 | 2.87 | 0 | 186.31 |
| Tamarind | 1 | 1 | 1.7 | 0 | 257.23 |
| Bread Fruit | 2 | 2 | 2.47 | 0 | 104.68 |
| Cashew | 2 | 2 | 2.28 | 0 | 12.92 |
| Tapioca | 80 | 80 | 82.63 | 0 | 7.37 |
| Banana | 20 | 45 | - | 20 | 0 |
| Pepper | 8 | 8 | 8.51 | 0 | 97.81 |
| Ginger | 8 | 8 | 34.22 | 0 | 3.03 |
| Turmeric | 8 | 10 | - | 8 | 0 |
| Curry Leaf | 2 | 2 | 4.71 | 0 | 24.61 |
| Papaya | 10 | 10 | 11.3 | 0 | 39.46 |
| Moringa | 1 | 1 | 5.98 | 0 | 42.24 |
| Colocasia | 12 | 12 | 17.32 | 0 | 0.91 |
| Dioscorea | 9 | 9 | 12.03 | 0 | 9.96 |
| Amorphophallus | 7 | 7 | 8.89 | 0 | 38.85 |
| Sapota | 0 | 1 | - | 0 | 0 |
| Annona | 1 | 1 | 1.31 | 0 | 156.99 |
| Bilimbi | 1 | 1 | 3.36 | 0 | 11.85 |
| Guava | 1 | 1 | 1.34 | 0 | 165.44 |
| Vegetables | 2 | 2 | 2.02 | 0.91 | 1146.53 |
| Cow | 3 | 3 | 3 | 2.9 | 767.91 |
| Goat | 4 | 4 | 4.01 | 3.48 | 1154.03 |
| Poultry | 10 | 15 | - | 10 | 0 |
| Jack | 1 | 1 | 1.25 | 0 | 381.15 |

vegetables in the homesteads.

Homestead area in the model provide abundant resource

with non binding constraints; hence shadow price is zero. The shadow price was always zero for non binding enterprises. However, rise in rate of the enterprises in the homesteads in turn provide more return, but at the expense of other enterprises which are more remunerative.

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Risk Assessment of Toxicity of Agricultural Pesticides to Brine Shrimp (*Artemia salina*)

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Abstract: Toxicity of one herbicide and two insecticides were determined using the marine crustacean *Artemia salina* called the brine shrimp. The brine shrimp larva were hatched in the laboratory and were exposed to five concentrations of the atrazine, nicotine and imidacloprid at 6 and 24 hours. The dose-response of the brine shrimp larva to the toxicants increased with the increasing time of the exposure and also the mortality increased. The LD₅₀ decreases until it levelled off and the acute toxicity of the insecticides were similar. The LD₅₀ of the Imidacloprid for 6 and 24 hours were 3.58 and 1.77 ppm, LD₅₀ of nicotine for the same 6 and 24 hours were 3.73 and 2.49 ppm while the least toxic was atrazine and the LD₅₀ were 17.12 and 3.14 ppm. The result of this study revealed that the pesticides were toxic to the brine shrimp larvae except the control.

Keywords: Risk assessment, Pesticides, Toxicity

The use of insecticides to control pests and weeds in agriculture in order to increase food production started long ago. Green revolution era led to technological development which increased the use of modern methods of crop production such as high yielding varieties of crops, fertilizer and pesticides. These modern methods are vital tools to increase and to ensure efficient food production especially in developing countries where millions of people cannot adequately feed themselves by relying on manual labour as means of food production. The various uses of these chemicals especially in agricultural production has led to environmental pollution which has caused mortality and long term deleterious effects on organisms including human beings. The first synthetic pesticides became available during the 1940s, generating large benefits in increased food production but the adverse impacts on the environment and human health started being voiced in the early 1960s (Aktar *et al.*, 2009). Since then research has been going on its impact on the environment and it was discovered that about 2.5 million tons of pesticides are applied to agricultural crops worldwide every year (Manindra *et al.*, 2011). The amount of these pesticides coming in direct contact with or consumed by target pests is extremely small percentage of the amount applied. Pimental (2009) stated that the proportion of pesticides applied reaching the target pests has been found to be less than 0.3%, so 99.7% went somewhere else in the environment so the use of pesticides in agriculture inevitable leads to exposure of non-target organisms and the

undesirable may occur in some species, communities or on ecosystems as a whole. Although an increasing number of environmental effects of pesticides are being taken into account by regulatory bodies by banning some of the pesticides or restricted the use of them especially in the developed countries but some of these harmful pesticides are still in use in the developing countries (Ecobichon, 2001).

Pesticides applied to crops, lawns and animals are commonly found in soil, water, and water contamination is often caused by more than one pesticide at relatively low concentration. The pesticides through precipitation, runoff and ground water can destroy aquatic habitats. Contaminants in the environment impair growth and development of larvae and ultimately lead to mortality (McCarthy *et al.*, 2003). The responses of organisms both at individual and population levels, to pesticides residues may be influenced by the presence of other biologically active substances, chemical pollutants including gases and natural substances. Two pesticides atrazine and imidacloprid are widely used for weeds and pest control respectively. The responsible use of these compounds can only be based on scientific study of the impacts of such compounds on the environment. In aquatic toxicology, the study of pesticide effect on aquatic organisms has dedicated considerable attention to fishes over the past four decades. Many authors have reviewed different aspect of fish, survival, physiology, development, biochemistry and behaviour (Rashid *et al.*, 2010, Helfrich *et al.*, 2009, Lawrence and Hemingway, 2003).

Pesticides are known to be one of the extremely useful and beneficial agents for preventing losses of crops as well as diseases in humans. Based on the action, pesticides can be classified as destroying, repelling and mitigating agents. Insects and pests are getting immune to the commercial pesticides due to over usage. (Speck-Planche *et al.*, 2012). Nowadays, chemical pesticides and insecticides are becoming a dominant agent for eliminating pests. Sometimes, these chemical pesticides are used in a combination of effective natural enemy and that result in enhanced integrated pest management and act as a comprehensive prophylactic and remedial treatment (Gentz *et al.*, 2010). On the level of population, the effects of pesticides depend on exposure and toxicity, as well as on different factors like life history, characteristics, timing of application, population structure and landscape structure (Schmolke *et al.*, 2010). Nerve targets of insects which are known for development of neuroactive insecticides include acetylcholinesterase for organophosphates and methylcarbamates, nicotinic acetylcholine receptors for neonicotinoids, gamma-aminobutyric acid receptor channel for polychlorocyclohexanes and K^+ channels and voltage gated sodium channels for pyrethroids and dichlorodiphenyltrichloroethane (Casida and Durkin, 2013). It is an observation that the use of neonicotinoid pesticides is increasing. These pesticides are associated with different types of toxicities (Van Dijk, 2010). Non-regulated use of pesticides has led the environment into disastrous consequences and serious concerns about human health and biodiversity are raising due to overuse of pesticides (Agrawal *et al.*, 2010). Pesticides are considered to be more water soluble, heat stable and polar which makes it very difficult to reduce their lethal nature. Pesticides are not only toxic to people related to agriculture, but they also cause toxicity in industries and public health work places. Depending upon the target species, pesticides can cause toxicities in natural flora, natural fauna and aquatic life (Rashid *et al.*, 2010).

Therefore the objective of the study is to determine the toxicity of the individual pesticides exposed to the brines shrimp larvae.

MATERIAL AND METHODS

In order to develop a sound methodology, preliminary experiments were carried out in order to familiarise with the equipment and develop sound methodologies. These preliminary works were carried out in two stages. The first preliminary work started with the hatching of the brine shrimp and the second stage was the determination of the range concentrations and preparation of stock solutions of the

pesticides used in this study.

Pesticide used: The pesticides used were atrazine {6-chloro-N-ethyl -N-(1-Methyl)-1, 3, 5-triazine-2, 4-diamine}(99%) and imidacloprid {1-(6-chloro-3-pyridylmethyl)-N-nitro-imidazolidin-2-ylideneamine} were obtained from VWR International Ltd UK and Sigma Aldrich respectively to ensure that certified products are purchased while nicotine is already in stock in the laboratory.

Culture of organism: The brine shrimp eggs were purchased from Blade Biological Ltd UK and were reared from eggs in aqueous sodium chloride (15g/l) in a small glass tank, at 30° C. In this study beaker was used and 15g of sea salt were dissolved in 500ml of distilled water and then 3g of shrimp eggs were added and placed in incubator at 30°C for 24 hours. In the next 24 hours all the eggs were hatched and with aid of light, larvae moved around the beaker where they could be collected free of eggs and eggshells. Unfed larvae up to 24 hours old were used.

Preparation of stock solutions: During the preliminary studies, a range of stock solutions were prepared from the pesticides and applied to the brine shrimp, then between the range of concentrations at which all the shrimp died and the range at which no shrimp died, five concentrations were prepared and the control with acetone only were used for the bioassay. The solutions of the individual chemicals were prepared by weighing out the Technical grade and preparing stock solutions using acetone as a solvent. The concentrations required for bioassay were obtained from stock solutions by serial dilution with water. Samples for the experiment were prepared weighing out 5.0mg of each pesticide and dissolved in 2 ml of acetone. Appropriate amounts of the acetone gave 2500ppm as a stock solution with 2 times serial dilution. Then 1ml of stock was added to 1ml of acetone gave 1250ppm, 1ml was taken from 1250ppm and added to 1ml of acetone gave 625ppm, the next is, 156.25ppm and 78.125ppm were used.

Bioassay methods: The bioassays were done in micro titre plates with 96 wells per plate having a capacity of 300 μ l. The shrimp larvae were collected from the rearing tanks with Gilson micropipette taking 250 μ l brine and 5-7 shrimp and transferred to each well of the micro titre plate. The acute toxicity bioassays were performed every 2, 6 and at 24 hours. The brine shrimp larvae (*Artemia Salina*) were exposed to the five concentrations and a control of each pesticide. The appropriate dilutions of each pesticide were prepared in acetone and the same procedures were used to treat the brine shrimp larvae with corresponding concentrations of acetone in water only as control. The treatments were individual chemicals at constant mass ratios at a range of concentrations to give mortality responses between 0 and

100%. 48 wells (half of micro titre plates) were used for each treatment. 250µl of brine with 5-7 shrimp were introduced to each well, then 5µl of the five concentrations and 5µl of acetone only for control was applied to each well and was replicated 8 times. The total population of the shrimp used in each treatment were at least 240 shrimps. (5 shrimps x 6 concentrations x 8 replicates). Then following the application of the concentrations, the micro titre plates was covered with Clingfilm and placed in a dark incubator at 30°C for 24 hours. Mortality responses were scored at every 2, 6 and at 24 hours.

Statistical –Probit analysis: The data produced as a result of the experiment was subjected to statistical and probit analysis using POLO-PC software package to drive a probit mortality against log-dosage regression line from which the median lethal dose (LD50) of each dataset was obtained. The transformation of percentages (%) of mortalities to probit –mortalities were also carried out in Microsoft excel using the formula =NORMINV (B2/100, 5, 1) while dosages were converted to log dosages using polo-pc. These conversions were conducted in order to convert the s-shape (sigmoid) curve into a straight line. Then the graphs of the mortality responses were plotted using probit against log dosages. In order to test the goodness of fit of the derived probit mortality –log dosage regression lines, Chi square test at the 5 % significance level, g values (0.95) and R-squared values were used. Accordingly, if the actual chi-square value calculated from the test lines is greater than the critical value in the standard table for the respective degree of freedom, the g (0.95) value greater than 0.4 and R-squared value less than 1, then the lines does not fit the data well. Finney (1972) stated that with almost all good sets of data, g will be substantially smaller than 1.0 and seldom greater than 0.4. Corrected mortality were carried out where mortality occur in the control using the Abbott's formula PO-PC/100-PC (where PO= Observed Mortality and PC= Control Mortality).

RESULTS AND DISCUSSION

Toxicity of imidacloprid to brine shrimp larvae: In

acute bioassay of short duration it can be assumed that internal concentration of the toxicant increases with time as long as there is sufficient concentration of the toxicant in the media (Sanchez-Bayo and Goka, 2007). In this case, the highest doses will reach its plateau early whereas lower doses will take longer time to reach their threshold. This study showed increase in mortality with increase in times of exposure. The response of brine shrimp to imidacloprid showed increase in mortality rates from 30 and 32 % to 75 and 92% for 24h at highest concentrations. Lower concentrations showed increase in mortality rates from 10 and 14 % to 43 and 52% for 24 h. Imidacloprid was relatively fast-acting insecticides to brine shrimp larvae. Some brine shrimp larvae recovered 1-hour after treatment after which time no further recovery were observed. Imidacloprid acts on the central nervous system, irreversibly blocking the post –synaptic nicotinic acetylcholine receptors (Tomlin 1994). In this study, the toxicity of imidacloprid to brine larvae has been confirmed to be high with LD₅₀ of 3.5808 and 1.7659 for 6 and 24 hours respectively. In contrast imidacloprid was less toxic larvae of *Drosophila melanogaster* (LD₅₀=11.70ppm) but however found imidacloprid to be highly toxic to *Drosophila melanogaster* (LD₅₀=1.89 ppm) (Papadimitriou 2003 unpublished).The rapid knockdown effects were observed in first 6 hours, thus indicating imidacloprid excellent kinetics and this may have resulted in the wide differences in toxicity of this chemical among crustacean groups.

The tabular chi-square value for 3 degree of freedom at 5% significance level is 7.81, which is greater than the actual one calculated from the test line by Polo-PC (0.2725) . However, as the g (0.95) value is less than 0.4 and R –squared value approaches 1, therefore, it is reasonable to conclude that the produced lines fit the resulting data well.

The tabular chi-square value for 3 degree of freedom at 5% significance level is 7.81, which is greater than the actual one calculated from the test line by Polo-PC (1.3467) while g value at (0.95) is less than 0.4 and R –squared value is approaches 1. This showed that the produced line fits the

Table 1a. 6-Hour mortality of brine shrimp larvae with imidacloprid

| Concentration (ppm) | Log dosage (ppm) | No. of shrimp used | No of dead shrimp | % Dead | Empirical probit |
|---------------------|------------------|--------------------|-------------------|--------|------------------|
| 0 (Control) | 0.00000 | 47 | 0 | 0 | – |
| 1.07 | 0.029384 | 48 | 18 | 38 | 4.68 |
| 2.14 | 0.330414 | 51 | 21 | 41 | 4.78 |
| 4.29 | 0.632457 | 48 | 25 | 52. | 5.05 |
| 8.58 | 0.933487 | 50 | 30 | 60. | 5.25 |
| 17.16 | 1.234517 | 50 | 35 | 70. | 5.524 |

LD₅₀ = 3.5801ppm Chi-square = 0.2725 Degree of Freedom = 3. g (0.95) = 0.277
Log(L) = -163.9 Slope= 0.719+-0.193 Heterogeneity = 0.0

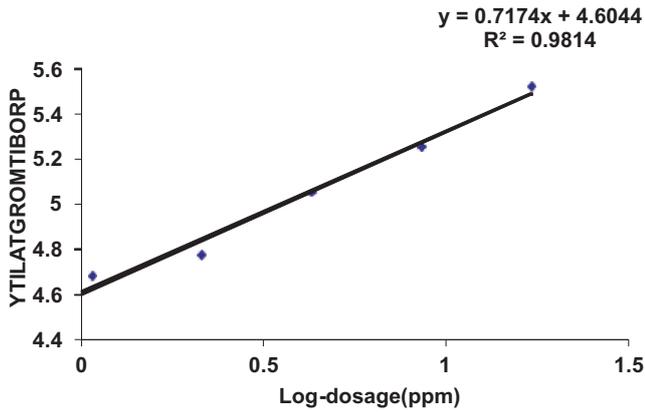


Fig. 1. Relation between probit of kill of brine shrimp and log dosage of imidacloprid for 6 hour, showing probit regression line

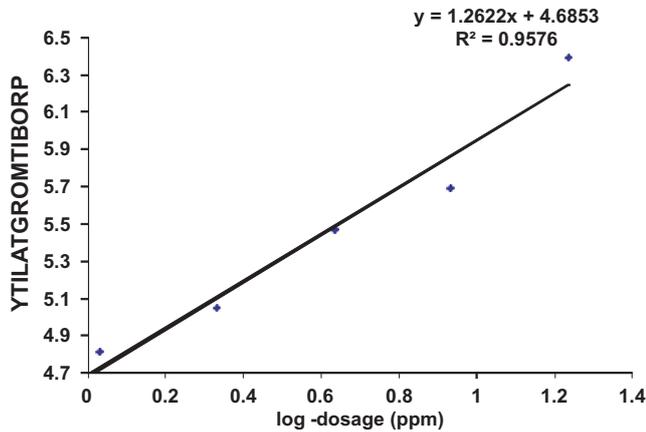


Fig. 2. Relation between probit of kill of brine shrimp and log dosage of imidacloprid for 24 hour, showing probit regression line

resulting data well

Toxicity of atrazine to brine shrimp larvae: Due to the extent of atrazine application in the agricultural crops in the tropics especially in the United States, the occurrence of atrazine in surface and ground waters is inevitable. Atrazine

and chlorpyrifos are the most commonly used herbicides and organophosphate insecticides in the United States (Kiely *et al.*, 2004) and are frequently detected in streams and agricultural basins (Larson *et al.*, 1999). In this study it observed that atrazine was toxic to brine shrimp larvae with LD₅₀ values of 17.1208 and 3.1374ppm for 6 and 24 hours respectively. Although atrazine was the least toxic to brine shrimp larvae among the three pesticides used, these observations were not unexpected since atrazine is demonstrably more toxic to plants than invertebrates (Anderson and Zhu, 2004). In contrast these results did not agree with those of Wilkins and Metcalfe (1976) who also exposed brine shrimp larvae to atrazine and found LC₅₀ as 41.78mg/l. The differences in these two researches may be due to environmental factors. However, the extrapolation of laboratory data to the field is not always relevant because field populations might already have resistance to these pesticides. For example, the field population of the closely related species *C. riparius* was 13-fold more tolerant to DDT than the population of the same species in the laboratory (Delaplane, 2000). In the environment, some many factors such as leaching, adsorption affect the rate of atrazine. Over a limited range of atrazine concentrations, nonlinear adsorption isotherm for Freundlich is observed for atrazine, which is poorly soluble and show a relatively high K_{ow} value. For Freundlich adsorption isotherm for atrazine are 4.56(L/kg), 0.92 and 0.31. In understanding sorption kinetics allows prediction of how fast such reaction reaches equilibrium especially atrazine kinetic studies provides important information about atrazine fate in soil (Dehghani *et al*/2005).

The tabular chi-square value for 3 degree of freedom at 5% significance level is 7.81 which is greater than the actual one calculated from the test line by Polo-PC (0.3663). g(0.95) value is greater than less than 0.4 and R-squared value approaches 1. Therefore it showed that the produced line does not fit the resulting data very well.

The tabular chi-squared value for 3 degrees of freedom at

Table 1b. 24 –Hour mortality of brine shrimp larvae with imidacloprid

| Concentration (ppm) | Log dosage (ppm) | No. of shrimp used | No of dead shrimp | % Dead | Corrected % Dead | Empirical probit |
|---------------------|------------------|--------------------|-------------------|--------|------------------|------------------|
| 0 (Control) | 0.00000 | 47 | 1 | 2 | - | - |
| 1.07 | 0.29384 | 48 | 21 | 44 | 43 | 4.81 |
| 2.14 | 0.330414 | 51 | 27 | 53 | 52 | 5.05 |
| 4.29 | 0.632457 | 48 | 33 | 69 | 68 | 5.47 |
| 8.58 | 0.933487 | 50 | 38 | 76 | 75 | 5.69 |
| 17.16 | 1.234517 | 50 | 46 | 92. | 92 | 6.39 |

LD₅₀ = 1.76594ppm. Chi-square = 1.3467. Degree of Freedom = 3 g (0.95) = 0.125
 Log(L) = -145.0 Slope= 1.213+-0,219 Heterogeneity = 0.45 nat. resp. =0.022

5% significance level is 7.81, which is greater than the actual one calculated from the test line by Polo-PC (0.2336). The g (0.95) value is slightly greater than 0.4 and R-squared value approaching 1. Therefore, the produced line does not fit the resulting data well.

Toxicity of nicotine to brine shrimp larvae: Nicotine on its own is a very poisons and was also found to be toxic to brine shrimp larvae with increasing times of exposure producing

LD_{50} of 3.7312 and 2.4948ppm for 6 and 24-h respectively. Nicotine inhibits the function of acetylcholine receptors located at neuromuscular junctions and causes stimulation of the ganglions in low does as well as causes blockade at higher concentrations (Bourzac, 2003). It stimulates and then blocks the acetylcholine receptor, locking the ion channels in the position and impairing signalling ability leads to death (Bourzac, 2003),

Table 2a. 6 Hour mortality of brine shrimp larvae with atrazine

| Concentration (ppm) | Log dosage (ppm) | No. of shrimp used | No of dead shrimp | % Dead | Empirical probit |
|---------------------|------------------|--------------------|-------------------|--------|------------------|
| 0 (Control) | 0.00000 | 46 | 0 | 0 | - |
| 1.83 | 0.262451 | 47 | 14 | 30 | 4.47 |
| 3.68 | 0.565848 | 42 | 17 | 41 | 4.76 |
| 7.36 | 0.866287 | 45 | 19 | 42 | 4.80 |
| 14.71 | 1.167613 | 47 | 22 | 47 | 4.92 |
| 29.41 | 1.468495 | 45 | 25 | 56 | 5.14 |

LD_{50} = 17.12085ppm. Chi-square = 0.3663 Degree of Freedom = 3. g (0.95) = 0.610
 Log(L) = -129.4 Slope= 0.499+-0.199 Heterogeneity = 0.12

Table 2b. 24-Hour mortality of brine shrimp larvae with atrazine

| Concentration (ppm) | Log dosage (ppm) | No. of shrimp used | No of dead shrimp | % Dead | Corrected % Dead | Empirical probit |
|---------------------|------------------|--------------------|-------------------|--------|------------------|------------------|
| 0 (Control) | 0.00000 | 46 | 1 | 2 | - | - |
| 1.83 | 0.262451 | 47 | 21 | 45 | 43. | 4.84 |
| 3.68 | 0.565848 | 42 | 23 | 55 | 54 | 5.09 |
| 7.36 | 0.866287 | 45 | 27 | 60. | 59 | 5.23 |
| 14.71 | 1.167613 | 47 | 30 | 64 | 63 | 5.33 |
| 29.41 | 1.468495 | 45 | 33 | 73 | 73 | 5.60 |

LD_{50} = 3.13743ppm. Chi-square = 0.2336. Degree of Freedom = 3. g (0.95) = 0.462
 Log (L) = -153.3 Slope= 0.589+-0.204 Heterogeneity = 0.08

Table 3a. 6 -Hour mortality of brine shrimp larvae with nicotine

| Concentration (PPM) | Log dosage (PPM) | No. of shrimp used | No. of dead shrimp | % dead | Empirical probit |
|---------------------|------------------|--------------------|--------------------|--------|------------------|
| 0 (control) | 0 | 50 | 0 | 0 | - |
| 1.41 | 0.149219 | 47 | 18 | 38 | 4.70 |
| 2.82 | 0.450249 | 49 | 21 | 43 | 4.82 |
| 5.64 | 0.751279 | 48 | 27 | 56 | 5.16 |
| 11.27 | 1.051924 | 50 | 32 | 64 | 5.36 |
| 22.55 | 1.353147 | 50 | 39 | 78 | 5.77 |

LD_{50} = 3.73124 ppm. Chi-square = 0.6309 degree of freedom = 3. g (0.95) = 0.193
 Log (L) = -157.0 slope = 0.885+-0.198 heterogeneity = 0.21

Table 3 b. 24 -Hour mortality of brine shrimp larvae with nicotine

| Concentration (PPM) | Log dosage (PPM) | No. of shrimp used | No. of dead shrimp | % dead | Corrected % kill | Empirical probit |
|---------------------|------------------|--------------------|--------------------|--------|------------------|------------------|
| 0 (control) | 0 | 50 | 2 | 4. | - | - |
| 1.41 | 0.149219 | 47 | 20 | 43 | 40 | 4.74 |
| 2.82 | 0.450249 | 49 | 26 | 53 | 51 | 5.03 |
| 5.64 | 0.751279 | 48 | 32 | 67 | 65. | 5.39 |
| 11.27 | 1.051924 | 50 | 40 | 80 | 79 | 5.81 |
| 22.55 | 1.353147 | 50 | 45 | 90 | 90 | 6.26 |

LD_{50} = 2.49485ppm Chi-square = 0.2751 degree of freedom = 3. g (0.95) = 0.124
 Log (L) = -146.3 slope = 1.250+-0.22. Heterogeneity = 0.09. nat.resp. = 0.040+-0.028

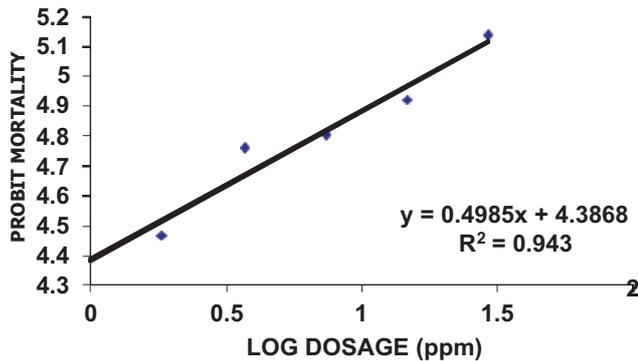


Fig. 3. Relation between probit of kill of brine shrimp and log dosage of atrazine for 6 hour after treatment, showing regression line

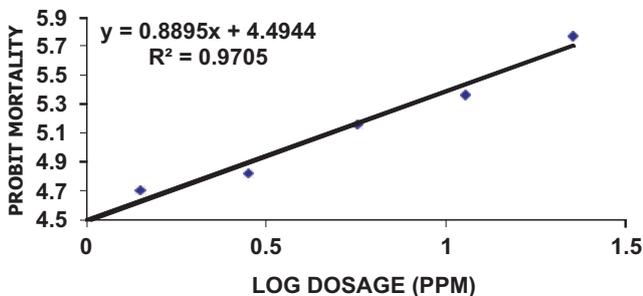


Fig. 5. Relation between probit of kill of brine shrimp and log dosage of nicotine for 6 hour after treatment, showing regression line

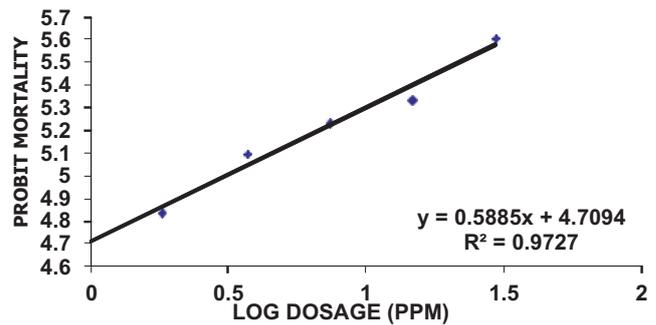


Fig. 4. Relation between probit of kill of brine shrimp and log dosage of atrazine for 24 hour after treatment, showing regression line

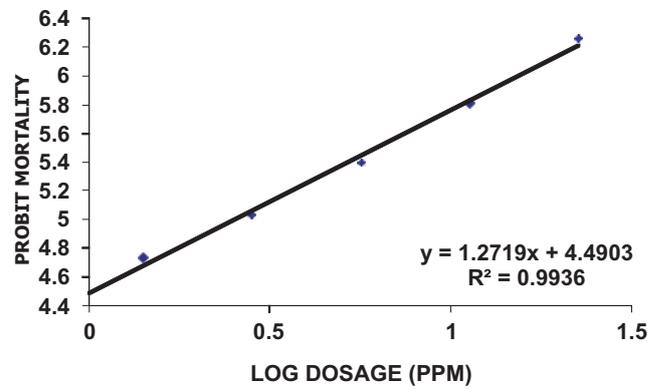


Fig. 6. Relation between probit of kill of brine shrimp and log dosage of nicotine for 24 hour after treatment, showing regression line

The tabular chi-square value for 3 degrees of freedom at 5% significance level is 7.81, which is greater than the actual one calculated from the test line by Polo-PC (0.2751). However, the g value at (0.95) is less than 0.4 and R-square value approaches 1. Therefore; the produced line fits the resulting data well.

CONCLUSION

The individual pesticides were all highly toxic to the brine shrimp larvae with increasing times of exposure. Therefore, individual pesticides that are used in our farms to control weeds and pests can cause mortality organisms in aquatic ecosystem.

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Litter Decomposition *Vis-a-Vis* Carbon and Nitrogen Dynamics of *Tephrosia candida* Components in Different Fallow Periods Following Shifting Cultivation in Mizoram

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Abstract: Shifting agriculture is primitive agriculture system which is being recently replaced by agroforestry systems or sloping Agricultural Land Technology (SALT) through plantations of *Tephrosia candida* hedgerows to reduce soil erosion, adds organic matter and nutrients in the soil. Besides, fixing atmospheric N, the species has been considered as the main source of input of organic matter and nutrients to the soil for sustained crop productivity. This study was conducted to assess the rate of organic matter decomposition and release of C and N from different components (i.e. leaf, branch, root <2 mm and root 2-5 mm) of *T. candida* in different fallows (3 years: FL-3, 5 years: FL-5 and 10 years: FL-10) using litter bag techniques in Muallungthu village, Mizoram. The rate of decomposition and C and N release was significantly varied with respect to litter components, fallow length and seasons. The rate of organic decomposition and C and N release was fastest in leaf and fine root (<2 mm) components compared to branch and root (2-5mm). Further, the rates were highest in longer fallow (FL-10) compared to shorter fallows (FL-3 and FL-5), and rainy season compared to dry seasons. Results indicate that litter decomposition and C and N release pattern largely depends on the initial litter quality, abiotic variables and site fertility levels due to changing pattern of litter microorganisms. It is concluded that litter biomass of *T. candida* play an important role in soil fertility and sustainable agricultural practices in northeastern hill regions of Mizoram.

Keywords: Shifting cultivation, Litter decomposition, Fallow length, *Tephrosia candida*, Carbon and nitrogen dynamics

Mizoram is one of the seven sister states of northeastern India, located in tropical hilly areas dominated by tribal populations involved in shifting agricultural practice for their livelihood through centuries. During shifting cultivation, farmers slash the piece of forest land and burns the dry mass *in situ* followed by sowing seeds of desired crops manually without tilling the soil (Grogan *et al.*, 2012; Yadav, 2013), and continue cropping for 1-2 years depending on the soil fertility. Farmers move to other forest lands for cultivation and left this land as fallow to recover soil fertility. This agricultural system was adequately productive, economically viable and ecologically efficient due to prolonged fallow period (~20-30 years) in the past. However, in recent years as a result of exponential increase in human population, the fallow periods have been considerably reduced to ~<5 years which led to decrease in soil fertility and crop productivity (Grogan *et al.*, 2012). The distinctive features of shifting cultivation practice of Mizoram is its steep slopes which causing land degradation and deterioration of surface water quality because of soil erosion (Tripathi *et al.*, 2017).

Government of Mizoram has introduced a New Land Use Policy in March 2010, which discourages shifting cultivation and encourages the farmers to adapt to other alternative land use system of food production like agroforestry. Numbers of

farmers in Lunglei and Aizawl district of Mizoram have been using Sloping Agriculture Land Technology (SALT) for production of cereals, vegetables, fruits and medicinal plants using *Tephrosia candida* as hedgerow. Establishing *T. candida* hedgerows is believed to add carbon and nutrients to crops annually through decomposition but the extent of carbon and nitrogen addition is not known. *T. candida*, a shrub species, is widely planted in degraded land for improvement of the soil. It is widely grown in mixed cultivation as well as alley cropping in tropical region due to its high biomass yield, dense vegetative cover, deep root system and its nitrogen fixation ability (Nguyen and Thai, 1993). It helps in rehabilitation of degraded land though fixing atmospheric nitrogen, controlling soil erosion and increasing the level of soil nutrients by adding organic matter and nutrients through the process of decomposition. However, we know little about the organic matter and nutrient released from *T. candida* in the study sites. This study aimed to determine the rate of litter decomposition and nutrient release from different components (leaf, fine and coarse roots and branches) of *T. candida* in three fallow lands. We hypothesize that the decomposition of various components of *T. candida* varies under different fallow periods. The main objectives of the present study are: (1) to determine temporal variations in

litter decomposition and C and N release from various components of *T. candida*; (2) and to find out the factors (abiotic and litter quality) affecting the rate of litter decomposition and C and N release in different fallows following shifting agriculture in Mizoram.

MATERIALS AND METHODS

Site description: The study was conducted at three fallow lands of 3 years (FL-3), 5 years (FL-5) and 10 years fallow (FL-10) in Muallungthu village, Mizoram. The geographic position of the study sites are between 23°36'30" N lat. and 92°42'87" E long, 23°35'69" N lat. and 92°43'09" E long. and 23°35'66" N lat. and 92°48'08" E long, respectively. The temperature, humidity and rainfall data of the study sites during the sampling period are presented in Fig. 1. The ages of fallow lands were identified by interviewing the land owner. The soil of the study sites belongs to order inceptisol and falls under red soil group, having light to medium texture (sandy loam and clay loam) and slope of the land varied between ~35° and 40° (Hauchhum and Tripathi, 2017).

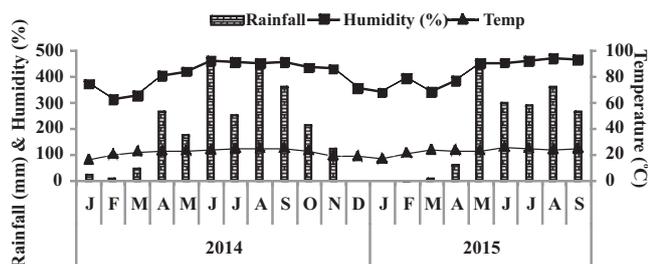


Fig.1. Ombrothermic representation total monthly rainfall, mean monthly temperature and mean monthly relative humidity of the study site

Soil physico-chemical characteristics: Soil pH was measured in a soil-water suspension (1:2.5 w/v H₂O) using a digital pH meter. The soil moisture was determined gravimetrically as described by (Anderson and Ingram, 1993). Total Organic Carbon (TOC) and Total Nitrogen (TN) in soil were determined by a Heraeus CHN-O-S Rapid Auto-analyzer employing Sulphanilamide (C₆H₈N₂O₂S) standard. Bicarbonate available P (P_{avail.}) was estimated using ammonium molybdo-blue color method (Allen *et al.*, 1974). NH₄-N was estimated by Indophenol Blue colour Method (Rowland, 1983). (NO₃-N) was estimated as described by Jackson (1958). Soil Bulk Density (BD) (g cm⁻³) was measured using a metallic tube of known inner volume to determine the dry weight of a unit volume of soil (Brady, 1984).

Experimental design and litter decomposition: At the beginning of the first year cropping, *T. candida* was planted in

hedgerows in all three fallows (FL-3, FL-5 and FL-10) in April 2013 to enhance soil fertility and crop productivity. At the beginning of the next year cropping in April 2014, *T. candida* was pruned and placed on soil surface. From the pruned material, small amount (5 g) of *T. candida* leaves and branch litter were collected in polythene bags. Further, some *T. candida* plants from different random locations were uprooted to collect the roots of two diameter classes (<2 mm and 2-5 mm). Roots were cleaned with water to remove adhering soil particles. All litter components (leaves, branches and roots i.e. <2 mm and 2-5 mm) were air dried and the weighed amount (5 g) of litter of each components were enclosed in nylon litter bags (10 cm x 10 cm, 2 mm mesh). The mesh size was large enough to permit aerobic microbial activities and allow easy movement of small soil micro-fauna. For each litter component 30 bags were prepared with a total of 360 litter bags for four litter components and three fallows. All litter components were randomly placed on soil in the bunch of five in three fallow lands in July 2014 for decomposition and five bags of each component (1 bag per litter component from 5 bunches) were retrieved every two months interval. A total of six recoveries were made in a year.

Analysis of carbon and nitrogen: All retrieved litter samples were brought to the laboratory and brushed off to clean soil particles, and dried at 80°C for 48h to constant weight. The air dried litter samples were grounded and passed through a 1mm mesh screen for chemical analysis. C and N contents were determined by CHN-O-S Rapid Auto-analyzer employing Sulphanilamide (C₆H₈N₂O₂S) standard.

Calculation and Statistical analysis: The main relative decomposition rate (RDR) was calculated by using formula:

$$\text{RDR (g g}^{-1} \text{ day}^{-1}) = \ln(W_t - W_0) / (t_1 - t_0) \quad (1)$$

Where W_0 = mass of litter present at time t_0 , W_t = mass of litter at time t_1 , and $t_1 - t_0$ = sampling interval (days).

The daily instantaneous decayed constant (k) of litter was calculated through the negative exponential decay model of Olson (1963):

$$W_t / W_0 = \exp^{-kt} \quad (2)$$

Where W_0 = initial mass of the litter, and W_t = mass remaining after time t , the time series of carbon and nitrogen content were used in this model to calculate the k (mineralization constant) values for C and N. As suggested by Olson (1963), the time required for 50% mass loss and C and N release was calculated as $t_{50} = 0.693/k$ and for 95% mass loss as $t_{95} = 3/k$.

Correlation analysis was performed between abiotic variables (rainfall, temperature, humidity and soil moisture) and mass loss. One-way analysis of Variance (Tukey's HSD) was performed to determine variation in soil variables with

fallow periods. All analyses were conducted using SPSS software package (20.00 Version).

RESULTS AND DISCUSSION

Impact of fallow length on soil properties: Soil of the study sites was strongly acidic in reaction with soil pH ranged from 4.30-5.08 (Table 1). The pH was lowest (4.3) in 3 years fallow and highest (5.08) in 10 years fallow. The increased soil pH with fallow period may be associated with addition of more alkaline cations from burning of greater plant biomass in FL-10 than FL-3 (Dikici and Yilmaz, 2006; Granged *et al.*, 2011). The BD was affected by length of fallow period. The BD was highest in FL-3 (1.04 g m⁻³) and the lowest in FL-10 (0.62 g m⁻³). Significant decrease in BD from FL-3 to FL-10 may be attributed to increase accumulation of soil organic matter with increased fallow length (Sarkar *et al.*, 2015). After burning of biomass, fallow sites may be prone to increase soil erosion and loss of soil organic matter. The fallow sites with higher soil organic matter content was susceptible to burning loss although maintained higher SOC up to second year as a result of higher temperature during burning due to the accumulation of more biomass in the longer fallow period compared to shorter fallow (Lungmuana *et al.*, 2017). The amount of SOC, TN, P_{avail}, NO₃-N and NH₄-N were significantly enhanced with fallow periods. The percent increase in FL-10 compared to FL-3 was 21% for TOC, 40% for TN, 68% for P_{avail}, 85% for NO₃-N and 63% for NH₄-N. Increased input of organic residues and nutrients was responsible for enhanced soil chemical properties in longer fallow (Jiang *et al.*, 2009; Lungmuana *et al.*, 2017). Further, increased vegetation cover and well developed plant roots systems could decline soil erosion that tends to avoid soil nutrient (C, N and P) loss which may lead to greater nutrient content in longer fallows.

Decomposition of different litter components of *T. candida*: Decomposition of different components of *T. candida* litter showed almost similar pattern of mass loss. Mass loss (30-45%) of *T. candida* litter was rapid in the initial 2 months which decreased in the later stages of decomposition (Fig. 2). Similar findings have been reported by Munthali *et al.* (2015) in two species of *Tephrosia* (*T. candida* and *T. vogelii*) in Malawi, Africa. The rapid mass loss in the initial stages in the present study may be related to the high concentration of labile substances like water solubles (such as sugars, amino acids and soluble phenolics) during this period (Wang *et al.*, 2004) as reflected by low C/N ratio (16-22) in initial litter components. On the other hand, recalcitrant materials such as lignin, hemicelluloses and soil microbial by products (Saviozzi *et al.*, 1997) dominate due to decreased concentration of easily decomposable substances that retarded the litter decomposition in the later

Table 1. Soil physico-chemical characteristics of the study sites

| Soil parameters | Fallow periods | | |
|--|------------------------|--------------------|--------------------|
| | 3 yrs | 5 yrs | 10yrs |
| pH | 4.30 ^c | 4.57 ^b | 5.08 ^a |
| BD (g cm ⁻³) | 1.04±0.12 ^a | 0.82 ^b | 0.62 ^c |
| TOC (%) | 1.27 ^c | 1.48 ^b | 1.59 ^a |
| TN (%) | 0.10 ^b | 0.12 ^{ab} | 0.14 ^a |
| P _{avail} (µg g ⁻¹) | 10.30 ^c | 14.15 ^b | 17.34 ^a |
| NO ₃ (µg g ⁻¹) | 3.20 ^c | 5.15 ^b | 5.92 ^a |
| NH ₄ (µg g ⁻¹) | 22.45 ^c | 30.97 ^b | 36.66 ^a |
| C/N ratio | 12.7 ^a | 12.3 ^a | 11.3 ^a |

Values are means ± SD (n=3)

BD-Bulk Density, TOC-soil organic carbon, TN-total nitrogen

Different letters indicate significant differences ($p < 0.05$) with fallow periods

stages (Pandey *et al.*, 2007). Among all the components, leaf and fine root (<2 mm) decomposition was faster than the branch and coarse roots (<5 mm). At the end of the study period, initial mass remaining in branch (47-55%) and root 2-5 mm (45-52%) were significantly high compared with leaf (35-43%) and root <2 mm (33-40%). Slow decomposition in branch and coarse root may be because of the presence of more stable polysaccharides like lignin, waxes and polyphenols (Zech *et al.*, 1997). The daily instantaneous decay constant (k), number of days required for 50% (T_{50}) and 95% (T_{95}) decomposition for all litter components were in the order: fine root>leaf>coarse root>branches (Table 2).

Among the litter components studied (e.g. leaves, branches, roots<2 mm, 2-5 mm), the initial C content was highest in roots of 2-5 mm (31%-40%) and lowest <2 mm roots (25%-37%) (Table 3). The release of C followed the pattern similar to that of mass loss which was rapid during the first two months followed by a slow release later (Fig. 3). The

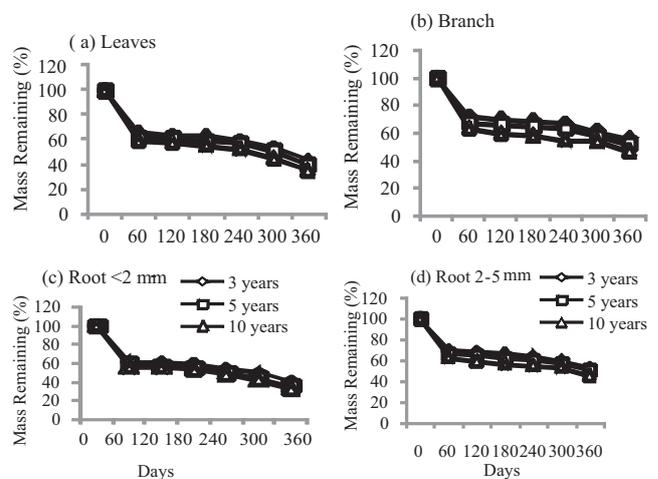


Fig. 2. Mass remaining of four litter components (a) branch (b) leaves (c) root <2 mm (d) root 2-5 mm of *T. candida* in different fallow periods

C release in the initial two months was 48-56% in small root (<2 mm) and leaf. The corresponding values for C loss in coarse root (2-5 mm) and branch varied from 37-47%. The amount of C mass lost at the end of the sampling period was 79-81% and 76-78% in root (<2 mm) and leaf, respectively. This suggests that fine root and leaf are the main source for C input to the soil. High initial C/N ratio in branch and root (2-5 mm) (Table 3) may partially be responsible for slow rate of decomposition rate and nutrient release in the soil (Bauder *et al.*, 2000; Fosu *et al.*, 2007).

Similarly, N mass loss was also rapid during the initial 2 months as a result of higher initial N content in litter components (i.e. 1.54 -2.86%) and lower C/N ratio (Table 3) that may favor the release of N during first recovery (Hoorman *et al.*, 2010). The low N content at the initial stage have significant impact on the decomposition of plant residues as it limits the growth and activity of soil microorganisms. According to Albers *et al.* (2004) the growth of microorganisms in litter decay is limited by nutrients. Quideau *et al.* (2005) reported that leaf litter with significantly higher N content showed faster decay rate in Chaparral ecosystem, in southern California. The percent N mass remaining at the end of sampling period (i.e.1 year) in different component varied from 6-13% with lowest in leaf and highest in the branch litter (Fig. 4). Hoorman *et al.* (2010) reported that the critical values of C/N required for plant residues to transit from immobilization to mineralization was 20:1. The present result showed that the C/N ratio in litter component was below this critical value that tends to speed up the rate of decomposition in plant residues.

Impact of fallow length on litter decomposition and N release pattern

The length of fallow had significant impact on the mass

Table 3. Initial chemical composition of litter components (leave, branch, roots-<2 mm, 2-5 mm) from three different fallow periods in Muallungthu village, Mizoram

| Fallow periods | Litter components | Carbon (%) | Nitrogen (%) | C/N |
|----------------|-------------------|------------|--------------|-----|
| 3 yrs | Leaves | 30±2.28 | 1.88±0.02 | 17 |
| | Branches | 32±2.20 | 1.63±0.03 | 20 |
| | Roots (<2 mm) | 29±2.3 | 1.64±0.03 | 18 |
| | (2-5 mm) | 34±2.37 | 1.54±0.02 | 22 |
| 5 yrs | Leaves | 31±2.25 | 1.93±0.03 | 16 |
| | Branches | 34±2.50 | 1.83±0.03 | 19 |
| | Roots (<2 mm) | 31±2.69 | 1.87±0.02 | 17 |
| | (2-5 mm) | 36±2.69 | 1.81±0.02 | 20 |
| 10 yrs | Leaves | 37±2.53 | 2.86±0.02 | 13 |
| | Branches | 39±2.54 | 2.71±0.02 | 14 |
| | Roots (<2 mm) | 37±2.77 | 2.60±0.02 | 14 |
| | (2-5 mm) | 40±2.30 | 2.54±0.02 | 16 |

Values are means ± SE (n=3)

loss of litter components. Amount of mass lost from different components at the end of study period ranged from 65-55% in FL-10, 61-49% in FL-5 and 57-45% in FL-3. This indicates that the mass loss rate was highest in longer fallow than shorter fallow (Table 2). Similarly, the release of C and N was also higher in FL-10 followed by FL-5 and FL-3. The higher mass loss in longer fallow than shorter fallow may be due to greater rate of decomposition as a result of increased organic matter that act as source of energy and stimulate the activity of decomposers. Likewise, the nutrient release pattern of litter components was affected by the site conditions depending on the fallow age. This is reflected by the higher soil nutrients in the longer fallow compared shorter fallow (Table 1). Ostertag *et al.* (2008) found that litter

Table 2. Decomposition rate, daily decay rate (*k*) and time required for decomposition (*t*₅₀ 50%, *t*₉₅ 95% mass loss) of litter components of *T. candida* in different fallow periods

| Fallow periods | Litter components | Mass remaining (% initial) 365 days | Daily decay rate (<i>k</i>) | <i>t</i> ₅₀ (days) | <i>t</i> ₉₅ (days) |
|----------------|-------------------|-------------------------------------|-------------------------------|-------------------------------|-------------------------------|
| 3 yrs | Leaf | 42.80 ^b | 2.32 ^a | 298.06 ^{ac} | 1290.31 ^a |
| | Branch | 55.27 ^a | 1.62 ^a | 426.55 ^b | 1846.54 ^a |
| | Root (<2mm) | 39.67 ^b | 2.53 ^{ab} | 273.55 ^{abc} | 1184.22 ^a |
| | Root (2-5 mm) | 52.13 ^a | 1.78 ^{ab} | 388.33 ^{ab} | 1681.08 ^a |
| 5 yrs | Leaf | 39.47 ^a | 2.54 ^a | 272.07 ^a | 1177.78 ^a |
| | Branch | 52.13 ^b | 1.74 ^a | 388.33 ^b | 1681.08 ^b |
| | Root (<2mm) | 35.33 ^a | 2.85 ^{ab} | 243.14 ^c | 1052.54 ^a |
| | Root (2-5 mm) | 51.00 ^b | 1.84 ^a | 375.65 ^d | 1626.21 ^b |
| 10 yrs | Leaf | 34.93 ^a | 2.88 ^{ab} | 240.50 ^a | 1041.14 ^a |
| | Branch | 47.00 ^b | 2.06 ^a | 335.02 ^b | 1450.29 ^b |
| | Root (<2 mm) | 32.60 ^a | 3.07 ^{ab} | 225.67 ^c | 976.93 ^c |
| | Root (2-5 mm) | 45.20 ^b | 2.17 ^a | 318.54 ^d | 1378.97 ^d |

Pattern of C and N release in different litter components of *T. candida*

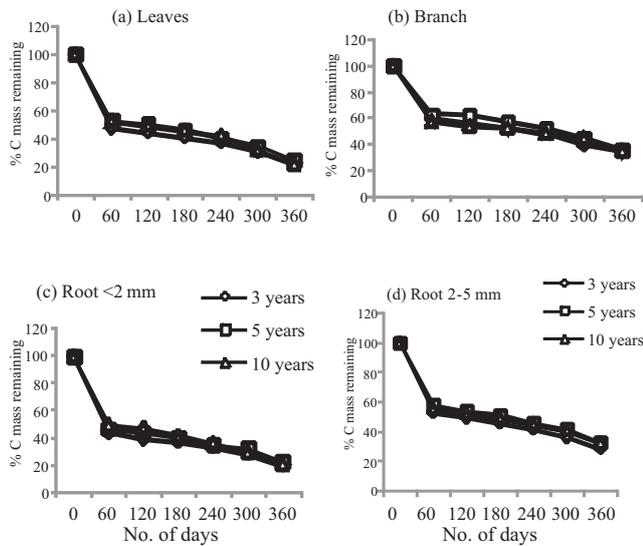


Fig. 3. Carbon (C) release pattern from four litter components (a) branch (b) leaves (c) root <2 mm (d) root 2-5 mm of *T. candida* in different fallow periods

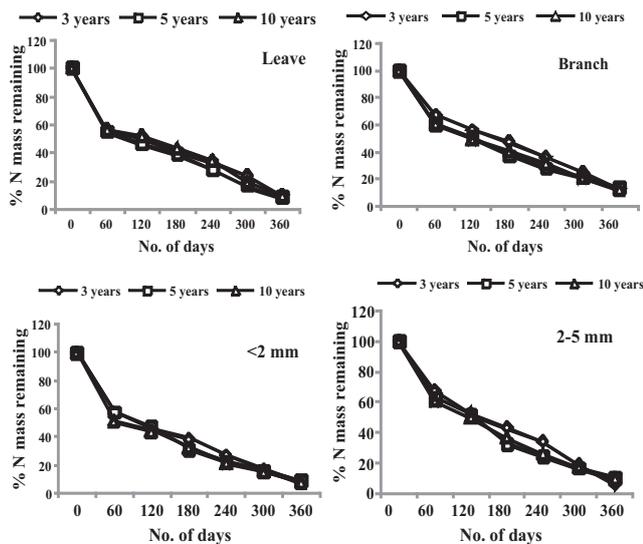


Fig. 4. Nitrogen (N) release pattern from four litter components (a) branch (b) leaves (c) root <2 mm (d) root 2-5 mm of *T. candida* in different fallow periods

decomposition was faster in 60 year old forest than 10 and 30 years old forest. Mayer (2008) also reported rapid litter decomposition in old forests (75 years old) compared to other successional stages.

Relationship between abiotic factors and litter decomposition rate: The abiotic factors (i.e. rainfall, humidity, soil moisture and temperature) had been reported to significantly affect the rate of litter decomposition and C and N release rates (Tripathi and Singh, 1992a and b). In the present study, mass loss was significantly positively correlated with abiotic factors (Table 4). This reflects that the

Table 4. Correlation matrix (r and P values) between mass loss and abiotic factors like rainfall, humidity, temperature and soil moisture of *T. candida* litter components in different fallow periods

| Fallow periods | Rainfall | | Humidity | | Temperature | | Soil | |
|----------------|----------|-------|----------|-------|-------------|-------|------|-------|
| | r | P | r | P | r | P | r | P |
| 3 yrs | 0.52 | 0.008 | 0.54 | 0.006 | 0.50 | 0.013 | 0.64 | 0.005 |
| 5 yrs | 0.51 | 0.010 | 0.53 | 0.007 | 0.49 | 0.013 | 0.51 | 0.010 |
| 10 yrs | 0.53 | 0.007 | 0.55 | 0.005 | 0.53 | 0.008 | 0.57 | 0.003 |

rainfall and its associated variables significantly affect the litter decomposition in all sites by promoting litter microorganisms. The present study demonstrates that abiotic factors play vital role in litter decomposition and C and N release in tropical evergreen forest fallows of Mizoram, northeast, India.

Based on the results, it can be concluded that the different components of *T. candida* can be considered as high quality litter resource to be applied as green manure in *Jhum* the fields for short duration crops such as rice, maize, vegetables etc. Further, the establishment of *T. candida* hedgerows in the *Jhum* fields may positively affect the soil fertility and crop productivity through addition of organic matter, C and N to the soil from different components mainly fine root (<2 mm) and leaf. Longer fallow may add greater organic matter and nutrients to the soil as result of higher decomposition kinetics due to the presence of resources for the microorganisms. Additionally, abiotic factors significantly affected decomposition of litter residue that was corroborated by high decomposition in wet season compared to dry season. High decomposition and nutrient release of *T. candida* litter components in the wet season synchronised the crop demand for nutrients that may lead to boost agriculture productivity in *Jhum* field.

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AMMI Biplot and Regression Analysis for Grain Yield of Basmati Rice Genotypes in Different Production Systems

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Abstract: In green revolutions states, government of India is prioritizing crop diversification replacing rice with alternate crops. Substituting rice with basmati and cultivation through resource conservation techniques like system of rice intensification (SRI) and direct seeding rice (DSR) has been advocated as one of the alternatives. With this aim basmati rice genotypes comprising released varieties and elite lines including an hybrid bred for conventional were evaluated under four production systems involving conventional and non-conventional resource conservation techniques. Estimates of G x E interaction and AMMI biplot analysis of conventional system basmati varieties adapted to non-convention production systems worked out and AMMI biplot model were significant for 5 traits only. The stability parameters and AMMI biplot analysis for grain yield identified genotypes adapted to non-conventional system SRI were Pusa RH 10, HKR 08-417 and Pusa basmati 1509, while Pusa basmati 1121, Pusa basmati 6, HKR 06-425, and HKR-06-434 too yielded better but with negative interaction. Genotype CSR-30, Improved Pusa Basmati-1 and Pusa Basmati-1 were adapted to DSR (wet). HKR 06-434 was found adapted to DSR (dry). The genotypes thus identified for specific production systems could be utilised for diversification replacing non-basmati cultivars in the green revolutionary states of Punjab, Haryana and western Uttar Pradesh.

Keywords: G x E interaction, AMMI biplot, Production systems, Basmati rice, *Oryza sativa* L.

Conventionally, rice is grown by transplanting one month-old seedlings into puddle and continuously flooded soil. The advantages of the conventional system include increased nutrient availability (e.g. iron, zinc, phosphorus) and weed suppression (Surendra, 2010). However, conventional transplanting system (TPR) during puddling creates a hard pan below the plough-zone and reduces soil permeability. It leads to high losses of water through puddling, surface evaporation and percolation. Water resources, both surface and underground, are shrinking and water has become a limiting factor in rice production in the original green revolution states of India namely Punjab, Haryana and Western Uttar Pradesh. Huge water inputs, labor costs and labor requirements for TPR have reduced profit margins. In recent years, there has been a shift from conventional to non-conventional cultivation techniques namely system of rice intensification (SRI) and direct seed rice (DSR) in several countries of Southeast Asia (Pandey and Velasco, 2002). Due to yield stagnation & over exploitation of water resources in the green revolutions states, government of India is prioritizing crop diversification replacing rice with alternate crops. A budgetary allocation of Rs 500 crores in 2013-14 has been made for diversification. Substituting rice with basmati and cultivation through resource conservation techniques has been advocated as one of the alternatives. The basmati

rice requires less water compared to non-basmati rice. The state governments plan to increase basmati rice acreage to around by 40-50% in the next five years while discouraging the cultivation of water-intensive non-basmati paddy (NAAS, 2014). Hence, to promote diversification and enable farmers to choose crop alternative for increased productivity and income technological innovation involving non-conventional production techniques such as SRI and DSR in basmati rice cultivation could be explored to enhance productivity and sustainability in agriculture. The "system of rice intensification" (SRI) that evolved in 1980s in Madagascar is a novel approach to increase the rice production by labor-saving over time, saving water (by 25-50%) and seed (by 80-90%), reducing costs (by 10-20%), and raising paddy output at least 25-50% more and promoting more abundance, diversity and activity of soil biota in and around the plant's rhizosphere. The set of six simple practices such as planting young seedlings (10-12 days), planting seedlings at wider spacing (25 x 25 cm), alternate wetting and drying during vegetative phase to keep soil moist, applying organic manures, weeding with cono weeders and incorporating the weed biomass and crop protection by bio pesticides and bio control agents are emphasized. Grihtlahre and Sarial (2011) reported on an average 12 to 24 % higher grain yield in SRI over normal transplanting. The SRI technology have been

successfully tried out in 25 countries. Many research institutes have initiated experimental trials on SRI across the country in several states including, Tamil Nadu, Andhra Pradesh, Orissa, Tripura, Punjab, West Bengal, Chattisgarh, Karnataka, Assam, Bihar, Himachal Pradesh, Uttarakhand, Jammu and Kashmir and Madhya Pradesh to promote among farmers SRI in paddy cultivation (Grihtlahre *et al.*, 2012).

Similarly an another non-conventional technique, the DSR has been the principal method of rice establishment since the 1950s in developing countries. It was replaced with transplanting during the 1970s in most parts of the world (Pandey and Velasco, 2005). At present, 23% of rice is direct-seeded globally (Rao *et al.*, 2007). As a result of water scarcity and labour issues, farmers are again considering direct-seeding systems in rice production. Direct-seeding methods have several advantages over transplanting. It helps reduce water consumption by about 30% (0.9 million liters acre⁻¹) and reduces the labour requirement. In addition to higher economic returns, DSR crops are faster and easier to plant, are conducive to mechanization, generally flower earlier leading to shorter crop duration (Farooq *et al.*, 2006) and mature 7–10 days earlier and have less methane emissions (Balasubramanian and Hill, 2002) than TPR. To

date, no specific varieties have been developed for the above water saving efficient technologies. Existing varieties used for TPR do not appear to be well-adapted under non-conventional techniques. Varieties differed in their genetic potential and all varieties are not promising for diversification. The varietal response to different production systems is wide (Grihtlahre & Sarial, 2011). Thus, in consonance with national priorities the present investigation was planned and executed with the aim to estimate genotype x environment interaction and AMMI biplot analysis of conventional system basmati varieties adapted to non-convention production systems.

MATERIAL AND METHODS

The experimental materials consisted of almost all released basmati varieties including elite lines grown in green revolution states (Table 1). They were collected from CCSHAU, Rice Research Station, Kaul and Indian Agricultural Research Institute, Regional Research Station, Karnal. The experiments were conducted during *kharif* season, 2014–2015 at CCS Haryana Agricultural University, College of Agriculture, Kaul farm (District, Kaithal) which falls under Sub Tropical region of north India. The soil was clay loam. The experiments were laid out in a randomized

Table 1. List of genotypes used in study

| Code | Genotypes | Pedigree | Year of release |
|------|-------------------------|-------------------------------------|-----------------|
| 1 | Pusa Basmati 1121 | P614-1-2/P614 2-4-3 | 2005 |
| 2 | Pusa Basmati 1509 | PUSA 1301/PB1121 | 2014 |
| 3 | Pusa Sugandh 2 | PUSA 1238-1/PUSA 1238-81-6 | 2001 |
| 4 | Pusa Sugandh 3 | PUSA 1238-1/PUSA 1238-81-6 | 2001 |
| 5 | Pusa Sugandh 5 | PUSA 3A/ HARAYANA BASMATI | 2005 |
| 6 | Pusa Basmati 6 | PUSA BASMATI-1/PUSA 1121-92-8-2-7-1 | 2008 |
| 7 | Pusa Basmati 1 | PUSA 150/ KARNAL LOCAL | 1989 |
| 8 | Improved Pusa Basmati 1 | PB 1//PB 1/ IRBB55 | 2007 |
| 9 | HKR 98-476 | Collected from RRS, Kaul, Haryana | - |
| 10 | HKR 03-408 | Collected from RRS, Kaul, Haryana | - |
| 11 | HKR 06-434 | Collected from RRS, Kaul, Haryana | - |
| 12 | HKR 06-443 | Collected from RRS, Kaul, Haryana | - |
| 13 | HKR 06-487 | Collected from RRS, Kaul, Haryana | - |
| 14 | HKR 08-417 | Collected from RRS, Kaul, Haryana | - |
| 15 | HKR 08-425 | Collected from RRS, Kaul, Haryana | - |
| 16 | Haryana Mahek-1 | Collected from RRS, Kaul, Haryana | - |
| 17 | Haryana Basmati-1 | SONA/BASMATI 370 | - |
| 18 | Traori Basmati | SELECTION BASMATI 370 | 1996 |
| 19 | Super Basamati | BASMATI 320/IR661 | 1996 |
| 20 | CSR-30 | BR4-10/BASMATI-370 | 2001 |
| 21 | Basmati-370 | OLD SELECTION | 1933 |
| 22 | Pusa RH-10 | PUSA 6A/PRR 78 | 2001 |

complete block with three replications in four environments created agronomically termed production systems of rice (Table 2). They are conventional transplanted rice (TPR) and non-conventional via; system of rice intensification (SRI), direct seeded dry (DSR, dry) and direct seeded wet (DSR, wet). Plot size consisted of 5 rows of 2m length and 0.20m breadth. In SRI production system reduced seed rate of 5 kg/ha, young seedling aged 15 days, planted at one seedling per hill in squared spacing of 25 x 25 cm² with fertilizers application of organic and inorganic in 50:50 ratios and irrigation at 5 days interval upto 45 days after transplanting (DAT) were practiced. In organic fertilization, FYM @ 15 t/ha was applied before transplanting. In DSR production system, 2 seeds per hill were sown at 5 cm depth into prepared seed bed on dry soil surface (dry seeding) while pre-germinated seeds after priming for 24 hours were dibbled in puddled soil surface (wet seeding). Irrigation was applied at an interval of 6-7 days when cracks developed on the surface in case of dry while at 5 days interval when surface was just moist in case of wet. In TPR (conventional) production system 25 days old seedlings were transplanted, 2-3 seedlings per hill spaced at 15x 20 cm² with inorganic fertilization of N (150 kg/ha), P (60 kg/ha) and K(60 kg/ha). Irrigation was applied at 3 days interval up to 45 DAT. Seed rate in all three systems was 20 kg/ha. Nursery was sown on 20 June, 2014 for both TPR cultivation and SRI while seedling were transplanted on 17 July in TPR and on 3 July in SRI. Sowing for DSR (dry) and DSR (wet) was done on the same day when nursery was sown. Spray of weedicide was followed in TPR and SRI while hand weeding at 30-35 DAS was done in DSR. The data were recorded for 15 quantitative traits. The G x E interaction was analyzed following Eberhart and Russell (1966) model and

AMMI biplot (Gauch and Zobel, 1989). Pooled analysis of variance combined with joint regression analysis proposed by Yates and Cochran (1938), modified by Finlay and Wilkinson (1963) and made popular by Eberhart and Russell (1966) has been, and still is a popular technique for studying G x E effects and stability. The main problem with stability statistics is that a single model cannot provide an accurate picture because of the genotype's multivariate response to varying environments (Lin *et al.*, 1986), whereas stability indices are usually univariate (Gauch, 1988; Crossa *et al.*, 1990). Stability methods have been used in both univariate and multivariate statistics (Lin *et al.*, 1986). Among the multivariate methods, the additive main effects and multiplicative interaction (AMMI) analysis is widely used for GEI investigation. It was observed only for five traits namely grain yield per plant, harvest index, days to 50% flowering, days to 75% maturity and test grain weight. This paper reports here G x E for grain yield of basmati genotypes adapted specifically to non-conventional production systems.

RESULTS AND DISCUSSION

Pooled analysis of variance: Inconsistent performance of a given cultivar in different environments is termed as G x E interaction. The pooled analysis (Table 3) was highly significant ($p < 0.01$) for genotypes and environments for all fifteen characters studied which revealed that there was considerable variability among genotypes and production systems. The mean squares due to genotype x environment interaction when tested against pooled error were significant for 5 of the 15 traits viz; days to 50% flowering, days to 75% maturity, grain yield per plant, test grain weight and harvest index indicating that genotypes interacted with environments

Table 2. Description of environment

| Environment | E1 | E2 | E3 | E4 |
|----------------------------------|-------|-------|-----------------------------|-----------------------------|
| Description | TPR | SRI | DSR(wet) | DSR(dry) |
| Seed rate (Kg ha ⁻¹) | 20 | 5 | 20 | 20 |
| Seedling age (Days) | 25 | 15 | Direct sowing at 5 cm depth | Direct sowing at 5 cm depth |
| Spacing (cm ²) | 15x15 | 25x25 | 20 (R-R) | 20 (R-R) |
| Seedling Hill ¹ | 2 | 1 | 2 | 2 |
| No. of Irrigation | 30-33 | 18-20 | 18-20 | 16-18 |
| Weeding | Spray | Spray | Hand 30-35 (DAS) | Hand 30-35(DAS) |

Source: Jain and Sarial, 2015

Table 3. Pooled Analysis of variance over 4 environments (production systems) for grain yield in rice (Eberhart and Russell, 1966 model)

| Source | Variety | Environment | Var. X Environment | Env+Var x Environment | Env (Linear) | Env X Var (Lin) | Pooled deviation | Pooled error |
|-------------------------------------|---------|-------------|--------------------|-----------------------|--------------|-----------------|------------------|--------------|
| d.f. | 21 | 3 | 63 | 66 | 1 | 21 | 44 | 168 |
| Grain yield plant ⁻¹ (g) | 21.159* | 399.069* | 10.272* | 27.945* | 1,197.21** | 17.956* | 6.138* | 5.591 |

Table 4. AMMI analysis of grain yield/plant in rice across 4 production systems

| Source | d.f. | Trials | Genotypes | Environments | G*E interaction | PCA I | PCA II | PCA III |
|---------------------------|-------------|--------|-----------|--------------|-----------------|---------|--------|---------|
| | | 87 | 21 | 3 | 63 | 23 | 21 | 19 |
| Grain yield per plant (g) | MSS | 26.306 | 21.158* | 399.06* | 10.27* | 17.34** | 7.10** | 5.20* |
| | % explained | - | 19.41 | 52.3 | 28.27 | 61.64 | 23.06 | 15.28 |

*, ** Significant at 5% & 1% level of significance, respectively

and performed inconsistently over different production systems. Partitioning of variance into linear and non-linear components showed that both linear and non-linear contributed towards $G \times E$ interaction and linear being predominant over non-linear except for days to flowering. This revealed the importance of both linear and non-linear components in determining interaction of the genotypes with environments, though linear showed preponderance. Grihtlahare and Sarial (2011) and Padmavati *et al.* (2013) also revealed the importance of both linear and non-linear components in determining interaction of the genotypes with environments.

Stability parameters: The Eberhart and Russell (1966) model used two parameters (bi and S^2_{di}) to determine stability. S^2_{di} is largely used to rank the relative stability of cultivars. The indication is that bi could be used to describe the general response to the goodness of environmental conditions whereas S^2_{di} actually measures the predictability. According to this model, a stable variety is one that has high mean (\bar{X}_i), unit regression coefficient ($b_i=1$) and the deviation from regression as small as possible ($S^2_{di}=0$). The stability analysis revealed that twenty genotypes had significant regression coefficient (bi) and three significant deviation from regression (S^2_{di}). Of these, nineteen genotypes had significant linear and non-significant nonlinear, two non-linear while one both linear and non-linear components of variance contributing to $G \times E$ interaction. The significant mean square due to genotype \times environment (linear) interaction indicated that a considerable proportion of genotype \times environment interaction was contributed by the linear component. Therefore, prediction for most of the genotypes appeared to be feasible for yield. Highly significant mean squares due to pooled deviation for yield revealed the importance of a non-linear component for total genotype \times environment interaction (Bose *et al.*, 2012). Genotypes Pusa Basmati 1121, Pusa Basmati-6, Pusa Basmati 1, Improved Pusa 1, HKR 06-434 and HKR 08-425 exhibited non-significant S^2_{di} , regression coefficient significantly greater than one, and mean greater than population mean were suitable for better environment. Better environment here refers to TPR and SRI. Genotype Pusa Sugandh 5, Basmati 370 and Pusa RH -10 with regression coefficient significantly less than one and non-significant

Table 5. Stability parameters for grain yield plant⁻¹ of rice genotypes tested over 4 environments (Production systems)

| Genotypes | Grain yield | | |
|--------------------|-------------|-------|------------|
| | Mean | Bi | S^2_{di} |
| Pusa Basmati 1121 | 15.64 | 1.81* | 7.54 |
| Pusa Basmati 1509 | 13.90 | 0.71* | 4.36 |
| Pusa Sugandh 2 | 13.98 | 0.87* | 4.83 |
| Pusa Sugandh 3 | 14.52 | 0.97* | 16.6* |
| Pusa Sugandh 5 | 15.02 | 0.47* | 2.71 |
| Pusa Basmati 6 | 16.51 | 2.17* | -0.17 |
| Pusa Basmati 1 | 14.11 | 1.23* | 0.95 |
| Imp Pusa Basmati 1 | 15.36 | 1.31* | 5.77 |
| HKR 98-476 | 9.70 | 0.53* | -1.32 |
| HKR 3-408 | 11.36 | 0.74* | -0.99 |
| HKR 06-434 | 15.08 | 1.67* | 3.60 |
| HKR 06-443 | 12.56 | 0.63* | 1.89 |
| HKR 06-487 | 11.86 | 1.21* | -1.50 |
| HKR 08-417 | 17.89 | 0.41 | 22.5* |
| HKR 08-425 | 17.11 | 1.59* | -1.30 |
| Haryana Mahek-1 | 11.29 | 0.81* | 1.26 |
| Haryana Basmati-1 | 14.02 | 1.27* | -0.82 |
| Travari Basmati | 14.87 | 0.57 | 18.1* |
| Super Basmati | 12.06 | 1.33* | 6.16 |
| CSR-30 | 10.0 | 1.50* | 0.89 |
| Basmati-370 | 14.26 | 0.44* | -1.04 |
| Pusa RH-10 | 17.60 | 0.32* | 3.93 |
| Mean | 14.03 | | |
| Standard error | | 0.336 | |

*Significant at 5% level of significance

deviation from regression and mean greater than population mean were identified suitable for unfavorable environments DSR (dry & wet). None of the genotypes was found stable. It could be attributed to the fact that majority of these have been bred for conventional transplanting system, hence failed to sustain their performance in direct seeded water deficient production environments.

AMMI analysis: On the other hand, biplot analysis is possibly the most powerful interpretive tool for AMMI models. There are two basic AMMI biplots, the AMMI 1 biplot where the main effects (genotype mean and environment mean) and IPCA1 scores for both genotypes and environments are plotted against each other. In the second AMMI 2 biplot scores for

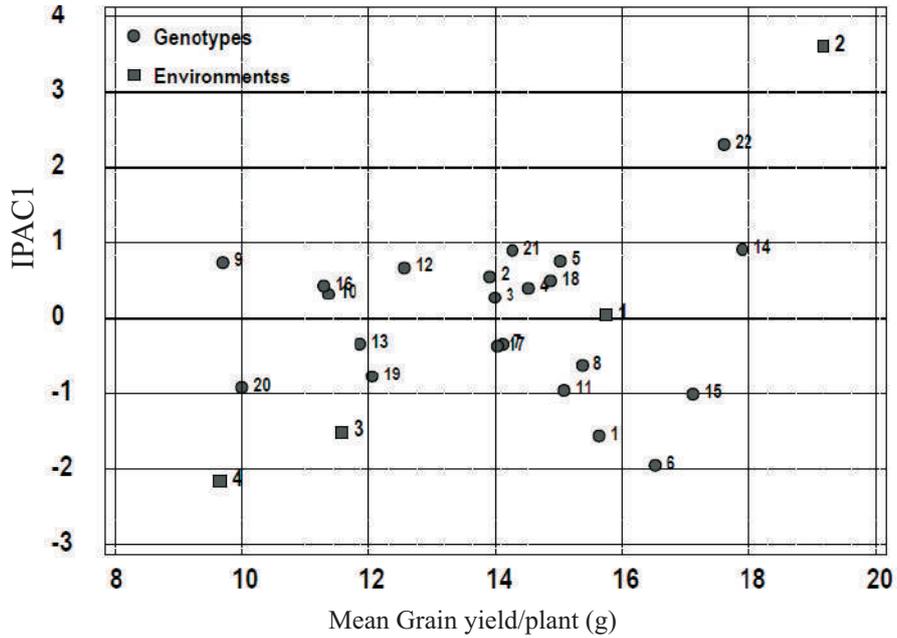


Fig. 1. AMMI biplot of grain yield main effects and GxE interaction of 22 rice genotypes in four environments for grain yield per plant

Legend : 1: Pusa Basmati 1121, 2: Pusa Basmati 1509, 3: Pusa Sugandh 2, 4: Pusa Sugandh3, 5: Pusa Sugandh 5, 6: Pusa Basmati 6, 7: Pusa Basmati 1, 8: Imp Pusa Basmati 1, 9: HKR 98-476, 10: HKR 3-408, 11: HKR06-434, 12: HKR 06-443, 13: HKR 06-487, 14: HKR 08-417, 15: HKR 08-425, 16: Haryana mehak-1, 17: Haryana Basmati-1, 18: Traori Basmati, 19: Super Basmati, 20: CSR-30, 21: Basmati 370, 22: Pusa RH 10, E1: Normal production system, E2: SRI, E3: DSR(wet), E4: DSR (dry)

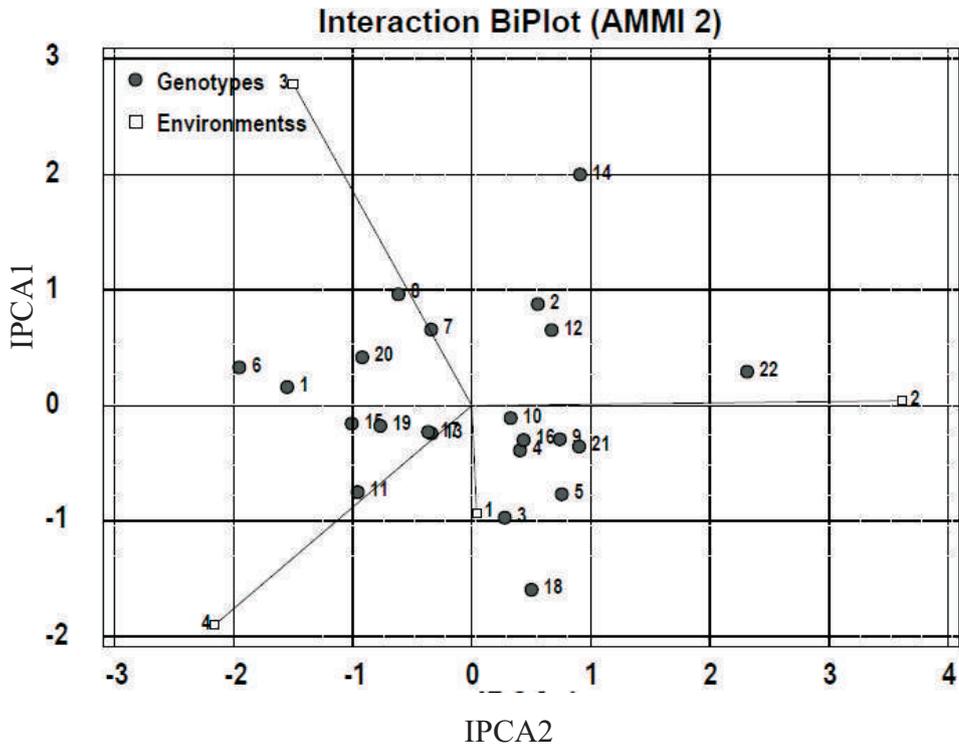


Fig. 2. AMMI-2 model for grain yield showing IPCA scores of rice genotype planted across environment (E)

IPCA1 and IPCA2 are plotted. In case of AMMI 1 biplot, the usual interpretation of biplot is that the displacements along the abscissa indicate differences in main (additive) effects, whereas displacements along the ordinate indicate differences in interaction effects. Genotypes that group together have similar adaptation while environments which group together influences the genotypes in the same way. The best adapted genotype can plot far from the environment. If a genotype or an environment has a IPCA1 score of nearly zero, it has small interaction effects and considered as stable. When a genotype and environment have the same sign on the PCA axis, their interaction is positive and if different, their interaction is negative. The biplot technique was used to identify appropriate genotype adapted to specific environment/ production system. ANOVA based on AMMI had been presented in Table 4. The total sum of squares was attributed to environmental effects (52.3%), genotypic (19.4%) and genotype × environment interaction effects (28.27%). The environments were diverse and caused the greatest variation in grain yield. The genotype × environment interaction mean squares was about 1.5 times larger than that for genotypes, which determined substantial differences in genotypic response across environments. The GE interaction was partitioned among the first three interaction principal component axis (IPCA) as they were significant ($p = 0.01$). The PCA1 explained 61.64% of the interaction while the PCA2 and PCA3 explained 23.06 and 15.28% respectively. They cumulatively captured 99.98% of total GEI using 63 DF. This implied that the interaction of the 22 rice genotypes with four environments was predicted by the first three components of genotypes and environments. The findings were in agreement with those of Islam *et al.*, (2014) and Gauch *et al.* (1996). The AMMI1 biplot of genotypes and environments on the same parallel line, relative or ordinate have similar yields and a genotype or environment on the right side of the midpoint of this axis had higher yields than those of left hand side (Akther, 2014). In AMMI2 biplot the environmental scores were joined to the origin by site lines. Sites with short spokes did not exert strong interactive forces. Those with long spokes exerted strong interaction. The environments of normal production (TPR) system (E1) had IPCA 1 score near zero and short spokes it did not exert strong interactive force, a number of genotypes were adapted to this system having least IPCA 1 score. While environment SRI (E2), DSR (wet) (E3) and DSR(dry) (E4) having long spoke exert strong interaction. Based on AMMI 1 and AMMI 2 the best genotype adapted to SRI production system were Pusa RH 10, HKR 08-417 and Pusa Basmati 1509, while Pusa 1121, Pusa basmati 6, HKR 06-425, Imp Pusa basmati 1 and HKR-06-434 too yielded better but with negative interaction.

Genotype CSR-30, Improved Pusa Basmati-1, Pusa Basmati-1 were adapted to DSR (wet). HKR 06-434 was adapted to DSR (dry).

In general, production systems wise SRI was the best production system in which eighteen genotypes performed better than TPR conventional (data not given). Higher grain yield of rice in SRI was attributed to more number of effective tiller per plant, more panicle length, more panicle weight, high number of filled grain per panicle (Sheehy *et al.*, 2004 and Sinclair and Cassman 2004). Ganesh *et al.* (2006) showed 25% higher grain yield when SR1 was adopted for seed production purpose. Singh, (2007) reported an average 50% increase in yield with 40-50% less requirement for water in experiments conducted over 3 years in SRI environments. Mishra *et al.* (2009) observed 16.6% higher grain yield in SR1 over normal transplanting. Uphoff (2001) observed that the roots of rice plants have least competition under wider spacing so that growth is stimulated by sunlight and space for the canopy expansion thereby increasing the yield attributes and yield. Chen (2013) SRI produced significantly higher grain yield than transplanting. But contrast with Grihtlahre and Sarial (2011) averaged over the environments majority of genotypes gave higher grain yield/plant in conventional production system than SRI. The lowest grain yield in DSR (dry) was due to competition from weeds during early stage of growth and less soil moisture under aerobic rice. The genotype thus identified for specific production systems could be utilised for diversification replacing non-basmati cultivars in the green revolutionary states of Punjab, Haryana and western Uttar Pradesh.

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Effect of Integrated Nutrient Management on Soil Biological Properties and Yield of Rice in Inceptisol

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Abstract: A study was conducted to find out the effect of integrated nutrient management on soil biological properties and yield of rice in Inceptisol at College of Agriculture and Research Station, Janjgir-Champa, IGKV, Raipur during *kharif* season of 2014. The application of 100% GRD+5 t FYM ha⁻¹ recorded significantly higher dehydrogenase activity and soil microbial biomass carbon (SMBC) followed by soil test crop response (STCR) dose (125:50:46) with 5 t FYM for YT 50 q ha⁻¹ over control at tillering and harvesting stage of rice. Whereas non-significant increase in total bacterial count was observed over control. The yield of rice was significantly higher in treatment STCR (125:50:46) with 5 t FYM for YT 50 q ha⁻¹ as compare to rest of the treatments, however it was statistically similar to 100% GRD+ 5 t FYM ha⁻¹, 100% GRD+ 10 kg BGA ha⁻¹ and 100% GRD (100:60:40). It can be concluded that integrated use of organic manures along with chemical fertilizers not only produced highest and sustainable crop yields but also improve the soil biological properties.

Keywords: INM, Rice, Biological properties, Yield, Inceptisol

Soil microbial biomass carbon (SMBC) is a very important biological indicator of soil health and the most sensitive one for assessing short-term changes in soil fertility and quality, although it comprises only 1-4% of the total organic carbon. Thus, low microbial biomass indicates stressed conditions in soil, while high microbial biomass is an indicator of a healthy soil, because physical and chemical properties are shaped by biological activity; and biological activity is enhanced or limited by chemical and physical condition of soil. The SMBC responds very well to seasonal or annual addition of inorganic and organic nutrient sources. Dehydrogenase is considered as an indicator of overall microbial activity because it occurs intracellularly in all living microbial cells and it is linked with microbial respiratory processes. The dehydrogenase activity is commonly used as an indicator of biological activity in soils (Lakshmi *et al.*, 2014). Introduction of efficient strains of biofertilizers in soils may help in boosting up production through increased bacterial population and consequently fixation of more atmospheric nitrogen and more solubilization of insoluble phosphorus from the soil. Organic manures hold promise to supply good amount of plant nutrients, improve soil health and can contribute to crop yields substantially. Integrated nutrient management of fertilizers and organic manures, therefore, is one of the viable options for sustaining soil health *vis-à-vis* crop productivity (Bajpai *et al.* 2006). Continuous integrated use of organic manures with chemical

fertilizers would be quite promising in assessing the sustainability of a cropping system *vis-à-vis* monitoring the soil properties. The present investigation was, therefore, undertaken to study the effects of chemical fertilizers along with different organics with reference to crop yields and soil biological properties.

MATERIAL AND METHODS

A field experiment was conducted during *kharif* season of 2014 to study the effect of integrated nutrient management on soil biological properties and yield of rice in Inceptisol at the Research Farm, College of Agriculture and Research Station, Janjgir-Champa, IGKV, Raipur located at north Mahanadi and the centre of Chhattisgarh and lies between 21°06' to 22°04' North latitude and 82°03' to 83°02' East longitude with an altitude of 294.4 meters above the mean sea level. The unit plot size was 8 × 3.4 m. and spaces between plot to plot and replication to replication were 0.6 and 1 m, respectively. The 21 days old seedlings of MTU – 1010 were planted at a spacing of 20 x 10 cm. The crop matured in about 115-125 days. Nutrients (Chemical fertilizers and Organic manures) were applied as per the treatments. Recommended doses of P and K were applied in the form of single superphosphate (SSP) and muriate of potash (MOP) as basal. Urea was applied in 3 equal splits *i.e.* 1/3rd basal, 1/3rd at tillering and 1/3rd at panicle initiation stages of the rice crop. The required quantity of basal doses of FYM

was applied one month in advance of transplanting. Blue green algae dry flakes were applied after seven days of transplanting in standing water @ 10 kg ha⁻¹ as per the treatments. There were 10 treatments of nutrient with three replications in a randomized block design. Initial soil samples were collected and analyzed for nutrient status by adopting standard procedures. The data on initial soil analysis revealed that the soil was sandy loam (Sand: 52%, Silt: 29.2%, Clay: 18.9%) in texture, neutral in soil reaction (pH 6.96) with non-saline conductivity (0.26 dS m⁻¹). The organic carbon content was 0.27%, and the available N content was low (202 kg ha⁻¹), available P was very low in status (5.3 kg ha⁻¹) and K content was medium (267 kg ha⁻¹). Treatment-wise soil samples were collected at tillering and at harvest stage of rice for dehydrogenase activity in soil was determined by method given by Klein *et al.* (1971). Total bacterial count was estimated by serial dilution method given by Wollum (1982). Soil microbial biomass carbon was determined by the fumigation extraction method as per the procedure of Jenkison and Powlson (1976). The grain and straw yields of rice were recorded at the time of harvest.

RESULTS AND DISCUSSION

Dehydrogenase activity: The dehydrogenase activities at tillering and maturity varied from 20.07 to 25.19 and 16.45 to 20.73 µg TPF g⁻¹ soil day⁻¹, respectively. All the treatments significantly increased dehydrogenase activity over control at both the stages. Dehydrogenase activity at tillering was significantly higher not only over control but also over rest of the treatments because of the treatment 100% GRD + 5 t FYM ha⁻¹ containing both inorganic (100% GRD) and organic (5 t FYM ha⁻¹) sources of nutrients in their treatment combination. However, after harvesting of rice maximum value of dehydrogenase activity was recorded with 100% GRD + 5 t FYM ha⁻¹ which was statistically superior over control but statistically similar with STCR dose with 5 t FYM for YT 50 q ha⁻¹, 100% GRD + 10 kg BGA ha⁻¹ and 75% GRD + 5 t FYM ha⁻¹. Significantly higher dehydrogenase activity in INM treatments might be due to addition of organic matter which in turn increased microbial activity and microbial biomass and consequently increased activity of dehydrogenase (Tejada and Gonzalez, 2009). The applied organic sources were able to get mineralized rapidly in early days of incubation hence, there was more mineralization than immobilization which consequently provided sufficient nutrition for the proliferation of microbes and their activities in terms of soil dehydrogenase. Similar observations were noted by Joychim *et al.* (2008) and Lakshmi *et al.* (2014).

Total bacteria: The population of total bacteria in soil ranged from 4.53 to 5.0 and 4.27 to 4.73 × 10⁷ CFU's g⁻¹ at tillering

and harvesting stage, respectively (Table). There was non-significant increase in total bacterial count over control at tillering and harvesting. A critical observation of the data reveals that the performance of treatment 100% GRD + 5 t FYM ha⁻¹ and STCR dose with 5 t FYM for YT 50 q ha⁻¹, in general was better over other treatments in increasing the total bacterial count in soil. Organic manure addition with inorganic fertilizer showed increase in the microbial population in comparison to chemical fertilizer used alone. Added organic matter acts as a source of the nutrients and also as a substrate for decomposition and mineralization of nutrients, thereby creating a favorable condition for the proliferation of microbes in the soil. Selvi *et al.* (2004) recorded highest bacterial counts at the end of the crop with the addition of FYM along with 100% NPK. Jain *et al.* (2003) reported that FYM + 100% NPK increased the population of *Azotobacter* in comparison to treatments not having FYM.

Soil microbial biomass carbon: The soil microbial biomass carbon in soil, as influenced by integrated nutrients varied from 103.56 to 133.39 and 74.86 to 110.01 µg C g⁻¹ dry soil at tillering and harvesting stage of rice, respectively (Table). All the treatments significantly increased SMBC in soil over control at both the stages. Application of FYM and BGA individually and in combination with inorganics resulted in significant increase in SMBC in soil over control at tillering and harvesting. Application of 100% GRD+5 t FYM ha⁻¹ recorded significantly highest value of soil microbial biomass carbon over control and rest of the treatments except STCR dose with 5 t FYM for YT 50 q ha⁻¹ and was statistically similar to 100% GRD+5 t FYM ha⁻¹. This can be ascribed to direct addition of organic matter through farmyard manure and increase in root biomass which helped in growth and development of soil microorganisms causing beneficial effect on SMBC, SMBN and DHA (Katkar *et al.*, 2011). Application of farmyard manure at 10 t ha⁻¹ significantly increased SMBC, SMBN and DHA over control which might be due to a steady source of organic carbon to support the microbial community (Bhattacharya *et al.*, 2008).

Grain and straw yield: The grain and straw yield of rice as influenced by integrated nutrient management. The grain and straw yield of rice increased from 7.79 to 45.93 and 9.97 to 54.95 kg ha⁻¹, respectively (Table 1). The higher grain and straw yield of rice was in treatment STCR dose with 5 t FYM as compare to rest of the treatments. However, it was statistically similar to 100% GRD+ 5 t FYM ha⁻¹, 100% GRD+ 10 kg BGA ha⁻¹ and 100% GRD (100:60:40). Application of BGA alone could not cause significant increase in yield of grain and straw over control, while FYM individually and in combination with BGA treatment FYM 5 t ha⁻¹ + 10 kg BGA ha⁻¹ significantly increased grain and straw yield of rice over

Table 1. Effect of integrated nutrient management on yield (q ha⁻¹) and biological properties of soil at both stages of rice

| Treatments | Grain yield (q ha ⁻¹) | Straw yield (q ha ⁻¹) | SMBC (µg C g ⁻¹ dry soil) | | DHA (µg TPF g ⁻¹ soil day ⁻¹) | | Total bacteria (CFU 10 ⁷ g ⁻¹ soil) | |
|---|-----------------------------------|-----------------------------------|--------------------------------------|------------|--|------------|---|------------|
| | | | Tillering | Harvesting | Tillering | Harvesting | Tillering | Harvesting |
| Control | 7.79 | 9.97 | 103.56 | 74.86 | 20.07 | 16.45 | 4.53 | 4.27 |
| FYM 5 t ha ⁻¹ | 13.43 | 16.85 | 119.69 | 95.62 | 23.18 | 19.24 | 4.67 | 4.30 |
| BGA 10 kg ha ⁻¹ | 10.13 | 13.05 | 110.60 | 98.75 | 22.10 | 19.30 | 4.67 | 4.30 |
| 100% GRD (100:60:40) | 42.60 | 50.68 | 122.30 | 97.38 | 23.28 | 19.73 | 4.80 | 4.33 |
| 100% GRD + 5 t FYM ha ⁻¹ | 44.76 | 53.38 | 133.39 | 110.01 | 25.19 | 20.73 | 5.00 | 4.73 |
| 75% GRD + 5 t FYM ha ⁻¹ | 40.46 | 48.32 | 129.82 | 102.38 | 23.80 | 20.14 | 4.87 | 4.37 |
| 100% GRD + 10 kg BGA ha ⁻¹ | 43.06 | 51.25 | 130.72 | 102.78 | 24.38 | 20.44 | 4.90 | 4.40 |
| 75% GRD + 10 kg BGA ha ⁻¹ | 38.77 | 46.62 | 122.67 | 86.34 | 23.57 | 19.82 | 4.80 | 4.37 |
| FYM 5 t ha ⁻¹ + 10 kg BGA ha ⁻¹ | 15.84 | 19.08 | 120.44 | 96.72 | 23.25 | 19.61 | 4.77 | 4.33 |
| STCR dose with 5 t FYM for YT 50 q ha ⁻¹ | 45.93 | 54.95 | 131.96 | 109.42 | 24.69 | 20.44 | 4.93 | 4.60 |
| CD (p = 0.05) | 3.96 | 5.16 | 1.71 | 1.01 | 0.46 | 0.68 | NS | NS |

SMBC: Soil microbial biomass carbon

GRD: General recommended dose of fertilizers

BGA: Blue green algae

YT: Yield target

DHA: Dehydrogenase activity

FYM: Farmyard manure

STCR: Soil test crop response

control. The integrated use of fertilizers with organic manures viz., FYM and BGA might have added huge quantity of organic matter in soil that increased grain and straw yield. This might be due to the improvement in physicochemical properties of soil that resulted in better productivity by increasing availability of plant nutrients (Chaudhary and Thakur, 2007). Further, the addition of organic matter also maintains regular supply of macro and micronutrients in soil resulting in higher yields. These results are in conformity with the finding of Gupta *et al.* (2006).

CONCLUSION

The application of organic manure along with chemical fertilizers not only increase yield of rice, but also improve the microbiological properties of soil compared to application of chemical fertilizers alone. The soil microbial biomass carbon and dehydrogenase activity of soil are significantly and beneficially influenced by the treatments of integrated nutrient supply. The performance of 100% GRD+ 5 t FYM ha⁻¹ and STCR dose with 5 t FYM for YT 50 q ha⁻¹ in general, was better over other treatments in increasing the soil biological properties and yield of rice crop. Thus, increase in microbial population due to integrated treatments with both organic and inorganic sources led to the higher soil microbial biomass carbon and dehydrogenase activity and bacterial population in soil which indicate a good soil health.

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Effect of Different Land Use on Quality of Water in Solan Block of Himachal Pradesh

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Abstract: Investigations were conducted in Solan, Himachal Pradesh to determine the quality of water from various sources under four different land use during 2012–2013. Analysis of various parameters viz. pH, EC, BOD, COD, Ca²⁺, Mg²⁺ and Cl⁻ was done. Maximum pH, EC, COD, Ca²⁺ and Cl⁻ were observed under institutional land use system. Maximum BOD and Mg²⁺ were under industrial land use system. Minimum EC, BOD, Ca²⁺ and Cl⁻ were under rural/agricultural land use whereas lowest pH and Mg²⁺ were recorded under urban/suburban land use and lowest COD was under industrial land use. Study indicated that set up of large number of industries and institutes in Solan Block have significantly impacted water quality in the region. Land-use regulation, improved sanitation, treatment plant installation and regulation in industries, provision of community awareness and implementation of catchment management in the area are recommended for water sustainability.

Keywords: Land use, Water quality, Institutional, Industrial, Rural, Urban

Understanding the relationship between land use and surface water quality is necessary for effective water management. The water quality is degraded due to rapid urbanization with intense land use and land cover (LULC) change within watershed and explosive population growth (Chen *et al.*, 2016; Huang *et al.*, 2013). Land use impacts water quality through non-point sources, which are major contributor of pollution to surface and ground water that are difficult to regulate. Land conversion for agriculture and urban development impacts stream and river ecosystem dynamics by changing hydrological regimes and increasing sediment and pollution loads (Zhang *et al.*, 2010). Increasing anthropogenic activities like mining, disposal of treated and untreated waste effluents containing toxic metals as well as metal chelates (Amman *et al.*, 2002; Meitei *et al.*, 2004) from different industries, indiscriminate use of heavy metal containing fertilizers and pesticides in agriculture, irrigation demands, urbanization, deforestation and technological advancement resulted in deterioration of water quality and sustainability of aquatic biodiversity. The availability and quality of fresh water resources is the most pressing of many environmental challenges on the national horizon in India. Stress on water resources is from multiple sources and the impacts can take diverse forms. Geometric increase in population coupled with rapid urbanization, industrialization and agricultural development has resulted in high impact on quality and quantity of water in India (CPCB, 2010). Indian rivers particularly large ones have become highly polluted

due to inflow of domestic, industrial and agricultural effluents. It has been reported that about 70 per cent of the surface water resources are already contaminated (Rao and Mamatha, 2004). Nutrient enrichment of freshwater from a variety of human activities including agricultural runoff, sewage and industrial sources is the most prevalent type of water quality problem (Kling *et al.*, 2014). In many cases groundwater is polluted by the inflow of pollutants such as sewage and industrial wastewater (Khanfar, 2008). The evaluation of water quality in different countries has become a critical issue in recent years due to population increase and growing demand for water (Pesce and Wunderlin, 2000; Paliwal *et al.*, 2007). The degree of pollution is generally assessed by studying physical, chemical and biological characteristics of the water bodies (Duran and Suicmez, 2007). The common land uses of mid hills in Solan have resulted in significant variations in physico-chemical properties of surface water (Rana *et al.*, 2016). Land use changes in Solan, Himachal Pradesh, like construction of roads, establishment of educational institutes, deforestation, change in cropping pattern and excessive use of agrochemicals for better crop production is expected to affect surface water quality. Therefore, regular monitoring of water quality is necessary so that appropriate prevention and remedial measures can be undertaken to control any future consequences related to water pollution (Chauhan and Verma, 2016). Problem of drinking water contamination, water conservation and water quality management has

assumed a very complex shape in the region. Therefore, present study was aimed to evaluate the physicochemical status of water that could provide information for sustainable land use practices in the area to regulate water quality and availability.

MATERIAL AND METHODS

Sample Collection: The collection of samples was done during the year 2012–2013 under different land use systems namely institutional, industrial, urban/suburban and rural/agricultural in Solan Block, which is located between 30°50'30" to 30°52'00" N latitude and 77°08'30" to 77°11'30" E longitude in District Solan of Himachal Pradesh. Twenty water samples were collected from randomly selected surface and ground water sources viz. bore well, hand pump, storage tank, stepwells, ravines, streams and river under each land use system during winter season for analysis. Samples were collected in acid washed one litre plastic bottles as per standard procedure (APHA, 1998). The location and elevation of the sampling sites is given in Table 1.

Water Quality Analysis: The collected samples were labelled adequately and preserved in refrigerator at 4°C. and further physicochemical analysis was carried out in the laboratory as per standard method Table 2.

Statistical Analysis and Comparison: The data emanating from above experiments were subjected to statistical analysis through Two Way Classification. The parameters concentration in water samples were compared with the water quality parameters standards for drinking and domestic purposes set by World Health Organisation (WHO), Central Pollution Control Board (CPCB) and Indian Council of Medical Research (ICMR) Table 3.

RESULTS AND DISCUSSION

Effect of different land use on water quality: pH, EC, COD, BOD, Calcium (Ca^{2+}), Magnesium (Mg^{2+}) and Chloride (Cl) content of water under different land uses Table 4 varied significantly.

Physical parameters: Major land use exerted a significant influence on pH of the water. Under different land use pH of water ranged from 7.24 – 7.92. Highest value of pH (7.92) was noticed in water under institutional land use followed by industrial (7.39) and rural area (7.25), whereas, minimum pH (7.24) was noticed under urban/sub-urban area. Institutional land use resulted in highest pH of water which was probably due to dumping of organic waste, direct discharge of sewage water and further percolation of sewage water that reached the water sources. Badmus *et al.*, (2001) also reported higher pH due to dumping of domestic/organic waste and percolation of waste water through the aquifer to the ground

water. EC ranged from 0.41 – 0.92 dS/m, being significantly higher under institutional areas (0.92 dS/m) followed by industrial area (0.58 dS/m) and urban/suburban (0.49 dS/m) whereas, minimum EC (0.41 dS/m) was noticed under rural land use. Except the water from institutional regions EC of water from other land uses was within the permissible limit as per CPCB standards. Gupta *et al.*, (2003); Nkwocha *et al.*, (2011) also reported that conductance of water increases due to enrichment of organic conducting species from soaps and detergents of the bathing places and dumping of urban waste.

Chemical Parameters: Water under different land use differed significantly in COD values Table 4. Significantly highest value of COD (111.08 mg/l) was noticed in water sources of institutional areas followed by rural areas (83.36 mg/l) and urban/suburban areas (70.08 mg/l) whereas, minimum COD (63.75 mg/l) was under industrial areas. In all the land uses COD of water was above permissible limits. Findings by Garg (1998) and Chadrashekar *et al.* (2003) also indicated increase in COD in the presence of excess oxidizable matter. BOD varied from 1.44 – 12.35 mg/l in water under different land use. Water of industrial area had significantly highest BOD (12.35 mg/l) followed by urban area (5.16 mg/l) and institutional area (2.92 mg/l), whereas, minimum BOD (1.44 mg/l) was under rural area. BOD of water samples was found to exceed the permissible limit under industrial and urban land use. Higher BOD in water sources was probably due to release of high organic matter containing urban solid waste in the urban areas and effluents in the industrial region. Minimum BOD value of water under rural land use may be ascribed to relatively less production of solid waste and recycling of the waste material in manures/compost preparation. Trivedi and Goel (1986) and Mathur *et al.* (2008) also indicated enrichment of water sources with organic matter, domestic waste, soaps and detergents as a reason for high BOD.

Under different land use the Ca^{2+} content of water in institutional area was significantly higher (90.48 mg/l) followed by industrial area (63.05 mg/l) and urban area (54.8 mg/l), whereas, minimum Ca^{2+} (51.28 mg/l) was under rural area. Calcium content of water under institutional land use exceeded the permissible limit. Present results are in agreement with the findings of Pallisamy and Geetha (2007) who have also reported that 98% of world water sources are dominated by calcium and bicarbonate due to limestone weathering. Also, according to Ohle (1955) the water of Solan may be considered calcium rich who has also reported water with calcium concentration of 25 mg/l as Ca^{2+} rich. Water of industrial area was found to have significantly highest value of Mg^{2+} (37.76 mg/l) followed by institutional area (32.43 mg/l)

Table 1. Details of water sampling locations under different land use in Solan

| Land-use | Study area | Locations of water sources | | | | | | |
|---------------------|------------------------|----------------------------|---------------|---------------|--------------|---------------|---------------|------|
| | | Latitude | Longitude | Elevation | Latitude | Longitude | Elevation | |
| Institutional | Bypass Solan | N 30°54'842" | E 077°05'520" | 1405 | N 30°54'675" | E 077°05'934" | 1436 | |
| | | N 30°54'995" | E 077°05'668" | 1430 | N 30°54'838" | E 077°05'514" | 1407 | |
| | Jabli Kyar | N 31°52'056" | E 077°08'102" | 1245 | N 31°52'046" | E 077°08'108" | 1241 | |
| | | N 30°52'077" | E 077°08'087" | 1269 | N 30°52'179" | E 077°08'004" | 1319 | |
| | Bajhol | N 30°51'638" | E 077°07'390" | 1141 | N 30°51'778" | E 077°07'063" | 1232 | |
| | | N 30°51'646" | E 077°07'354" | 1126 | N 30°51'770" | E 077°07'183" | 1248 | |
| | Tatool | N 30°51'601" | E 077°07'431" | 1121 | N 30°51'863" | E 077°07'386" | 1143 | |
| | | N 30°51'700" | E 077°07'366" | 1174 | N 30°51'855" | E 077°07'488" | 1232 | |
| | Nauni | N 30°51'604" | E 077°09'922" | 1247 | N 30°51'614" | E 077°09'917" | 1245 | |
| | | N 30°51'024" | E 077°11'215" | 921.3 | N 30°51'981" | E 077°10'123" | 984.9 | |
| | Industrial | Jatoli | N 30°52'496" | E 077°07'711" | 1387 | N 30°52'495" | E 077°06'767" | 1435 |
| | | | N30°52'519" | E077°07'712" | 1401 | N 30°52'526" | E 077°07'699" | 1378 |
| Shamti | | N 30°53'243" | E 077°06'826" | 1470 | N30°53'326" | E 077°06'745" | 1416 | |
| | | N 30°53'235" | E 077°06'514" | 1460 | N 30°53'292" | E 077°06'765" | 1462 | |
| Salogra | | N 30°55'620" | E 077°07'059" | 1416 | N 30°55'595" | E 077°07'045" | 1479 | |
| | | N 30°55'634" | E 077°06'963" | 1440 | N 30°55'698" | E 077°06'913" | 1455 | |
| Kailar | | N 30°54'844" | E 077°04'542" | 1450 | N 30°54'992" | E 077°04'611" | 1398 | |
| | | N 30°54'978" | E 077°04'626" | 1430 | N 30°54'902" | E 077°04'603" | 1445 | |
| Nagali | | N 30°51'798" | E 077°08'210" | 1332 | N 30°51'759" | E 077°08'211" | 1307 | |
| | | N 30°51'649" | E 077°07'744" | 1225 | N 30°51'688" | E 077°07'702" | 1180 | |
| Urban/ Sub-urban | | Chambaghat | N 30°53'990" | E 077°05'415" | 1443 | N 30°55'415" | E 077°06'027" | 1494 |
| | | | N 30°53'995" | E 077°05'668" | 1436 | N 30°52'018" | E 077°10'225" | 1259 |
| | Solan | N 30°54'120" | E 077°06'306" | 1485 | N 30°54'578" | E 077°06'329" | 1522 | |
| | | N 30°54'236" | E 077°06'412" | 1492 | N 30°54'560" | E 077°06'450" | 1504 | |
| | Salogra | N 30°56'233" | E 077°08'135" | 1304 | N 30°55'840" | E 077°07'818" | 1415 | |
| | | N 30°56'036" | E 077°08'053" | 1402 | N 30°55'915" | E 077°05'879" | 1459 | |
| | Deonghat | N 30°54'326" | E 077°04'960" | 1529 | N 30°53'863" | E 077°05'287" | 1560 | |
| | | N 30°53'765" | E 077°05'365" | 1568 | N 30°54'344" | E 077°04'953" | 1475 | |
| | Saproon | N 30°54'735" | E 077°05'200" | 1303 | N 30°54'391" | E 077°05'280" | 1364 | |
| | | N 30°53'964" | E 077°05'600" | 1411 | N 30°54'392" | E 077°05'091" | 1459 | |
| | Rural/ Agricultural | Sanhol | N 30°53'475" | E 077°06'839" | 1647 | N 30°53'497" | E 077°07'420" | 1827 |
| | | | N 30°53'646" | E 077°07'787" | 1787 | N 30°52'591" | E 077°07'375" | 1379 |
| Basaal | | N 30°55'620" | E 077°05'600" | 1485 | N 30°55'741" | E 077°05'668" | 1546 | |
| | | N 30°55'255" | E 077°05'636" | 1442 | N 30°55'202" | E 077°05'492" | 1469 | |
| Shamti and | | N 30°53'621" | E 077°06'275" | 1506 | N 30°53'590" | E 077°06'302" | 1489 | |
| | | N 30°53'951" | E 077°07'509" | 1923 | N 30°53'439" | E 077°06'917" | 1565 | |
| Shamlech | | N 30°53'230" | E 077°05'277" | 1493 | N 30°53'230" | E 077°05'277" | 1493 | |
| | | N 30°53'435" | E 077°05'216" | 1468 | N 30°53'216" | E 077°05'285" | 1472 | |
| Shamror | | N 30°52'067" | E 077°10'258" | 1286 | N 30°52'096" | E 077°10'241" | 1288 | |
| | | N 30°52'860" | E 077°10'165" | 1328 | N 30°52'197" | E 077°10'216" | 1293 | |

and rural region (27.76 mg/l), whereas, minimum Mg^{2+} (26.87 mg/l) was noticed under urban land use area. Water samples collected from the industrial and institutional land use were found to exceed the permissible limit for magnesium. High magnesium in these areas may be due to landfill leachates

and other wastes that may be the source of Mg^{2+} cations. The present findings are in confirmation with the finding of Hackley *et al.* (1996) who also recorded that landfill leachates were enriched in Ca^{2+} , Mg^{2+} , Na^+ , Cl^- and other anions and cations. The concentration of chloride ions

Table 2. Instruments used for estimation of physico-chemical parameters of water

| Parameter | Instrument/Method |
|----------------------------|--|
| Physical Parameters | |
| pH | pH meter (Model 510 of EIA make) |
| EC | Microprocessor based conductivity/TDS meter (Model 1601 of EIA make) |
| Chemical Parameters | |
| BOD | BOD-System Oxidirect (Aqualytic make) |
| COD | Photometrically by Spectroquant Pharo 300 (Merck made) |
| Calcium and Magnesium | |
| Chloride | |

Table 3. Permissible limits of water quality parameters for drinking and domestic purposes set by World Health Organisation (WHO), Central Pollution Control Board (CPCB) and Indian Council of Medical Research (ICMR)

| Parameters | CPCB | WHO | ICMR |
|--|---------|---------|---------|
| pH | 6.5-8.5 | 6.5-8.5 | 6.5-8.5 |
| EC (ds m ⁻¹) | 0.75 | - | - |
| COD (mg l ⁻¹) | - | - | 20 |
| BOD (mg l ⁻¹) | 5 | 5 | - |
| Ca ²⁺ (mg l ⁻¹) | 75 | 75 | 75 |
| Mg ²⁺ (mg l ⁻¹) | 30 | 30 | 50 |
| Cl ⁻ (mg l ⁻¹) | 250 | 250 | 200 |

Table 4. Effect of different land use on physico-chemical parameters of water

| Land Use | Parameters | | | | | | |
|--------------------|------------|--------------------------|---------------------------|---------------------------|--|--|---------------------------------------|
| | pH | EC (dS m ⁻¹) | COD (mg l ⁻¹) | BOD (mg l ⁻¹) | Ca ²⁺ (mg l ⁻¹) | Mg ²⁺ (mg l ⁻¹) | Cl ⁻ (mg l ⁻¹) |
| Industry | 7.39 | 0.58 | 63.75 | 12.35 | 63.05 | 37.76 | 37.2 |
| Urban/Sub-urban | 7.24 | 0.49 | 70.08 | 5.16 | 54.8 | 26.87 | 29.23 |
| Institutional | 7.92 | 0.92 | 111.08 | 2.92 | 90.48 | 32.43 | 38.06 |
| Rural | 7.25 | 0.41 | 83.36 | 1.44 | 51.28 | 27.76 | 14.05 |
| CD (p=0.05) | 0.34 | 0.39 | 61.54 | 4.45 | 12.85 | 17.65 | 9.57 |
| Permissible limits | 6.5-8.5 | 0.75 | 20 | 5 | 75 | 30 | 250 |

ranged from 14.05 to 38.06 mg/l in water under different land use system. Water of institutional area was found to have significantly highest value of Cl⁻ (38.06 mg/l) followed by industrial area (37.02 mg/l) and urban area (29.23 mg/l), whereas, minimum Cl⁻ content (14.05 mg/l) was noticed under rural land use. The higher content of chlorides was found under institutional area that may be due to sewage, kitchen waste and man excreta which contains higher quantity of chloride. These findings are in conformation with the findings of Dwivedi and Odi (2003), Sanap *et al.* (2006) and Shaikh & Mandre (2009) who reported that chlorides enter water by solvent action of water on salts present in the soil, from polluting material like sewage and trade wastes.

CONCLUSION

Study indicated that Industrialization and institutionalization in Solan has resulted in EC, COD, BOD, Ca²⁺ and Mg²⁺ content in water above the prescribed standards in some water sources. Developmental activities like setting up of more and more institutes and industries have started impacting the water quality due to organic pollution in the area. Therefore, regular water quality analysis, monitoring of land use, improved sanitation,

treatment plant installation and regulation in institutes and industries, provision of community awareness and implementation of catchment management in the area is required to conserve water resources and to maintain the water quality on sustainable basis.

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Impact of Scientific Interventions into Existing Farming Systems on Productivity, Soil Properties and Income Enhancement of Tribal Farmers of Jorhat District of Assam

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Abstract: A case study on inclusion of scientific interventions into existing farming systems of small and marginal tribal farmers were carried out in Silikha Sanatan village of Jorhat District of Assam during 2012-13 to 2014-15 to investigate the influence of inclusion on crop yield, soil properties and profitability of selected farmers. Twelve different existing farming systems were identified and 54 numbers of farmers practicing these were selected for the study. Selected farmers were categorized into resource constraint and resource available farmers and scientific interventions such as multiple cropping, nutrient management, balanced feeding to livestock, farm waste recycling technique and scientific management of crop, livestock, fishes etc. were introduced. Before intervention, mono-cropping of rice was predominant practice in that area. After incorporation of the interventions, multiple cropping with the inclusion of pulses and oilseeds was followed and scientific management led to an improvement in yield for rice crop for all the farming system modules ranging from 8.39 q ha⁻¹ (in case of Crop + Fishery + Duckery module) to 15.20 q ha⁻¹ (in case of Crop + Cattle + Poultry + Duckery + Fishery module). Soil properties such as pH, organic carbon and nutrient status were improved over initial more particularly in case of the farmers growing pulse crop in their cropping sequence. There was improvement in annual net income of the sample farmers after inclusion of scientific interventions for all the modules ranging from Rs. 32183.00 or 24.76 q ha⁻¹ (in case of Crop + Fishery + Duckery module) to Rs. 66987.00 or 51.53 q ha⁻¹ (in case of Crop + Cattle + Duckery + Goatery module).

Keywords: Farming system, Scientific interventions, Crop yield, Physico-Chemical properties of soil, Nutrient status, Profitability

Rural and agrarian nature is the characteristic feature of Assam's economy. The geographical area of the state is 78,438 square kilometer of which 98.4% area is rural, where agriculture and allied activities are the major occupation of the people. As a sector agriculture supports more than 75% of the state's population either directly or indirectly, providing employment to more than 50% of its total workforce. The state is economically backward and ecologically fragile situated in the high rainfall subtropical region, rich with fertile soils of Brahmaputra valley. In spite of having rich and diverse soil conditions, agriculture in the state is fraught with risk and uncertainty because of unpredictable weather conditions along with erratic rainfall and presence of various impediments like recurrent floods, soil erosion, occasional draught like situations, heavy population pressure on land and infrastructural weaknesses. Another striking feature of Assam's agriculture is its subsistence nature with economically unviable small farm size, the average size of operational holding being 1.10 hectares. More than 85% of the farmer families are either small or marginal with average land holding of only 0.63 hectares but in scattered manner

(Economic Survey, Assam, 2015-16). Apart from other natural risks inherent to agriculture, the agricultural activities in the state are predominantly dependent on monsoon. It has been observed that the impact of climate change has affected and led to erratic rainfall and unpredictable monsoon behaviour patterns in the state. This has in turn affected the agricultural productions to a great extent. The net cultivable area of the state is 28.11 hectares, which is about 87.38% of the total land mass available for agricultural cultivation in the state. The ratio of area sown more than once to the net area sown is 48.5%, the area sown more than once being 13.63 lakh hectares (Economic Survey, Assam, 2015-16). Thus more than half of the net cropped area is sown only once (or under monocropping) during a year in the state. Further, in Assam, the soil, topography, rainfall and climate in general are conducive mainly for the cultivation of paddy. Therefore, concentration is high for paddy and total area under paddy cultivation during the year 2014-15 was 24.95 lakh hectares or 72.30% of the total area under food grains in the state (Economic Survey, Assam, 2015-16). Thus, it is apparent that agriculture in the state of Assam is characterized by

mono-cropping (in most of the areas and double cropping in few) of paddy. In addition small size of holding and subsistence nature of farming in the state stands in the way of income and employment generation. Thus, with an average land holding of 1.1 hectare, farmers in Assam cannot fulfil their minimum requirement through mono-cropping or only crop component (Baishya *et al.*, 2017). Apart from helping in increasing population of pest, harmful microbes and weeds which are specific to the crop grown, monocropping also has an adverse affect on soil health and ecology. The steady decline in soil organic matter levels due to continuous cropping without recycling enough crop or animal residues, coupled with nutrient imbalances due to insufficient application of nutrient has led to negative nutrient balance in agriculture, impaired soil health and declining factor productivity (Baishya *et al.*, 2015). In such a situation diversification of crops with livestock, poultry, duckery, fishery, plantation crops, agro-forestry *etc.* in an appropriately planned and scientific manner appears to be promising in boosting up the rural economy. In diversified farming, though crop and other enterprises exist, the thrust is mainly to minimize the risk. While in the Integrated Farming Systems (IFS) a judicious mix of one or more enterprises along with cropping has a complimentary effect through effective recycling of waste and crop residues and encompasses additional source of income to the farmers. These existing farming systems are conducive to develop and practise integrated mode of farming through inclusion of scientific interventions in order to economically harness the outcome of complementary relationship among the integrated enterprises for enhanced yield, profitability, soil health, and for checking depletion of natural resource base, pollution and ecological imbalances. Considering above aspects as well as limitations of location specific studies on IFS, a study was undertaken to assess the impact of inclusion of scientific interventions into existing farming systems in terms of farm productivity, soil sustainability and economic status of the marginal (tribal) farmers in Silikha Sanatan village of Titabar Subdivision of Jorhat district of Assam under rainfed situation.

MATERIAL AND METHODS

Benchmark survey was carried out in the village and the details regarding the location, climatic condition, different experimental techniques, and constraints in the system and scientific interventions provided. The study was conducted during the year 2012-13 to 2014-15 and thus the data collected on meteorological parameters and the primary data on yield, soil properties, cost & returns pertains to the year 2013-14.

Location of the study area: The case study was conducted in Silikha Sanatan village of Titabar Sub-division of Jorhat District of Assam and people from this village mainly belong to Tribal Community and most of the farmers are marginal with a very limited land holding and remain outside the periphery of any kind of scientific interventions in the agricultural field as well as in their household.

Silikha Sanatan village geographically lies at a latitude of 26°33' North and longitude of 94°13 East and at an altitude of 249-410 feet. The climatic condition of Jorhat is sub-tropical humid with warm and humid summer and cool and dry winter. The mean minimum and maximum annual temperature were 19.3° and 29.6°C respectively. Highest total rainfall was recorded on July (462.3 mm) while the lowest was observed on February (10.3 mm). Average monthly relative humidity morning and evening during the year ranged from 55-80% and 90-97%, respectively. The average sunshine hours received during the year were of the range 3.1 hr/day to 7.1 hr/day during the month of May and November respectively.

Selection of farmers: Fifty four farmers were selected with nine identified farming systems. Selected farmers were divided into two groups namely resource constraint on the basis of their land holding, average annual income and resources available (Table 1). The farming systems are denoted as modules and have been given serial number from I to XII which was distributed among two groups depending upon resource availability and hence there was repetition of three farming systems in two groups of farmers (Table 1).

Collection of data: The relevant primary data were collected from the selected farmers with the help of specially designed

Table 1. Different farming systems practiced by the resource constraint and resource available farmers of the village

| Modules | Farming system | No. of farmers |
|------------------------------------|---|----------------|
| Resource constraint farmers | | |
| Module -I | Crop + Cattle + Piggery | 12 |
| Module -II | Crop + cattle + Poultry | 8 |
| Module -III | Crop + cattle + Poultry + Goatery | 1 |
| Module -IV | Crop + Cattle + Duckery + Goatery | 6 |
| Resource available farmers | | |
| Module -V | Crop + Fishery + Duckery | 4 |
| Module -VI | Crop + Cattle + Poultry | 3 |
| Module -VII | Crop + Cattle + Fishery | 3 |
| Module -VIII | Crop + Cattle + Poultry + Duckery | 3 |
| Module -IX | Crop + Cattle + Duckery + Goatery | 2 |
| Module -X | Crop + Cattle + Poultry + Goatery | 3 |
| Module -XI | Crop + Cattle + Poultry + Duckery + Fishery | 5 |
| Module -XII | Crop + Cattle + Poultry + Duckery + Goatery | 4 |

questionnaires through personal interview with the respondent farmers and accordingly the whole village was investigated and interventions were provided after performing constraint analysis. Scientific interventions identified and introduced are given in Table 2.

Soil analysis: Different methods used for analysis of soil properties are presented in Table 3.

Economic analysis: Economics of integrated farming systems was analyzed using different concepts like variable cost, gross return, net return and benefit: cost (B:C) ratio to assess the productivity and profitability of a farm. Variable cost were considered for calculation of cost of production of different enterprises viz., crops (cost involved are seed cost, fertilizer cost, fuel cost, pesticides cost, labour cost and other miscellaneous cost), fishery (fingerlings, fish feed, lime, inorganic fertilizer, organic manure, labour cost), dairy (cost of feed, labour cost, cost of medicine) and apiary (cost of bee-hive, cost of material inputs such as sugar). Thus, the cost of production of different modules was calculated by computing variable costs incurred in different enterprises included in the module, while gross return comprised of the total value of the economic yield obtained from all the enterprises within the

module at prevailing price and net return of a module was calculated by subtracting the total variable cost from the total gross return of a particular module. B:C ratio was computed by dividing gross return by variable cost.

Table 3. Different methods used for analysis of soil properties

| Characteristics | Method followed |
|------------------------------------|--|
| pH | Glass electrode pH meter (Jackson, 1973) |
| Organic carbon (%) | Walkley and Black's method (Jackson, 1973) |
| Available N (kg ha ⁻¹) | Alkaline potassium permanganate method (Subbiah and Asija, 1956) |
| Available P (kg ha ⁻¹) | Bray's method (Jackson, 1973) |
| Available K (kg ha ⁻¹) | Flame photometric method (Jackson, 1973) |

RESULTS AND DISCUSSION

Land use pattern under different cropping sequences in the modules:

Three cropping sequences were introduced in different size of holdings during three seasons viz., *kharif*, *rabi* and summer as intervention where existing was rice-fallow system. Resource constraint farmers were practicing Module-I to Module-IV and resource available farmers practiced Module-V to Module-XII. Highest size of plot among resource constraint farmers was in Module-IV with

Table 2. Scientific interventions identified and introduced

| Enterprises | Constraints Identified | Interventions introduced |
|------------------------------|---|--|
| Crop | i. Mono-cropping of rice ii. Cultivation of long duration improved varieties iii. Poor management iv. Imbalanced use of fertilizers vi. Pest and disease infestation vii. Non-adoption of recommended package of practices | i. Medium duration high yielding, scented rice (<i>Oryza sativa</i>) variety Rajendra Suwasini was introduced. ii. Oilseed crop Toria (<i>Brassica campestris</i>) variety TS-67 was introduced as the second crop in the sequence, where monocropping of rice was prevalent. iii. Pulse crop such as Green gram (<i>Vigna radiata</i>) variety Pratap & blackgram (<i>Vigna mungo</i>) variety PU-31 was introduced for resource constraint farmers as third crop. iv. Nutrient management on the basis of soil test value. v. Crop management following package of practices |
| Dairy | i. Local breed with low productivity ii. Imbalanced feeding and nutrition iii. Shortage of green fodder as well as grasses | i. Artificial insemination of cattle and balanced feeding was introduced. ii. Green fodder crop Setaria (<i>Setaria sphacelata</i>) was introduced. |
| Piggery | | Improved breed of pig (<i>Hempshire</i>) was introduced after de-worming. |
| Goatery | i. Indigenous breed | Improved breed of goat (<i>Beetal</i>) was introduced. |
| Poultry | ii. Unscientific rearing | Improved breed of poultry (<i>Kalinga</i>) was introduced. |
| Duckery | iii. Imbalanced nutrition | Improved breed of duck (<i>Khaki Campbell</i>) was introduced. |
| Fishery | i. Shortage of water by the end of the season iii. Farmers either use minimum amount of feed or never provide feed iii. Non availability of improved fingerlings iv. Fishery banks remain unutilized | i. Existing earthen dug well were converted to 300 m ² pond with the aim to act as fishery as well as water reservoir. ii. Scientific rearing of fishes. iii. Provision of quality fish fingerling. iv. Horticultural crops such as Banana (<i>Musa spp.</i>) variety Dwarf Cavendish, Pineapple (<i>Ananas comosus</i>) variety Kew, local variety of Assam lemon (<i>Citrus lemon</i>) and flower Tube-rose (<i>Polyanthes tuberosa</i>) hybrid Suhasini were introduced on the bank of the fish pond. |
| Apiary | Apiary was not a part of farming system | Introduction and scientific management of apiary near crop field. |
| Composting, Vermi-composting | Resource recycling was not scientific, composting, vermi-composting were not done | Scientific recycling of bio-wastes from IFS through composting and vermi-composting in a cost effective way was introduced. |

4933 m² followed by Module-III, II and I. Farmers following Module-I were having the small amount of holding with 933 m² only (Table 4).

Effect of inclusion of scientific interventions on crop yield: The farmers practicing Module-III (winter rice-toria-blackgram sequence) obtained highest (37.20 q/ha) average yield of rice which might be due to inclusion of legumes in the sequence leading to improvement in soil properties. During *rabi* season, toria was grown in all the areas of the farmer's field. The highest (7.39 q/ha) average yield of toria were obtained by the farmer's practicing Module-VI (rice-toria sequence). Cultivation of greengram and blackgram as summer crop were performed only by the resource constraint farmers practicing Module-I to IV. Module-I and II practicing farmers cultivated greengram where as Module-III and IV farmers cultivated blackgram. The farmers practicing Module-I (rice-toria-greengram sequence) generated highest average yield of greengram with 11.60 q/ha and Module-IV (rice-toria-blackgram sequence) generated highest average blackgram yield with 5.08 q/ha (Table 4). Increase in yield of pulses might be due to better soil properties with the application of fertilizers in addition to that of organic wastes applied in the field that were generated in the farm itself.

Changes in yield parameter in winter rice before and after intervention can be observed from Figure 1, while for the other crops, the intervention was completely new and those were not a part of the farmers existing farming system. Average yield of rice obtained from the existing farming system and from improved farming system varied from 21.50 (Module I) to 27.50 (Module V) and 34.50 (Module XII) to 37.20 (Module III) q/ha, respectively. There was an improvement in yield after inclusion of scientific interventions for all the modules ranging from 8.39 q/ha (Module V) to 15.20 q/ha (Module XI). Such increase in yield of rice might be attributed to scientific cultivation practices and proper nutrient management with inorganic and organic sources of nutrients where a part of the organic wastes generated in the farming systems were recycled for crop production purposes.

Horticultural crops such as pineapple, banana, tuberose and forage crop *Setaria* were introduced in the pond banks of the farmers maintaining fish ponds (Module-V, Module-VII and Module-XI), which before intervention were maintained unscientifically and the banks were left idle. Apart from these modules, green fodder *Setaria* was also grown by the farmers under Module III, IV, VI, VIII, X and XII in the boundaries. Yield from the horticultural and forage crops grown in the banks of fisheries are presented in Table 5.

Table 4. Average grain yield of crops under different cropping sequences

| Modules | Average area (m ²) | Cropping sequences followed | Number of farmers involved | Average grain yield (kg plot ⁻¹) | | | |
|---------|--------------------------------|------------------------------|----------------------------|--|------------------|-------------------|------------------|
| | | | | Winter rice | Toria | Greengram | Blackgram |
| I | 933 | Winter rice-Toria-Green gram | 12 | 340.54 (36.50) | 63.44 (6.80) | 108.22 (11.60) | - |
| II | 2266 | Winter rice-Toria-Green gram | 8 | 826.12 (36.89) | 160.65 (7.09) | 245.19 (10.82) | - |
| III | 3599 | Winter rice-Toria-Black gram | 1 | 1238.43 (37.20) | 229.70 (6.90) | - | 160.45 (4.82) |
| IV | 4933 | Winter rice-Toria-Black gram | 6 | 1815.34 (36.80) | 360.10 (7.30) | - | 250.59 (5.08) |
| V | 4933 | Winter rice-Toria | 4 | 1770.45 (35.89) | 350.24 (7.10) | - | - |
| VI | 4933 | Winter rice-Toria | 3 | 1780.31 (36.09) | 364.54 (7.39) | - | - |
| VII | 4933 | Winter rice-Toria | 3 | 1716.19 (34.79) | 354.68 (7.19) | - | - |
| VIII | 4933 | Winter rice-Toria | 3 | 1721.12 (34.89) | 340.37 (6.90) | - | - |
| IX | 4933 | Winter rice-Toria | 2 | 1809.91 (36.69) | 334.95 (6.79) | - | - |
| X | 4933 | Winter rice-Toria | 3 | 1765.52 (35.79) | 345.31 (7.00) | - | - |
| XI | 4933 | Winter rice-Toria | 5 | 1825.21 (37.00) | 315.71 (6.40) | - | - |
| XII | 4933 | Winter rice-Toria | 4 | 1701.88 (34.50) | 330.51 (6.70) | - | - |

N.B. Figures in parenthesis indicate average grain yield in q ha⁻¹

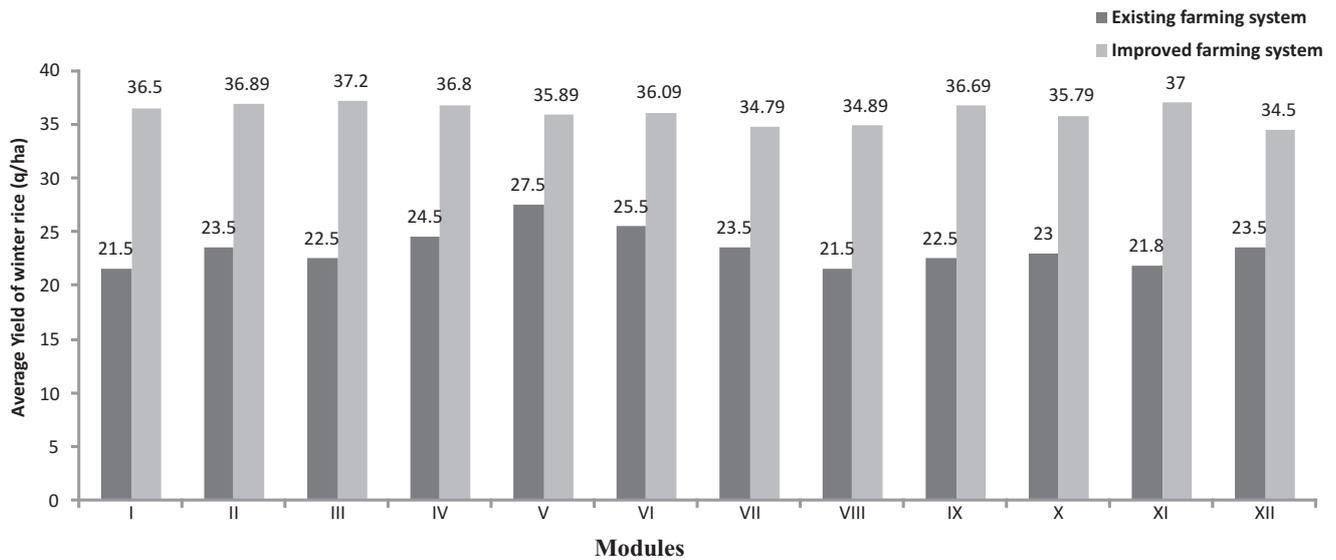


Fig. 1. Average yields of winter rice before and after intervention under different cropping sequences of different modules

Physico-chemical properties of soil: The pH of soil, after completion of the sequences varied from 4.55 to 5.03 (Table 6). There was considerable increase in soil pH after completion of the cropping sequences under different Modules of the farming systems over initial pH of soil (Table 6). Maximum 11.41% increase in soil pH was recorded with Crop + Cattle + Poultry (Module II), where the cropping sequence was rice-toria-blackgram. The soil pH might increase due to the conjunctive use of organic and inorganic sources of nutrients through balanced fertilizer application and application of farm produced organic manure. Such rise in pH value is in conformity with earlier findings of Baishya *et al.* (2015), Ram and Singh (1993) and Prakash *et al.* (2002).

An increasing trend was observed in post harvest organic carbon status of soil in case of all the treatments over the initial OC (Table 6). Soil organic carbon (SOC) ranged between 0.64 and 0.74 per cent and the rice-toria-greengram crop sequence + Cattle + Poultry (Module-II) showed the highest post harvest organic carbon content in soil. Highest (28.57%) increase in SOC was in Module-IV (Crop + Cattle + Duckery + Goatery system) where rice-toria-blackgram cropping sequence was followed. This increase in SOC over initial might be resulted from inclusion of legumes in the sequence. Proper nutrient management through recycling of the various sources of organics as well as use of fertilizers resulted in higher root and shoot growth of crops and thus, increased in production of biomass might have raised the organic carbon content in soil. Such results also correlated the findings of Baishya *et al.* (2015) and Babhulkar *et al.* (2000). The lowest content of organic carbon was recorded after rice-toria sequence in case of the Module-V (Crop + Fishery + Duckery).

Primary nutrient status of soil: Post harvest variation of available N content was from 322.34 to 338.00 kg ha⁻¹ after the cropping sequence (Table 7). Crop + Cattle + Duckery + Goatery Module (Module-IV) showed the highest available N in soil followed by Crop + Cattle + Poultry + Goatery (Module-III) at the end of rice-toria-blackgram sequence. Blackgram being a leguminous crop might be the reason for increasing available N in soil. In case of all the Modules, there was an increase in N over initial; where 1.78 to 8.01 per cent increases in available N over initial status of soil recorded. Similar results were also reported by Jagtap *et al.* (2007). The lowest available N was observed after rice-toria sequence under Crop + Cattle + Duckery + Goatery system (Module-IX).

The available phosphorus in soil (Table 7) revealed an increasing trend across the modules over their respective initial values and the changes in the values ranged from 3.79% (Module VI) to 16.98 % (Module III). Available

Table 5. Average yield of horticultural & fodder crops

| Modules | Average yield of horticultural and fodder crops | | | |
|---------|---|---------------|-----------------|---------------------|
| | Pineapple (Nos.) | Banana (Nos.) | Tuberose (Nos.) | Setaria fodder (Kg) |
| III | - | - | - | 1000 |
| IV | - | - | - | 800 |
| V | 23 | 120 | 277 | 1880 |
| VI | - | - | - | 853 |
| VII | 25 | 128 | 250 | 2000 |
| VIII | - | - | - | 746 |
| X | - | - | - | 826 |
| XI | 20 | 150 | 210 | 1786 |
| XII | - | - | - | 880 |

phosphorus (P_2O_5) was maximum in rice-toria-greengram crop sequence under Crop+ Cattle + Poultry Module (Module-II), followed by the same cropping sequence under Crop + Cattle + Piggery Module (Module-I). The highest available P_2O_5 recorded was 47.00 kg ha^{-1} whereas the lowest availability was 31.50 kg ha^{-1} after the end of the cropping sequence. Application of chemical fertilizers along with the recycling of nutrients by using available organic wastes in the farm itself might be the possible reason of more availability of P_2O_5 in soil. Thus, increase in P availability may be due to the reduction in fixation of water soluble P and increase in mineralization of P due to microbial action that enhanced

the availability of P. The organic anions and hydroxyl acids such as tartaric, citric, malonic and malic acids liberated during the decomposition of organic matter may complex or chelate Fe, Al, Mg and Ca and prevent them from reacting with phosphate. Jagtap *et al.* (2007) reported that organic matter increases the availability of phosphorus by chelating the phosphate fixing cations (Al^{3+} , Fe^{3+} , Ca^{2+}) and exchange of adsorbed PO_4^{3-} ions by organic anions by protective action. Addition of organic matter through recycling of organic wastes reduces the negative effect of P \times Zn interaction action. Such favourable effect of combined application of inorganic and organic source of nutrients in enhancing the

Table 6. Soil physico-chemical properties as affected by the inclusion of scientific interventions into existing farming system

| Modules | Farming system | pH | | | Organic C (%) | | |
|---------|--|---------|-------|----------|---------------|-------|----------|
| | | Initial | Final | % change | Initial | Final | % change |
| I | Crop ⁺ + Cattle + Piggery | 4.55 | 4.95 | 8.79 | 0.57 | 0.72 | 26.32 |
| II | Crop ⁺ + Cattle + Poultry | 4.47 | 4.98 | 11.41 | 0.63 | 0.74 | 17.46 |
| III | Crop ⁺ + Cattle + Poultry + Goatery | 4.49 | 5.00 | 11.36 | 0.56 | 0.71 | 26.79 |
| IV | Crop ⁺ + Cattle + Duckery + Goatery | 4.55 | 5.03 | 10.55 | 0.56 | 0.72 | 28.57 |
| V | Crop ⁺ + Fishery + Duckery | 4.53 | 4.80 | 5.96 | 0.58 | 0.64 | 10.34 |
| VI | Crop ⁺ + Cattle + Poultry | 4.52 | 4.67 | 3.32 | 0.64 | 0.68 | 6.25 |
| VII | Crop ⁺ + Cattle + Fishery | 4.43 | 4.55 | 2.71 | 0.59 | 0.67 | 13.56 |
| VIII | Crop ⁺ + Cattle + Poultry + Duckery | 4.55 | 4.87 | 7.03 | 0.56 | 0.65 | 16.07 |
| IX | Crop ⁺ + Cattle + Duckery + Goatery | 4.49 | 4.87 | 8.46 | 0.63 | 0.67 | 6.35 |
| X | Crop ⁺ + Cattle + Poultry + Goatery | 4.57 | 4.96 | 8.53 | 0.61 | 0.66 | 8.20 |
| XI | Crop ⁺ + Cattle + Poultry + Duckery + Fishery | 4.56 | 4.98 | 9.21 | 0.62 | 0.68 | 9.68 |
| XII | Crop ⁺ + Cattle + Poultry + Duckery + Goatery | 4.51 | 4.94 | 9.53 | 0.63 | 0.68 | 7.94 |

⁺Cropping sequence included is rice-toria-greengram; ⁺Cropping sequence included is rice-toria-blackgram; ⁺Cropping sequence included is rice-toria

Table 7. Primary nutrient status (kg/ha) of soil as affected by inclusion of scientific interventions in to existing farming systems of the sample farmers

| Modules | Farming system | Available N | | | Available P_2O_5 | | | Available K_2O | | |
|---------|--|-------------|--------|----------|--------------------|-------|----------|------------------|--------|----------|
| | | Initial | Final | % change | Initial | Final | % change | Initial | Final | % change |
| I | Crop ⁺ + Cattle + Piggery | 317.55 | 328.50 | 3.45 | 37.88 | 42.57 | 12.38 | 112.54 | 121.44 | 7.91 |
| II | Crop ⁺ + Cattle + Poultry | 320.45 | 331.00 | 3.29 | 41.61 | 47.00 | 12.95 | 109.56 | 122.00 | 11.35 |
| III | Crop ⁺ + Cattle + Poultry + Goatery | 312.85 | 337.33 | 7.82 | 33.45 | 39.13 | 16.98 | 105.43 | 121.60 | 15.34 |
| IV | Crop ⁺ + Cattle + Duckery + Goatery | 312.92 | 338.00 | 8.01 | 36.54 | 41.40 | 13.30 | 113.44 | 122.23 | 7.75 |
| V | Crop ⁺ + Fishery + Duckery | 319.87 | 325.97 | 1.91 | 37.21 | 39.11 | 5.11 | 102.59 | 108.45 | 5.71 |
| VI | Crop ⁺ + Cattle + Poultry | 318.68 | 327.06 | 2.63 | 38.54 | 40.00 | 3.79 | 112.56 | 115.78 | 2.86 |
| VII | Crop ⁺ + Cattle + Fishery | 314.28 | 321.78 | 2.39 | 29.20 | 31.50 | 7.88 | 102.67 | 108.55 | 5.73 |
| VIII | Crop ⁺ + Cattle + Poultry + Duckery | 318.56 | 324.66 | 1.91 | 37.33 | 39.50 | 5.81 | 102.11 | 107.67 | 5.45 |
| IX | Crop ⁺ + Cattle + Duckery + Goatery | 316.55 | 322.34 | 1.83 | 36.80 | 39.33 | 6.88 | 113.23 | 118.00 | 4.21 |
| X | Crop ⁺ + Cattle + Poultry + Goatery | 322.28 | 330.33 | 2.50 | 40.59 | 42.50 | 4.71 | 108.45 | 113.56 | 4.71 |
| XI | Crop ⁺ + Cattle + Poultry + Duckery + Fishery | 313.23 | 324.27 | 3.52 | 37.22 | 40.11 | 7.76 | 112.34 | 117.56 | 4.65 |
| XII | Crop ⁺ + Cattle + Poultry + Duckery + Goatery | 319.54 | 325.22 | 1.78 | 38.00 | 41.15 | 8.29 | 114.45 | 117.75 | 2.88 |

⁺Cropping sequence included is rice-toria-greengram; ⁺Cropping sequence included is rice-toria-blackgram; ⁺Cropping sequence included is rice-toria

availability of P was also documented by Sharma *et al.* (2001) and Gogoi (2011).

The changes in soil available potassium illustrated a positive K_2O balance in the acid soil of Titabar Sub-division (Jorhat district) of Assam (Table 7) for all the modules. The available K_2O after harvest of cropping sequence varied from 107.67 to 122.23 kg ha⁻¹. The highest was recorded after rice-toria-blackgram cropping sequence in case of Module-IV (Crop + Cattle + Duckery + Goatery), which was at par after rice-toria-greengram sequence under Module-II (Crop + Cattle + Piggery). The lowest content of available K was found under Module-VIII (Crop + Cattle + Poultry + Duckery) after rice-toria sequence. While there was a positive change in case of available K_2O for all the modules when compared with their respective initial values, percentage increase in available K_2O was highest in case of Module III (15.34%). This net gain in soil available K after the cropping sequence under different module of IFS may be due to recycling of organic wastes available in the farm itself along with NPK application through chemical fertilizers.

Effect of inclusion of scientific interventions on farm profitability:

Economics of different modules had been calculated and presented in Table 8. Out of different modules practiced by the farmers Module-IV, VII and V practicing farmers received the highest average gross return (Rs. 147523), net return (Rs. 85636) and B:C ratio (2.80), respectively. Out of all the modules, Module-II and Module V offers highest benefit (B:C ratio being 2.65 & 2.80 respectively) for resource constraint and resource available farmers respectively.

Table 8. Economics of different farming system modules practiced by the sample farmers

| Modules | Average gross return (Rs.) | Average variable cost (Rs.) | Average net return (Rs.) | B:C ratio |
|---------|----------------------------|-----------------------------|--------------------------|-----------|
| I | 86029 | 41351 | 44678 | 2.08 |
| II | 109920 | 41514 | 68406 | 2.65 |
| III | 115877 | 51931 | 63946 | 2.23 |
| IV | 147523 | 62256 | 85267 | 2.37 |
| V | 79970 | 28537 | 51433 | 2.80 |
| VI | 118005 | 47190 | 70815 | 2.50 |
| VII | 140882 | 55246 | 85636 | 2.55 |
| VIII | 119410 | 50949 | 68461 | 2.34 |
| IX | 126816 | 50261 | 76555 | 2.52 |
| X | 137680 | 52428 | 85252 | 2.63 |
| XI | 141399 | 58071 | 83328 | 2.43 |
| XII | 138267 | 54622 | 83645 | 2.53 |

Average annual income before intervention (existing farming system) and after intervention (improved farming system) under different cropping sequences of different modules are presented in Figure 2. The notable improvement in annual income of after inclusion of scientific interventions for all the modules ranging from Rs. 32183.00 (Module V) to Rs. 66987.00 (Module IV). Such increase in profitability of the farmers could be attributed to increase in yield from different components of farming systems and improvement in quality of the products due to scientific cultivation/rearing practices and proper nutrient management for all the components of the farming systems. Further, inclusion of suitable farming system components as a part of scientific interventions and

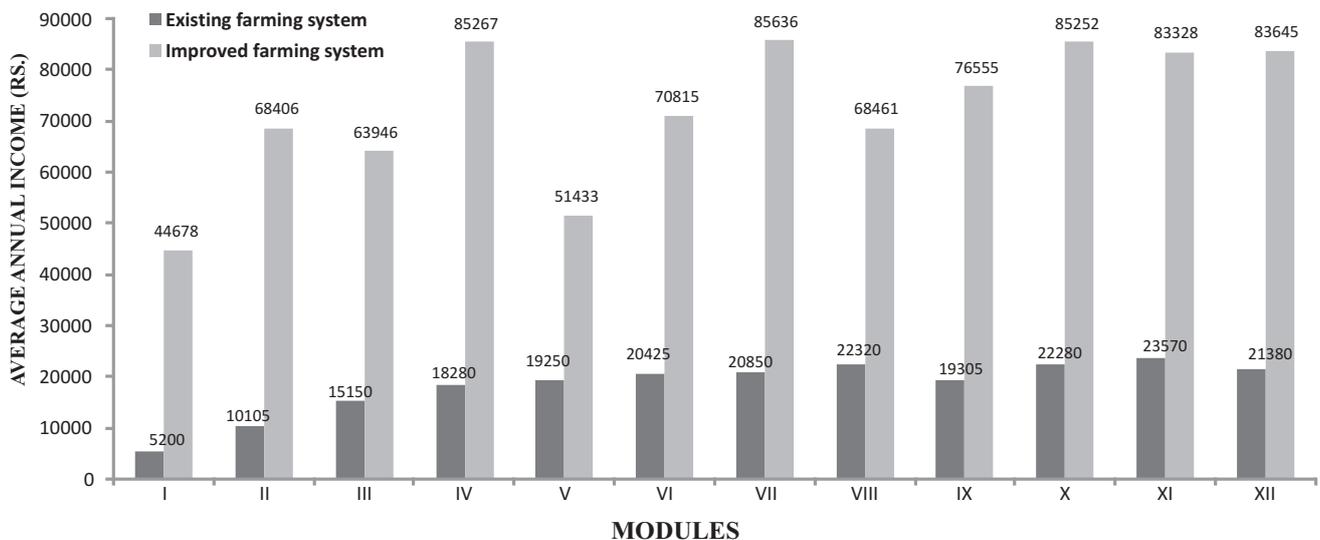


Fig. 2. Average annual income before intervention (existing farming system) and after intervention (improved farming system) under different cropping sequences of different modules

resource (including bio-waste) recycling led to reduction in cost of cultivation and cost of rearing. Prein (2002) and Nhan *et al.* (2007) also found that integration of 2 bullocks + 1 cow + 1 buffalo and 10 goats along with other subsidiaries like poultry and duck is the most beneficial system which can supplement the income of tribal people to improve their socio-economic status. Ugumba *et al.* (2010) also reported that crop, livestock and fishery in an Integrated Farming System (IFS) can be very profitable for the farmers. Ramasamy *et al.* (2008) reported that the income from integrated crop + livestock + goat + poultry was Rs. 98,270 whereas Rs. 28,600 only obtained in traditional farming system. The synergy between different components of an integrated farming system not only provides increased yield but also minimizes dependence on outside purchased chemicals and other inputs, thereby helping in achieving economic efficiency and providing chemical/residue free healthy food apart from a clean surrounding in an environment friendly sustainable way. The continuous flow of money from one or other component system minimizes the financial burden on the farmers (Baishya *et al.*, 2017) (Fig. 2).

From the present study, it can be concluded that with the introduction of medium duration rice variety in the rice-fallow system, *rabi* and *summer* crops can easily be cultivated with available soil moisture as well as pre-monsoon rainfall under the climatic condition of Assam. Inclusion of legumes in cropping sequence (*i.e.* Winter rice-toria-greengram/blackgram) in case of Crop + Cattle + Duckery + Goatery (Module IV) was found to be profitable in case of resource constraint farmers in Silikha Sanatan Village of Titabar Sub-division (Jorhat District) of Assam. On the other hand, module VI (Crop + Cattle + Fishery module) and X (Crop + Cattle + Poultry + Goatery module) with rice-toria sequence may be suggested for the resource available farmers of Silikha Sanatan Village of Titabar Sub-division of Assam for increasing the year round income and employments. Over all, scientific interventions in case of all the IFS modules through complementary relationship by recycling of farm wastes helps in enhancing crop yield, reducing input cost and maintaining the soil health in one way and increasing the productivity and profitability of the system besides reducing environmental pollution caused by bio-wastes generation, in other.

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Optimal Operating Microclimatic Conditions for Drip Fertigated Cucumbers in Soilless Media under a Naturally Ventilated Greenhouse

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Abstract: A study was undertaken to monitor the microclimate within the plant community of cucumbers cultivated in soilless media under a naturally ventilated greenhouse in order to project the desirable microclimatic conditions favourable to plant growth. The air temperature in plant community (T_{apc}) varied in the range of 2.6–14.7 percent and 2.5–17.2 percent respectively for season 1 and season 2 from 0.5 m to 2.0 m height. Both leaf temperature (T_L) and root-zone temperature (T_{rz}) were linearly affected by T_{apc} . On an average $T_{apc} > T_L$, $T_L > T_{rz}$ and $T_{apc} > T_{rz}$ by 8.5, 10.2 and 19.0 percent respectively. VPD which significantly affected the crop performance was directly related to plant water requirement even for higher values (>3.5 kPa). Natural ventilation, shading and fogging (evaporative cooling) significantly affected the impact on greenhouse microclimate and can be adopted to control the microclimate to a great extent through efficient operation. The desirable range of T_{apc} , T_L , T_{rz} , E_{apc} , I_{rad} and VPD were 22.0–27.0°C, 20.5–25.1°C, 16.9–22.9°C, 60.0–85.0 percent, 100.0–169 Wm⁻² and 0.53–1.10 kPa respectively for optimal plant growth and development.

Keywords: Cucumber, Greenhouse, Microclimate, Optimal, Soilless

Cucumber (*Cucumis sativus* L.) grows successfully under conditions of high temperature, humidity and light intensity with an uninterrupted supply of water and nutrients (El-Aidy *et al.*, 2007). Thus, the microclimate within the plant community under a protective structure should be according to the requirement of the crop grown (Singh *et al.*, 2016). Temperature and relative humidity are the two key climatic parameters (Singh *et al.*, 2016, 2017) which affect the cucumber growth, development and quality to a great extent, and consequently the yield. Inappropriate heating during winter and cooling during summer significantly affect the greenhouse microclimate making it unfavourable for plant growth and development. During summer season, when relative humidity goes down and approaches to its minimum value, evaporative cooling can play an important role in maintaining the inside air temperature and relative humidity. The greenhouse cooling can be accomplished by natural ventilation (Willits, 2003), shading and fogging (evaporative cooling) independently or in combination. Natural ventilation is the cheapest, simplest and most energy efficient method of controlling microclimate inside a greenhouse. The entry of unwanted radiation can be controlled by shading which favours the plant growth and development irrespective of nutrients applied (Patil and Bhagat, 2014). Furthermore, greenhouse cooling efficiency can be increased if evaporative cooling is combined with a reduced ventilation

rate.

Vapour pressure deficit (VPD) which is mainly governed by temperature, humidity and radiation level inside the solar greenhouses, affects the greenhouse crop transpiration. Transpiration increases linearly with VPD even for values >3.0 kPa (Medrano *et al.*, 2005) and the mean fruit weight of cucumber gets reduced with an increase in VPD under high relative humidity (Bakker, 1991). The present study was thus undertaken to project the desirable microclimatic conditions for cultivating cucumbers in soilless media under a naturally ventilated greenhouse.

MATERIAL AND METHODS

Description of study area: Research trials were conducted during two consecutive growing seasons of 2016–17 inside a naturally ventilated greenhouse located at Punjab Agricultural University, Ludhiana (latitude 30°56'N and longitude 75°52'E with an altitude of 247.0 m above mean sea level). The naturally ventilated greenhouse was facilitated with foggers and a thermal shade net. The characteristics of the greenhouse are demonstrated in Table 1.

Crop management: The ready cucumber plants were transplanted in soilless growing media (coco-peat) at 3–4 leaf stage. The plant density was 3 plants m⁻². The plants were trained vertically upward to an average height of 1.80 m by

Table 1. Greenhouse characteristics**Characteristics of the naturally ventilated greenhouse (NVG)**

| | | | |
|---------------------------------|--------------|--|----------------------|
| Length (m) | 28.0 | Heating | None |
| Width (m) | 20.0 | Ventilation | Natural |
| Area of floor (m ²) | 560.0 | Net used for NV | 40.0 mesh insect net |
| Orientation | North-South | Area under side ventilation | 20.0 percent |
| Height at gutter (m) | 4.5 | Area under fixed top ventilation | 10.0 percent |
| Height at centre (m) | 6.5 | Foggers | 2.0 m above floor |
| Thickness of cover (m) | 200.0 | Shade net | 2.8 m above floor |
| Transmissivity of cover | 69.0 percent | Area under shade net (m ²) | 384.0 |

interlinking the main stem with a nylon string with the help of roller hooks suspended from an overhead horizontal support wire. The older leaves from the bottom of plants of about 0.30-0.45 m were removed. Cucumbers were fertigated with nutrient solution on daily basis through a semi-automated fertigation system. The nutrient solution was monitored on daily basis for EC, pH value and deficiency of micronutrients as suggested in Shah *et al.* (2009).

Data recording: The climatic parameters viz. radiation, temperature and relative humidity were recorded both inside and outside the greenhouse using sensors installed through a data logger (Delta-T Devices) placed inside the greenhouse. The parameters viz. leaf temperature and root-zone temperature were recorded using infrared thermometer and mercury thermometers respectively. VPD was computed using the equation given by Arellano *et al.* (2006).

Microclimate control: The high temperature particularly from mid May onward imposed serious deteriorating consequences such as loss of firmness, weight loss, decay incidence and reduction in storage life of the fruits. Thus, the greenhouse crops, particularly cucumber should not be kept between 30.0-35.0°C for a long time (Bailey, 2006). In the present study, efforts have been made to maintain the T_{apc} and E_{apc} in the range of 22.0-27.0°C and 60.0-85.0 percent respectively through different possible cooling methods for optimal plant growth. The microclimate under greenhouse was controlled by three possible techniques viz. natural ventilation from sides, fixed ventilation from the top, shading and fogging (evaporative cooling) as suggested in past (Arbel *et al.*, 2003; Bournet and Boulard, 2010).

Natural ventilation: Natural ventilation which directly affects the transport of sensible heat, latent heat and CO₂ to or from the interior air was commonly used for controlling the internal microclimate through ventilation from roof and sides as suggested in a study (Bournet and Boulard, 2010). During autumn, natural ventilation was given at a desired rate for a fixed time during a day (08:45 am-05:00 pm). While, during spring, when the temperature was mounting with time from

mid of March to mid of May, side ventilation was operated between 08:45 am to 05:00 pm from 0 to 34 DAT, between 08:45 am and 07:00 pm from 35 to 45 DAT and finally kept operated at desired rate (day and night) for rest part of the season.

Shading: Thermal shade net was used for improving greenhouse microclimate especially during spring. Shading helped in improving the inside microclimate due to avoidance of direct sunlight, reduced temperature, higher humidity and lower evapotranspiration (El-Aidy, 1990). Shading was not required during autumn season of cucumber cultivation when the inside temperature was low. While during spring, shading was initially used from 12-35 DAT throughout the day, except between 08:45 am and 11:00 pm and finally kept under operation during day solar hours rest of the crop growth period (>35 DAT). Shading positively affected the growth and yield parameters of cucumber.

Fogging (evaporative cooling): Evaporative cooling was the third important tool used for improving the greenhouse microclimate based on spraying water in form of smallest possible drops of diameter 2-60 mm so as to enhance heat and mass exchange between the water and air. During spring, when the relative humidity started reducing and approaches to its minimum value, due to abrupt increase in temperature (>35 DAT), the fogging (evaporative cooling) was performed with reduced ventilation rate to increase humidity and control the temperature.

RESULTS AND DISCUSSION

Variation of air, leaf and root-zone temperature: The air temperature in plant community (T_{apc}) decreased linearly with DAT during season 1 with a negative correlation ($R^2=0.86$). While during season 2, T_{apc} increased linearly with DAT with a positive correlation ($R^2=0.73$). Similarly, leaf temperature (T_L) and root-zone temperature (T_{rz}) decreased and increased during season 1 and season 2 respectively as a result in decrease and increase in air temperature. Both T_L and T_{rz} increased with increase in T_{apc} . T_{apc} was highest and T_{rz} was

lowest throughout the growing period (i.e. $T_{apc} > T_L > T_{rz}$). On an average, $T_{apc} > T_L$, $T_L > T_{rz}$ and $T_{apc} > T_{rz}$ by 8.5, 10.2 and 19.0 percent respectively. Fig. 1 demonstrates the variation in air, leaf and root-zone temperature with time. The desirable range for T_{apc} , T_L and T_{rz} are presented in Table 2. The minimum T_{rz} during both growing seasons, was within the optimum range. The leaf temperature remained consistently lower than air temperature in plant community during both growing seasons.

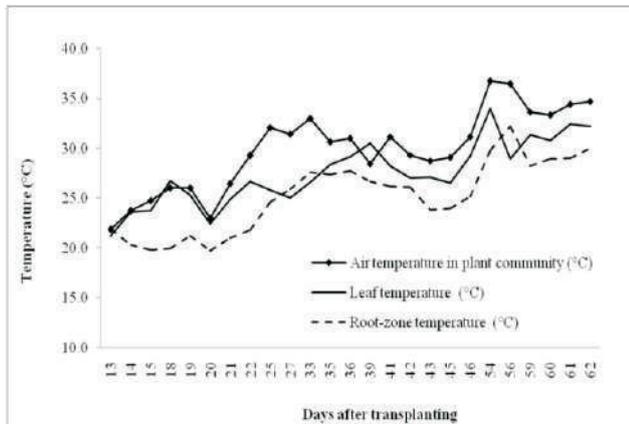


Fig. 1. Variation of T_{apc} , T_L and T_{rz} with time

Variation of air temperature vertically in the plant community: T_{apc} was certainly affected with height within the plant community during both growing seasons (Fig. 2a and 2b). During season 1, T_{apc} increased significantly with height from 0.5 to 2.0 m with an average increment of 7.6 percent. The increment in T_{apc} with height from 0.5 m to 2.0 m was in the range of 2.6–14.7 percent. Similarly during season 2, the increment in T_{apc} with height followed a trend similar to that in season 1. The increase in T_{apc} with height from 0.5 m to 2.0 m was in the range of 2.5–17.2 percent with an average increment of 9.6 percent.

Spatial variation of air temperature in plant community

Taking west boundary of the greenhouse as a reference, the air, leaf and root-zone temperature was monitored at 4.5 m (near west face), 10.5 m (mid of greenhouse) and 16.5 m (near east face) along the width. The air temperature at 10.5 m was higher by 0.4, 3.4, 3.6, 1.7, 3.4, 2.3 and 2.6 percent compared to that at 4.5 m on 10th March, 20th March, 4th April, 14th April, 24th April, 3rd May and 12th May respectively (Fig. 3). However, at 16.5 m, the air temperature was higher by 3.4, 6.4, 8.0, 2.2, 8.0, 3.6 and 4.2 percent on 10th March, 20th March, 4th April, 14th April, 24th April, 3rd May and 12th May respectively. The air temperature remained highest at 16.5 m compared to that at 4.5 m and 10.5 m respectively.

Spatial variation of leaf temperature with respect to plant position in horizontal plane

During season 2, at 13 DAT, there was an increase in leaf temperature (T_L) from 09:00 am to 11:00 pm followed by a decrease from 11:00 am to 15:00 pm and finally an increase from 15:00 pm to 17:00 pm. T_L at 16.5 m was significantly lower compared to that at 4.5 m and 10.5 m respectively. T_L was in the range of 15.9–29.9°C, 15.7–29.8°C and 15.3–26.6°C respectively at 4.5 m, 10.5 m and 17.5 m with lower and upper limits at 09:00 am and 11:00 pm respectively. Fig. 4a and 4b demonstrate variation of T_L with respect to plant position in horizontal plane and day time. Similarly at 42 DAT, there was an increase in leaf temperature from 09:00 am to 12:00 pm followed by a decrease from 12:00 pm to 16:00 pm and finally an increase from 16:00 pm to 17:00 pm. T_L remained highest at 16.5 m and lowest at 10.5 m. T_L was in the range of 24.2–29.3°C, 25.9–28.0°C and 27.9–31.7°C respectively at 4.5 m, 10.5 m and 17.5 m.

Spatial variation of root-zone temperature (T_{rz}) with respect to plant position in horizontal plane: Taking west boundary of the greenhouse as a reference, T_{rz} was monitored respectively at 4.5 m, 10.5 m and 16.5 m distances

Table 2. Seasonal range of microclimatic parameters and desirable range

| Parameter | Seasonal range | | Desirable range | | |
|-----------|----------------|-------------|-----------------|---|----------------------------|
| | Season 1 | Season 2 | Present study | Literature | |
| T_{apc} | 18.0–31.3 | 21.8–36.7 | 22.0–27.0 | Day: 23.9–26.7°C Night: 21.1–23.9°C | Johnson and Hickman (1984) |
| T_L | 15.4–26.6 | 21.2–34.0 | 20.5–25.1 | – | – |
| T_{rz} | 13.7–24.9 | 19.7–32.2.0 | 16.9–22.9 | 20.0 °C | Karlsen (1981) |
| E_{apc} | 43.3–99.9 | 35.3–86.1 | 60.0–85.0 | – | – |
| I_{rad} | 0.001–0.162 | 0.003–0.203 | 0.100–0.169 | – | – |
| VPD | 0.81–2.68 | 0.01–4.55 | 0.53–1.10 | Between 0.8 and 0.95 (Ideal range, 0.45–1.25) | Anon (2017) |

T_{apc} = Air temperature in plant community (°C), T_L = Leaf temperature (°C), T_{rz} = Root-zone temperature (°C), E_{apc} = Relative humidity of air in plant community (percent), I_{rad} = Incoming solar radiation (kWm^{-2}) and VPD = Vapour pressure deficit (kPa).

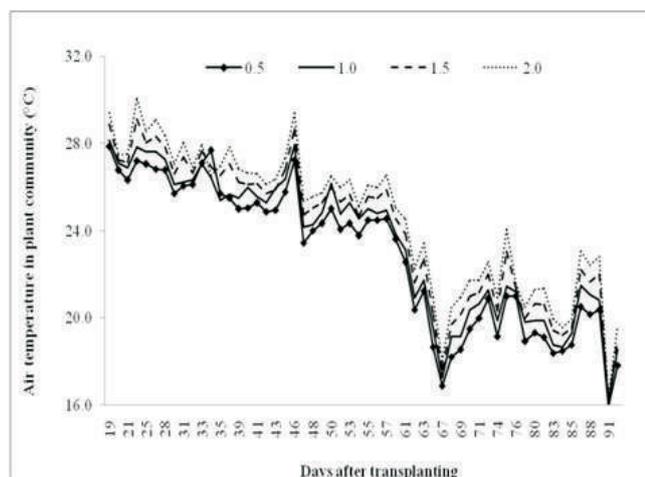


Fig. 2a. Variation of T_{apc} in vertical profile within plant community during season 1

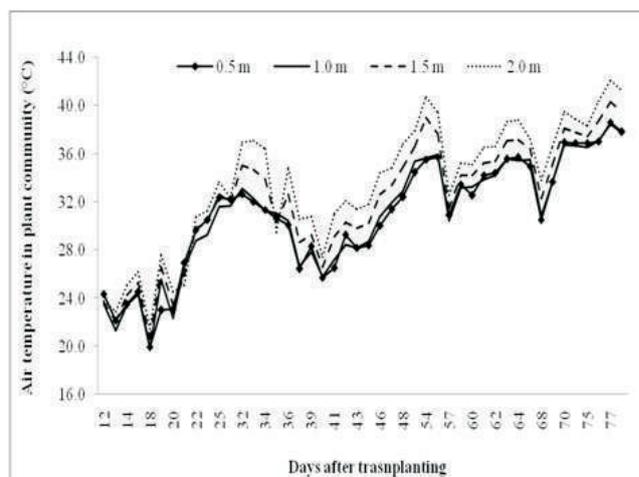


Fig. 2b. Variation of T_{apc} in vertical profile within plant community during season 2

in the horizontal plane and the variation was studied. At 35 DAT, T_{rz} at 16.5 m was significantly higher from that at 4.5 m and 10.5 m respectively. T_{rz} was significantly affected with position of plant in horizontal plane and day time. T_{rz} was highest and lowest at 16.5 m (near east boundary) and 4.5 m (near west boundary) respectively throughout the day time. This temporal and spatial variation in T_{rz} within the greenhouse was responsible for non-uniform plant growth and development. Therefore, maintaining a constant T_{rz} is of great concern for optimal plant growth and development. T_{rz} was in the range of 23.0–28.0°C, 23.5–29.0°C and 26.0–31.0°C respectively at 4.5 m, 10.5 m and 17.5 m. Similarly, at 50 DAT, T_{rz} remained highest and lowest at 16.5 m (near east boundary) and 4.5 m (west boundary) respectively throughout the day time. The difference in T_{rz} at the three selected locations (4.5 m, 10.5 m and 16.5 m) increased with progress of the growing season 2. T_{rz} was in the range of 21.0–27.0°C, 21.5–28.0°C and 27.0–31.0°C respectively at 4.5 m, 10.5 m and 16.5 m. T_{rz} at 16.5 m was significantly higher from that at 4.5 m and 10.5 m respectively. The optimum range of T_{rz} was 19.5–23.5°C. Fig. 5a and 5b demonstrate the variation of T_{rz} with plant position in horizontal plane and day time respectively at 35 and 50 DAT.

Effect of temperature on fruit yield of cucumber: The fruit yield of cucumber was significantly affected by air temperature in plant community, plant temperature and root-zone temperature. Irrespective of the cultivars and fertigation levels, the fruit yield at 16.5 m was higher by 10.7 and 17.7 percent compared to that obtained at 4.5 m and 10.5 m respectively. At the same time, the yield at 4.5 m was higher by 6.3 percent from that obtained at 10.5 m. This happened mainly because of the non-uniform light or radiation

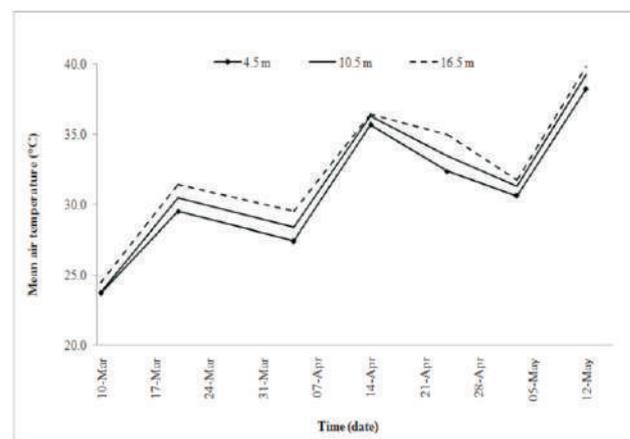


Fig. 3. Spatial variation of air temperature in plant community

interception by the plants. During summer, when radiation intensity or light intensity becomes high and shade nets are used for reduction in entry of light intensity or radiation level to plant community, the insufficient light in the plant community may result in decreased fruit yield in case of cucumber crop as observed in the present study. The radiation or light interception by cucumber plants was lowest at 10.5 m compared to that at 4.5 m and 16.5 m respectively which in turn resulted in lowest fruit yield at 10.5 m.

Vapour pressure deficit (VPD): During season 1, VPD decreased with progress of the growing season. VPD was in the range of 0.03–1.45 kPa, 0.01–0.79 kPa and 0.01–1.27 kPa respectively on 10 October, 10 November and 10 December having upper limits between 13:00 pm and 16:00 pm. The diurnal VPD was generally within optimum range (0.10–1.13 kPa) between 10:00 am to 18:00 pm. Fig. 6a and 6b demonstrate the diurnal variation of VPD with time.

While during season 2, VPD increased abruptly with

progress of the growing season particularly from mid March onward. VPD was in the range of 0.01-2.74 kPa, 0.02-2.79 kPa and 0.26-4.55 kPa respectively on 01 March, 01 April and 01 May having upper limits between 13:00 pm and 14:00 pm. The increasing VPD with progress of growing season significantly affected the plant growth and enhanced the crop transpiration. The desirable range of T_{apc} , T_L , T_{rz} , E_{apc} , I_{rad} and VPD for optimal plant growth and development are given in Table 2.

Effect of temperature, relative humidity and radiation on VPD: VPD was linearly related to temperature and relative humidity and non-linearly with solar radiation throughout the cucumber growth period. On Jan 01, the VPD increased linearly ($R^2=0.85$) with temperature and decreased linearly ($R^2=0.99$) with E_{apc} . VPD was highest (1.44 kPa) at 23.4°C (T_{apc}), 55.9 percent (E_{apc}) and 0.0612 kWm^{-2} (I_{rad}). On Jan 30, when there was no crop in soilless media, the trend was again similar for VPD with respect to temperature, relative humidity and solar radiation for a duration of 24 hours (diurnal variation) having R^2 values of 0.90, 0.99 and 0.69

respectively. However, the maximum value of VPD (1.09 kPa) was at 21.5 °C (T_{apc}), 60.4 percent (E_{apc}) and 0.073 kWm^{-2} (I_{rad}).

Variation of transpiration with VPD: Transpiration increased linearly with VPD and vice-versa. Transpiration was also a function of leaf area index (LAI) and increased with increasing LAI. Both transpiration and VPD were highest during day solar hours generally between 12:00 pm and 03:00 pm. The maximum and minimum values of transpiration and VPD on 01 March, 01 April and 01 May were 207.1, 224.9 and 328.1 $gm^{-2} hr^{-1}$ and 2.7, 2.8 and 4.5 kPa respectively. Transpiration varied linearly with VPD even for higher values of VPD (>3.5 kPa). Similar observation has been made by Medrano *et al.* (2005). The increased transpiration with increasing VPD particularly under hot climate may significantly increase the input irrigation water or nutrient solution. Furthermore, knowing transpiration may help to improve irrigation control in soilless cultivation of crops under greenhouse conditions (De Boodt and Verdonck, 1972). Transpiration was highly correlated with VPD in each case (R^2 0.95).

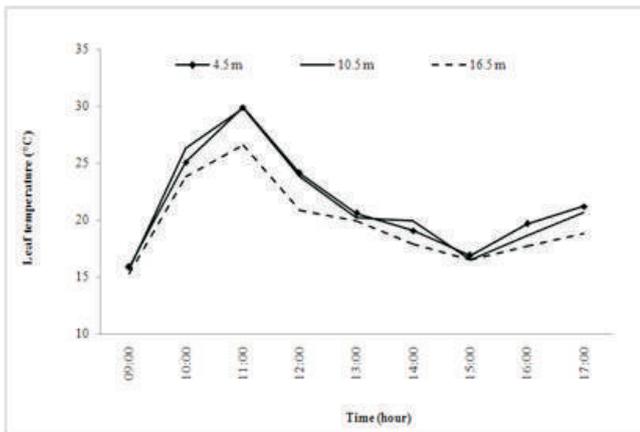


Fig. 4a. Variation of T_L in horizontal plane at 13 DAT

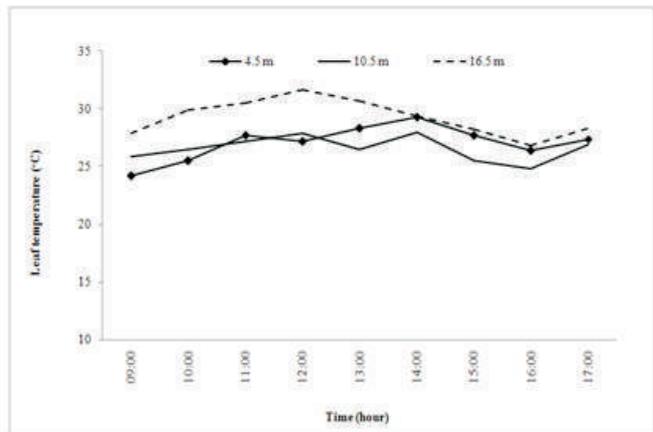


Fig. 4b. Variation of T_L in horizontal plane at 42 DAT

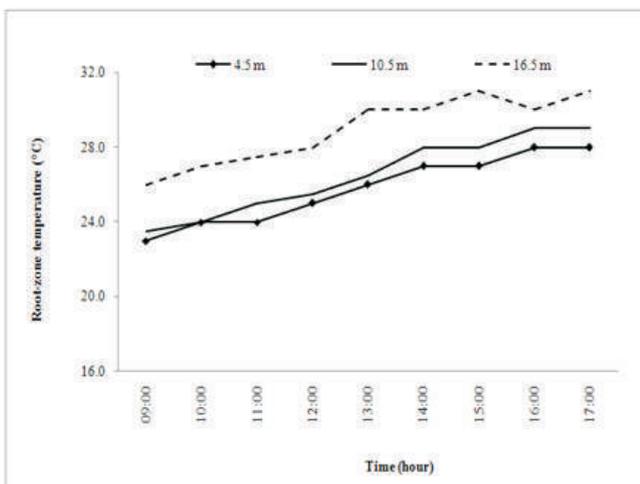


Fig. 5a. Variation of T_{rz} in horizontal plane at 35 DAT

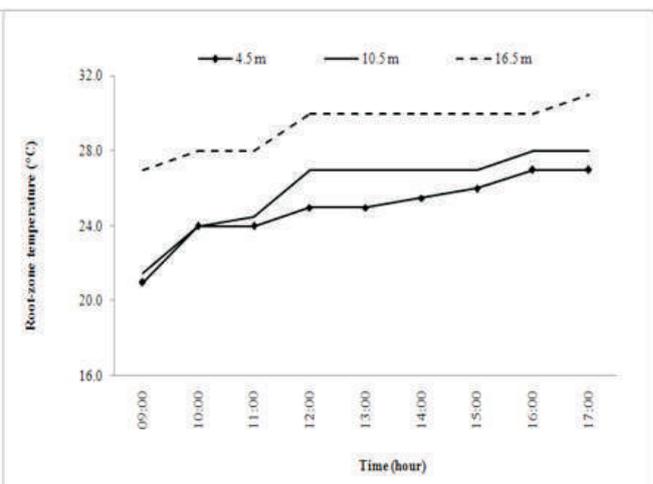


Fig. 5b. Variation of T_{rz} in horizontal plane at 50 DAT

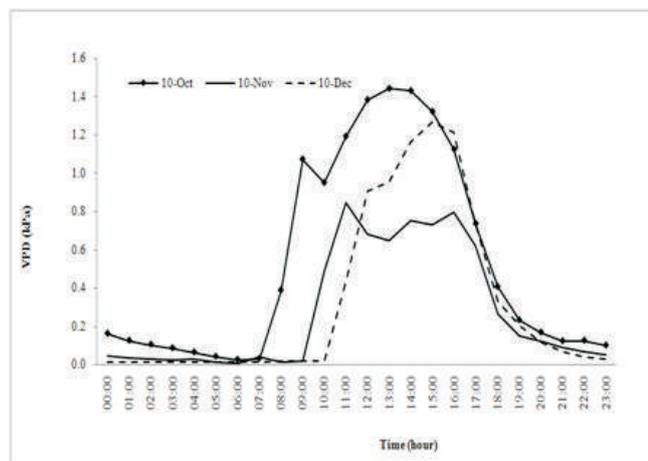


Fig. 6a. Diurnal variation in VPD during season 1

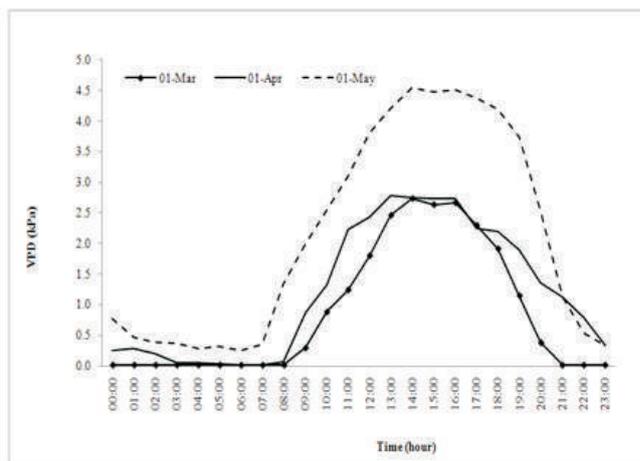


Fig. 6b. Diurnal variation in VPD during season

CONCLUSIONS

The fruit yield of cucumber was affected by non uniform distribution of air temperature (T_{apc}), leaf temperature (T_L), root-zone temperature (T_{rz}), relative humidity (E_{apc}), solar radiation (I_{rad}), vapour pressure deficit (VPD) and transpiration. Natural ventilation, shading and fogging (evaporative cooling) had a significant impact on greenhouse microclimate and can be adopted to control the microclimate to a great extent through efficient operation. The desirable range of T_{apc} , T_L , T_{rz} , E_{apc} , I_{rad} and VPD were 22.0–27.0°C, 20.5–25.1°C, 16.9–22.9°C, 60.0–85.0 percent, 100.0–169 Wm⁻² and 0.53–1.10kPa respectively for optimal plant growth and development. Thus, monitoring and maintaining the greenhouse microclimate in desired range is of great concern for optimal plant development and productivity.

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Effect of Varying Drip Irrigation Levels and Different Methods of NPK Fertilizer Application on Growth And Productivity of Broccoli (*Brassica oleracea* L.var. *Italica*)

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Abstract: The present study was conducted at experimental farm of CSK HPKV, Palampur, during the year 2012–2013 with the objectives of evaluating the effects of drip irrigation levels applied at CPE 0.4, 0.6 and 0.8 and different methods of fertilizer application on growth, quality parameters, productivity and nutrient uptake of broccoli. The treatments comprised of (a) three drip irrigation levels viz., $I_{0.4}$ – Drip at 40 per cent CPE, $I_{0.6}$ – Drip at 60 per cent CPE and $I_{0.8}$ – Drip at 80 per cent CPE (b) three fertilizer application levels viz., F_{100} – 100 per cent recommended dose of fertilizer through fertigation, $F_{C25+F75}$ – 25 percent recommended dose of fertilizer through conventional method as a basal dose and 75 per cent through fertigation and F_{CF} – 100 per cent of recommended dose of fertilizer through conventional method and fertilizers, (c) control – Flood irrigation of 4 cm at 8–10 days interval + 100 per cent recommended dose of fertilizer and (d) absolute control – No recommended dose of fertilizer and flood irrigation of 4 cm at 8–10 days interval. The broccoli cv. Palam Samridhi was transplanted on October 31, 2012. The results indicated that $I_{0.8}$ and I_{Rec} had higher soil water content in comparison to $I_{0.4}$ and $I_{0.6}$. The $I_{0.8}$ treatment due to favorable soil moisture regimes led to better root and shoot growth, higher leaf area index and marketable curd yield in comparison to $I_{0.4}$, $I_{0.6}$ and I_{Rec} . The F_{100} and $F_{C25+F75}$ treatments had higher root and shoot growth and marketable curd yield in comparison to F_{CF} . The marketable curd yield obtained under $I_{0.4}F_{100}$ was at par with $I_{0.6}F_{100}$ treatment, which resulted in saving of 20 per cent irrigation water.

Keywords: Drip irrigation, Fertigation, Leaf area index, Marketable yield

The competition for water between agricultural, industrial and urban consumers creates the need for continuous improvement of irrigation practices in crop production in the world. Efficient use of water by irrigation is becoming increasingly important, and drip irrigation may contribute substantially to the best use of water for agriculture, improving irrigation efficiency (Sezen *et al.*, 2006). Earlier studies have shown that drip irrigation is the most suitable method for vegetable crops and it is possible to increase water use efficiency (WUE) by well scheduled irrigation programs, such as broccoli (Thompson *et al.*, 2002), cucumber (Yuan *et al.*, 2006), eggplant (Aujla *et al.*, 2007), potato (Erdem *et al.*, 2006), tomato (Cetin and Uygan, 2008), and watermelon (Erdem and Yuksel, 2003). The right combination of water and nutrients is the key for increasing the yield and quality of produce. The availability of N, P and K nutrient was found. Limited information is available on the quantity of water to be applied through drip and on application of water soluble fertilizer through fertigation, which have become recently available in the market in broccoli (*Brassica oleracea* var. *italica*). With this background, the study has

been planned with the objectives on water and nutrient use efficiency.

MATERIAL AND METHODS

A field experiment was conducted at CSK Himachal Pradesh Krishi Vishwavidyalaya, Palampur, during *rabi* season 2012–13. The broccoli cv. Palam Samridhi was transplanted on Oct 31, 2012 at 45 cm x 45 cm spacing in 6 x 2 m (12 m²) plots. The area lies in Palam Valley (32°06' N latitude and 76°33' E longitude) at an elevation of 1290 m above mean sea level of Kangra district of Himachal Pradesh and represents the mid hills sub humid agro climatic zone of Himachal Pradesh in North Western Himalayas. The soil is classified as Alfisols–Typic Hapludalf (Verma 1979) with a pH value of 5.08, low in available N (198.76 kg ha⁻¹), high in available P (46.79 kg ha⁻¹) and medium in available K (224.88 kg ha⁻¹). The mean weight diameter of the aggregates for the surface layer was 1.919 mm with infiltration rate of 1.753 x 10⁻⁵ m s⁻¹. The experiment was laid out in a randomized block design with eleven treatments comprising of (a) Three drip irrigation levels viz., $I_{0.8}$ (0.8 CPE), $I_{0.6}$ (0.6 CPE) and $I_{0.4}$ (0.4

CPE) and three methods of fertilizer application levels viz., 100 per cent through fertigation, 25 per cent basal dose through conventional fertilization method and 75 per cent through fertigation and conventional fertilization. The RDF (Recommended dose of fertilizer) was kept same in all the treatments. Besides this there was one recommended practice (RP) i.e., control (I_{rec}) i.e. flood irrigation of 4 cm at 8–10 days interval along with 100 per cent recommended dose of fertilizer and (d) absolute control where flood irrigation of 4 cm was given at 8–10 days interval and with no recommended dose of fertilizer. The treatments were replicated thrice. The averaged pan evaporation data (2004–05 to 2011–12) was used to determine the amount of water to be given in the ratio of 0.8, 0.6 and 0.4 cumulative pan evaporation (CPE). The drip irrigation was given at 2 day interval. In NPK fertigation treatments, water soluble fertilizers viz., 19:19:19+12:61:0+Urea was applied in different calculated proportions injected through overhead fertilizer tank at 8–10 days interval. In fertigation treatments NPK fertilizer doses calculated as per treatment were applied in 10 equal splits at 8–10 day interval through fertigation in 100 per cent fertigation treatment and in seven equal splits at 8–10 day interval in 75 per cent fertigation treatment. In conventional fertilization treatment and control half of nitrogen fertilizer and full of phosphorous and potassium fertilizers were applied at transplanting. The remaining half of nitrogen fertilizer was applied in two splits, first after 30 days of transplanting and second at head formation stage.

The drip laterals fitted in 27 plots were selected starting from first to last plot. In each plot, 10 drippers were selected and the containers were kept at the respective drippers. The whole system was operated for one minute and water was collected in each container. The discharge variation was calculated by the following equation (El Nemr 2012).

$$\text{Discharge variation (\%)} = \frac{Q_{\max} - Q_{\min}}{Q_{\max}} \times 100$$

where,

' Q_{\max} ' is the maximum discharge rate (Litre h^{-1}) and ' Q_{\min} ' is the minimum discharge rate (Litre h^{-1})

The uniformity coefficient (U.C) was calculated by the following equation (Christiansen 1942).

$$U.C (\%) = 100 \left[1 - \frac{\sum_{j=0}^n [q^j - \bar{q}]^2}{n \bar{q}^2} \right]$$

Where, 'n' represents number of emitters evaluated, ' q_j ' is the discharge through emitter and ' \bar{q} ' is the average discharge rate.

The overall averaged discharge rate and discharge variation was 4.05 Litre h^{-1} and 17.11 per cent respectively. Also the overall averaged uniformity coefficient was 94.57

per cent. Depth wise soil samples were collected from three replications at four places 15 cm away from the dripper. For analyzing the growth pattern of the crop, five plants were selected randomly from the net plot area in each treatment. Plant height (cm) was measured from base of the plant to the tip of the growing point at 90 DAT. Number of leaves per plant were counted in randomly selected five plants at 90 DAT. The fresh marketable curd yield and haulm of broccoli was recorded at harvest and expressed in $Mg\ ha^{-1}$. Leaf area index was determined at 90 DAT. Leaf area index was calculated by the formula given below

$$\text{Leaf area index} = \frac{\text{Leaf area}}{\text{Ground area}}$$

Root growth parameters, viz. root volume, root length and root mass per plant were determined at 90 DAT. The cores were excavated from randomly selected plants to obtain roots. Root length was measured in a glass bottom shallow dish of 40 x 20 cm dimension. The wet roots were cut from the root shoot joint and spread randomly into the dish containing some water with the help of forceps and needle so that they did not overlap. The long branched roots were cut into smaller pieces. The counts for inter sections of roots (N) with vertical and horizontal lines of one cm grid from the graph paper were recorded. Care was taken to avoid more than 400 counts at one instance. Root length was computed using the modified version of Newman (1966) method as proposed by Marsh (1971) as

$$\text{Root length} = \frac{11}{14} \times \text{number of intersections (N)} \times \text{grin unit}$$

The volume of roots was determined by volume displacement method. The roots then dried in an oven at 65°C to a constant weight and finally the dried weight was taken. The primary root diameter was determined by vernier calliper.

RESULTS AND DISCUSSION

Growth parameters

Plant height: The plant height recorded at 90 DAT indicated that the plant height in $I_{0.8}$ was significantly higher than $I_{0.4}$ and $I_{0.6}$ and this may be attributed due to higher quantity of irrigation applied throughout the crop growth period Table 1. The plant height recorded in F_{100} was significantly superior over $F_{C_{25+F75}}$ and F_{CF} . Similar results were reported by Domber *et al.* (2010), Patel *et al.* (2011). The higher plant height in F_{100} was probably due to better utilization of recommended NPK dose through drip system applied through water soluble fertilizers in comparison to the conventional method of fertilizer application in F_{CF} . The plant height recorded under 'control' vs. 'others' treatment varied significantly with a higher value in 'others' treatments than 'control'. Similar

findings were reported by *Nilesh and Gulati (2004)*.

Number of leaves per plant: The highest number of leaves per plant was in $I_{0.6}$ followed by $I_{0.8}$, both were statistically at par Table 1. However, number of leaves per plant in $I_{0.6}$ and $I_{0.8}$ was significantly higher than $I_{0.4}$. The number of leaves per plant was higher under $I_{0.8}$ and $I_{0.6}$ due to application of more quantity of water indicating higher soil moisture availability in comparison to $I_{0.4}$. Similar findings were also reported by *Arunadevi et al. (2007)*.

Table 1. Effect of drip based irrigation and method of fertilizer application on shoot growth and leaf area index during crop growth

| Treatment | Shoot growth 90 DAT | | Leaf area index 90 DAT |
|---|---------------------|--------------|------------------------|
| | Plant height (cm) | No of leaves | |
| Drip irrigation levels | | | |
| $I_{0.4}$ | 36.28 | 16.00 | 0.84 |
| $I_{0.6}$ | 41.39 | 19.22 | 1.02 |
| $I_{0.8}$ | 44.60 | 19.00 | 0.95 |
| CD ($p=0.05$) | 1.548 | 1.936 | 0.140 |
| Method of fertilizer application | | | |
| F_{100} | 43.17 | 18.78 | 0.92 |
| $F_{C25+F75}$ | 40.70 | 17.89 | 1.01 |
| F_{CF} | 38.40 | 17.56 | 0.88 |
| CD ($p=0.05$) | 1.548 | NS | NS |
| Control vs. Others | | | |
| Control | 37.00 | 16.67 | 0.65 |
| Others | 40.76 | 18.07 | 0.95 |
| CD ($p=0.05$) | 1.998 | NS | 0.180 |

Leaf area index: The leaf area index values were significantly higher in $I_{0.6}$ and $I_{0.8}$ in comparison to $I_{0.4}$ but were statistically at par with each other. The higher values in $I_{0.6}$ and $I_{0.8}$ may be due to more number of leaves due to application of more quantity of water than $I_{0.4}$. This may also be due to better crop growth in terms of number of leaves due to frequent irrigation application.

Root parameters: The primary root length was statistically at par in $I_{0.4}$, $I_{0.6}$ and in $I_{0.8}$ Table 2. However, the secondary root length was highest in $I_{0.8}$ which was significantly superior over $I_{0.6}$ and $I_{0.4}$. Root volume was highest in $I_{0.6}$ and $I_{0.8}$ which was significantly superior over $I_{0.4}$. The $I_{0.8}$ and $I_{0.6}$ had higher root weight over $I_{0.4}$. In case of different methods of fertilizer application, the primary root length in F_{100} , $F_{C25+F75}$ and F_{CF} were at par with each other. Of the Secondary roots, the root length was highest in $F_{C25+F75}$ which were significantly superior over F_{100} and F_{CF} . The root volume was also significantly higher under $F_{C25+F75}$ over F_{100} and F_{CF} . Further, the root weight was at

par with each other. The root diameter was found to be significantly higher in $F_{C25+F75}$ and F_{100} over F_{CF} . The better root growth in $F_{C25+F75}$ was primarily due to application of 25 per cent RDF as a basal dose which might have improved the root growth. The root volume, root weight and root diameter however, were significantly higher in 'others' in comparison to 'control'. The higher root volume, root weight and diameter in 'others' were due the application of recommended NPK doses with drip fertigation with water soluble fertilizers applied in 7-10 splits in comparison to the conventional method of fertilizer application where only 3 splits of nitrogen and phosphorous and potassium was applied as a basal dose only at the time transplanting. Similar results were found by *Hebber et al. (2004)*.

Biological yield: The highest curd yield was recorded under $I_{0.8}$ which was significantly superior over $I_{0.6}$ and $I_{0.4}$ Table 3. The highest fresh weight of plant without curd was with $I_{0.8}$ which was statistically superior over $I_{0.6}$ and $I_{0.4}$. The higher broccoli biological yield in $I_{0.8}$ was due to more quantity of water application thereby improving the plant shoot and root growth parameters which resulted in increase nutrient uptake in comparison to $I_{0.4}$ and $I_{0.6}$. Similar findings were also reported by *Gadissa and Chemedda (2009)* and *Jayapiratha et al. (2010)*.

Different fertilizer application methods significantly affected the curd yield of broccoli. The highest curd yield of broccoli was recorded under treatment $F_{C25+F75}$ which was significantly superior (5.10 and 13.00 %) over F_{100} and F_{CF} , respectively. The fresh weight of plant without curd obtained with $F_{C25+F75}$ was also significantly superior over F_{100} and F_{CF} . The higher biological yield under $F_{C25+F75}$ may be attributed to application of 25% fertilizers as a basal dose and the remaining amount of fertilizers i.e. 75% was applied through fertigation in comparison to F_{100} where entire amount of fertilizer was applied through fertigation and F_{CF} where entire amount was applied through conventional method. The application of 25 per cent NPK as a basal dose might have helped in better early establishment of seedlings. Similar findings were also reported by *Sturm et al. (2010)*; *Badr et al. (2011)* and *Tanaskovik et al. (2011)*. The highest curd yield was recorded with $I_{0.8}F_{C25+F75}$ and lowest under $I_{0.4}F_{CF}$ (Table 2). The highest curd yield was due to more quantity of irrigation applied with a fertilizer method in which 25 per cent was applied as basal dose and 75 per cent through fertigation, resulting in better root and shoot growth due to increased nutrient availability. Also, the treatment combinations $I_{0.4}F_{100}$ and $I_{0.6}F_{100}$ were statistically at par with each other resulting in saving of 20 per cent irrigation water. Similar findings were also reported by *Sathya et al. (2008)*. By producing broccoli

Table 2. Effect of drip irrigation and method of fertilizer application on root growth (0-0.30 m) and biological yield of broccoli

| Treatment | Root length (m) | | Total root volume ($\times 10^{-6} \text{ m}^3$) | Root weight ($\times 10^{-3} \text{ kg}$) (Primary) | Root diameter ($\times 10^{-2} \text{ m}$) (Primary) | Marketable Curd yield (Mg ha^{-1}) | Fresh weight of haulm (Mg ha^{-1}) |
|---|-----------------|-----------|---|---|--|--|---|
| | Primary | Secondary | | | | | |
| Drip irrigation levels | | | | | | | |
| $I_{0.4}$ | 0.09 | 1.21 | 36.11 | 15.08 | 1.90 | 5.89 | 17.98 |
| $I_{0.6}$ | 0.09 | 2.33 | 51.11 | 17.49 | 2.32 | 6.05 | 18.47 |
| $I_{0.8}$ | 0.08 | 2.69 | 50.56 | 16.10 | 2.37 | 6.27 | 20.37 |
| CD ($p=0.05$) | NS | 0.262 | 6.915 | 1.642 | 0.336 | 0.178 | 1.583 |
| Method of fertilizer application | | | | | | | |
| F_{100} | 0.09 | 1.91 | 43.33 | 16.22 | 2.21 | 6.13 | 18.89 |
| $F_{C_{25}+F_{75}}$ | 0.09 | 2.23 | 53.33 | 16.99 | 2.36 | 6.46 | 20.60 |
| F_{CF} | 0.08 | 2.09 | 41.11 | 15.47 | 2.02 | 5.62 | 17.33 |
| CD ($p=0.05$) | NS | 0.262 | 6.915 | NS | 0.336 | 0.178 | 1.583 |
| Control | 0.10 | 1.62 | 25.00 | 12.81 | 1.50 | 5.60 | 18.33 |
| Others | 0.09 | 2.08 | 45.93 | 16.22 | 2.20 | 6.07 | 18.94 |
| CD ($p=0.05$) | NS | 0.338 | 8.928 | 2.120 | 0.434 | 0.230 | NS |

Table 3. Interaction effect of drip irrigation and method of fertilizer application on curd yield (Mg ha^{-1})

| Drip irrigation levels | Method of fertilizer application | | |
|------------------------|----------------------------------|---------------------|----------|
| | F_{100} | $F_{C_{25}+F_{75}}$ | F_{CF} |
| $I_{0.4}$ | 5.87 | 6.35 | 5.46 |
| $I_{0.6}$ | 6.06 | 6.44 | 5.66 |
| $I_{0.8}$ | 6.46 | 6.59 | 5.75 |
| CD ($P=0.05$) | | 0.309 | |

curd yield of 6.35 Mg ha^{-1} , $I_{0.4}F_{C_{25}+F_{75}}$ was the best treatment as it produced yield at par with the $I_{0.6}F_{C_{25}+F_{75}}$ and $I_{0.8}F_{C_{25}+F_{75}}$ and superior to all other treatment combinations, thereby saving water as well as fertilizer.

CONCLUSION

Increasing the drip irrigation quantity IW/CPE ratio from 0.4 to 0.8 and application of fertilizer 25 per cent as basal and 75 per cent through fertigation significantly increased the curd yield and NPK uptake. Curd yield obtained in $I_{0.4}F_{100}$ and $I_{0.6}F_{100}$ was statistically at par with each other which resulted in saving of 20 per cent irrigation water. The $I_{0.4}F_{C_{25}+F_{75}}$ was found to be the best treatment as it produced yield at par with the $I_{0.6}F_{C_{25}+F_{75}}$ and $I_{0.8}F_{C_{25}+F_{75}}$ and superior to all other treatment combinations, thereby saving water as well as fertilizer. Drip based irrigation scheduling resulted in higher soil water content, water use efficiency and saving in irrigation water in comparison to conventional method of irrigation. Gravity fed drip based irrigation along with fertigation through water soluble fertilizers had comparatively lower net return and B:C ratio in comparison to flood irrigation and conventional

fertilizer application.

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Promotion of Crop Diversification in Mountainous Areas using Geospatial Technologies

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Abstract: The GIS and Remote sensing technology has played an important role for improving the agriculture practices under various different Agro climatic zones. In Himachal Pradesh, the highly diversified topography has posed a challenge in incorporating the geospatial technologies to the agriculture sector. In the present study nearly 4700 hectares across five districts have been selected for promoting shift from traditional agriculture practices to diversified cropping system. A GIS based SDI model was developed for 210 project sites using the ESRI Arc GIS containing the detailed agriculture improvement plans(irrigation network, natural resources, crops sown, management practices, capacity and layout plans) for judicious and effective utilization of limited irrigation sources thereby shifting to crop diversification in their farms and improving the farm income. A web based GIS Tool portal is made available to the Farmers and planners to potentially contribute to the scientific plans at regional level for assets. The SDI Model can also be used for monitoring and predicting the crop produce as well.

Keywords: Geospatial technologies, Crop diversification, Arc Server, Web portal, Agriculture

Agriculture is the main occupation of 89.96 percent rural population Himachal Pradesh (Census of India 2011). The rich diversity of agro-climatic conditions, topographical variations coupled with fertile, deep and well drained soils are also suitable for cultivation of ancillary and diversified crops like peas, capsicum, chillies, cauliflower along with horticultural produce like flowers, mushroom, honey and hops. The area under fruits, which was 792 hectares in 1950–51 with total production of 1,200 tonnes increased to 2,26,799 hectares during 2015–16 (Economic and Statistics Department 2017). Given the limitations of agricultural inputs in less favoured areas with limited irrigation; new technologies for diversified and sustainable agriculture holds enormous promise for yield increase. In such systems, the resource-conserving technologies and practices becomes vital for achieving two to threefold increase in yields. Himachal Pradesh is a hilly state located at the foot of the Western Himalayas, with an area of 556.7 million hectares and a population of approximately 6 million (Census of India 2011). The low agriculture productivity partly attributes to the fact that the area available for growing crops is limited to 10% of the total land of the state, due to the hilly terrain, thus more than 80% of the farmers are marginal and small landholders with less than 2.0 ha (Economic and Statistics Department 2017). Also, only 20% of the cultivable area has irrigation facilities, and the rest has to depend on the rain-fed cultivation. In order to boost the agricultural development and enhance the farm income in the rural areas, it is therefore

important to increase the productivity of the existing cultivated area, through shifting self-subsistence crop cultivation to diversified agriculture, by overcoming the major constraints, such as shortage of irrigation facilities, farm roads and insufficient marketing facilities. Crop diversification with efficient technologies can conserve existing on-farm resources (nutrients, water and soils) and improve livelihoods. Lack of availability of resource inventory and mapping available to visualize the irrigation water availability remains the most sought deciding factor for the development and implementation of agriculture and horticulture.(El-Kawy *et al.*, 2010) developed a GIS-based Land Evaluation Model for Agricultural Land Suitability Assessments in Arid and Semi-Arid Regions. Spatial location and planning with available resources is a major common aspect of all the asset data and GIS can map all the assets along with information for visualization and proper decision making. (Tan, 2016) used the cloud source services into decision support systems for precision farming. Similarly, (Tayyebi *et al.*, 2016) designed SmartScape™ system for stakeholders to monitor the crop changes spatio-temporally. Water conservation can also be improved during irrigation using the web services by improving the irrigation plan and scheduling (Giusti and Marsili-Libelli, 2015). (Abdelfattah and Kumar, 2015) developed a web-based secure repository of soil data with geographical representation with components including a geospatial soil database, a field operating system. Even with the previous novel technologies

in agriculture domain, there was no attempt to prepare a GIS model for mountainous agriculture for direct usage by farmers and planners. The main objective of the study was to develop a transparent Geodatabase model that helps to improve improving the irrigation plan and scheduling and actual locations of assets developed on ground at the regional level using the GIS technology to support the Government agencies and others involved in agriculture diversification framework for e-governance in the five districts in the State of Himachal Pradesh.

MATERIAL AND METHODS

The state of Himachal Pradesh is situated between 30° 22'44" to 33° 12' 40" N latitude and 75° 45' 55" to 79° 04' 20" E longitude with geographical area of 5.57 million ha. The project has been implemented at 210 sub project sites spread across five district across the state namely Bilaspur, Hamirpur, Kangra, Mandi and Una. The study area is mostly rainfed and there is a huge challenge of meeting the irrigation requirements with the available water. The traditional crops require more water as compared to the more diversified crops like, Tomato, Onion, chillies Cabbage, Cauliflower (Table 1).

During the study, GIS based action plans were designed for development of necessary infrastructure such as irrigation facilities and farm access roads, alongwith develop or rehabilitate existing facilities in project sites in the area to bring additional area of 3,712 ha under assured irrigation. The importance of connecting the farmland to the main market yards was introduced as a parameter while preparing the action plans. Connectivity was proposed in the system by construction of 147 farm access roads. Web based micro scale level spatial data infrastructure (SDI) model (Fig.1) was developed for operative uses of watershed development planning at block and project site levels. The main aim of incorporating geospatial technologies for the Project Management Units (PMU) is to develop an information system comprising of two components-spatial and non-spatial (attribute data) that shall be used to input, store, retrieve, moderate, analyse and output data for each project site in order to support decision making for planning, management, execution as well as display of other relevant

Table 1. Water consumptive use for various crops in Himachal Pradesh

| Crops | Irrigation (mm) | Crops | Irrigation (mm) |
|-----------|-----------------|-----------------------------------|-----------------|
| Paddy | 100-1700mm | Maize | 600-1200 mm |
| Wheat | 450 mm | Onion | 350-600 mm |
| Sugarcane | 2200 mm | Cauliflower, Cabbage, Chillies | 500-1000 mm |
| Tomato | 400-1300 mm | | |

Source: (Bhagat et al., 2006)

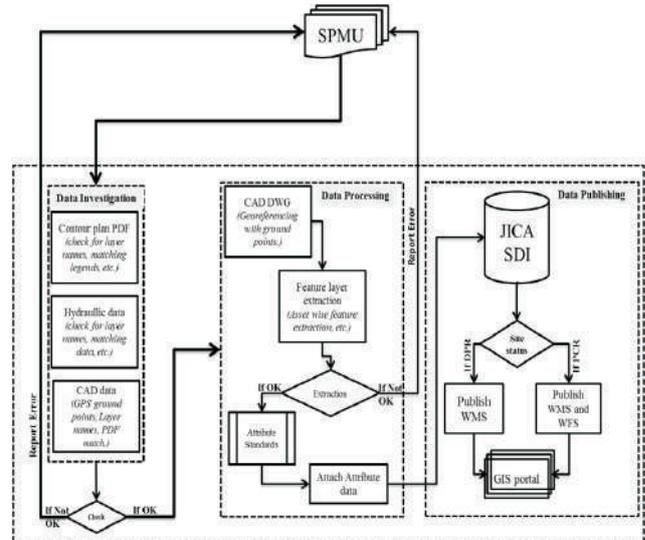


Fig. 1. Framework for web based Geospatial system

project data and activities. Other objective of the study was to develop an online solution for the spatial data that could be easily maintained and monitored at National and International agencies. The system required maintenance of a dedicated database system that can easily incorporate the regular updates besides a mechanism of back-ups. Various web based GIS solutions were explored like Mapserver, Chamleon, postgresQL for designing and implementing the SDI for the study. The major shortcoming in going to the open source solution was requirement of experts in programming/scripting who can code and encode the spatial data with the database and display the theme based output. The spatial database that was to be ported over the internet also required to be queried and updated (WMS and WFS) from the client end (survey groups), this was also a bit tedious to do in open source solutions. The best solution that met the requirement of the study was ESRI Arc server. The advantage of using the arc server to port and publish the spatial data as service was its compatibility with Arc Map10.3.1. Project site(s) were prepared in ArcMap (Desktop) and published directly on the server(ArcServer) which were easy to maintain and configure at any time as and when required. There are three stages for implementation of GIS in the project data investigation, data processing and data publishing (Fig.1). Data publishing stage is purely dependent on data processing stage.

Data Investigation: The project action plans were designed using AutoCAD software at PMU levels for each project site. The cad files were investigated for geographic coordinates and spatial and non-spatial attributes for SDI.

Data Processing: The CAD files were geo-referenced using ground surveyed GPS points. Feature transformation from

CAD files to Geodatabase (SDI) was performed with Universal Transverse Mercator (UTM) Coordinate system Zone 43 North, which was ported on the Geodatabase (JICA.gdb), developed for the project. The feature datasets were classified into proposed and actual assets containing feature class as: site boundary, land parcels, assets (pump house, outlets, tanks, irrigation channels, farm roads, distribution channels, rising mains and pipe lines. The attribute data was attached to each of the feature class by using a customized Arc toolbox created by using ESRI Model Builder. Geotagged images of the assets constructed within a project plan were also incorporated into the Geodatabase (JICA.gdb).

Data Publishing: In this phase the final Map documents (MXD) were prepared using ArcMap 10.3.1 with standardized symbology for all the project sites. Two types of services were published for each project site namely:

Web Mapping Service (WMS): These services provide a simple HTTP interface for requesting geo-registered *map* images from the geospatial databases. A *WMS* request defines the geographic layer(s) and area of interest to be processed and displays it in the form of map.

Web Feature Service (WFS): These services are used for the online discovery, query, or data transformation operations. The client generates the request and posts it to a *web feature* server using HTTP.

Three times multi temporal satellite imagery were procured to monitor the pace and actual activities on the ground. The major advantages of the SDI system developed on Arc server the maintenance of the system with least programming skills, visualizations of assets in real time mode, Geotagged images of the sub project sites providing area covered under diversification. The record and details for beneficiary alongwith their crop production and agriculture inputs utilized for diversification is also available with a single click. Using the GIS technology spatial feasibility of how and where the irrigation system can be improved to enhance the farm income by diversifying towards more cash crops mainly vegetables was planned. During the mapping of the plans it was also observed that there were some existing irrigation channels and storage tanks which were in bad conditions. Using the Geospatial hydrological analysis, buffer zonation was created to visualize the area that can be served with the existing channels and command serving areas using the storage tanks. Hence few plans were framed for improvement of the existing irrigation channels to serve the beneficiaries.

RESULTS AND DISCUSSION

In Himachal Pradesh agriculture is purely dependent on

the rainfall. Since rains are erratic and irregular the crop cultivation becomes challenging. The monsoonal climate of Himachal Pradesh is characterised by two distinct wet and dry seasons. The state has some unique growing climates for different crops available at different times of the year. In general, in the lower parts of Himachal Pradesh (< 4000 m) the two (April to October; November to May) distinct growing seasons (wet and dry) are visible. Thus the stress on the natural resources and water regulations mechanisms became a necessary requirement to use the available water for improving the produce. The crop suitability parameters i.e. elevation, rainfall, temperature, soil and land use type for each crop under study area were considered. Using the survey and GIS technology selection of sites were carried out under which in Bilaspur 298 ha, in Hamirpur 474 ha, in Kangra 2441 ha, in Mandi 1261 ha and in Una 194 ha of net cultivable area has been put for crop diversification across the five districts. The Geodatabase developed in the study provided a tool with which alternate plans for cropping are framed. The Spatial location is a major common aspect of all the asset data and GIS can map all the assets along with information for visualization and proper decision making (Fig. 2 a, b, c). The variability in the climatic conditions across the study area was observed and incorporated as one of the factors in influencing the package and practices. The various water consumption requirements varies significantly. The niches for suitable vegetable growing areas were identified and the irrigation development plans for infrastructure development were prepared (Table 1). The lower regions of the study area which receive minimal rainfall during the peak cropping season, and have higher range of maximum temperature shifting certain area from Sugarcane and wheat cultivation to more vegetables was planned using the GIS tools. Another area where GIS tool and Geodatabase was efficiently used in the study was for diversifying the type of irrigation system across the five districts (Fig. 2d). District Una, District Bilaspur has null or very less potential for irrigation using open channels due to the higher temperature ranges and very less gradient. Hence the potential for gravity based irrigation channel was not an option for those low lying areas. Using the GIS technology the Lift irrigation schemes were designed and irrigation was planned with sub surface covered pipes which ensure the water flow to the directed areas thereby reducing the water loss caused by climatic factors. With the online Geodatabase in place the beneficiaries and monitoring teams can check the water usage and can raise alarm if over pumping is carried out. Similarly, in the other variable higher regions of the study area like Kangra, Mandi and Hamirpur the flow irrigation schemes were planned. Here also in certain areas where the

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Effect of Biocolours and Inorganic Dyes on Ornamental Dry Flower Grasses

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Abstract: The present investigations were carried out at Dr YS Parmar University of Horticulture and Forestry, Nauni, Solan (HP) during 2013–14. Bromus and Briza are the important introduced ornamental grasses which were used for making various products in dry flower industry. Different dyes like fabric, indicator, food and bio-colours were used to enhance the value of dried flowers for aesthetic beautification and product diversification. The findings revealed that among four different categories of fabric dye (yellow, dark green, violet, magenta pink) and indicator dye (Brilliant Green, Eosin Yellow and Crystal Violet) were the excellent in performance dyes scored maximum for quality parameters even after ten months of storage. Quality parameters in case of food dyes were medium to high at the time of dyeing but the colours faded very fast and retention was not good after ten months. Out of the bio-colours turmeric and liliun pollen were quite satisfactory, whereas beet root and wild henna were very poor in performance.

Keywords: Dyeing, Indicator dyes, Fabric dyes, Bio-colours, Ornamental grasses

Since ancient times flowers have been used to celebrate, commemorate and decorate for occasions like wedding, birthdays and festivals. However, decorating with live flowers is not long-lasting, as the fresh flowers, wither and die very soon. Dry flowers have come up with the contemporary alternative to fresh flowers as these are near to natural, long lasting, eco-friendly products and available throughout the year. In recent year, dried flowers and foliage have been forming a large part of floricultural product export from India. The country has exported 22,947.23 MT of floriculture products to the world for the worth of Rs. 460.75 crores in 2014–15. Out of the total floricultural exports, values Rs 329.3 crores were comprised of dry flowers. India is the fifth largest exported of dried flowers and second largest exporter of dry foliage in the world. The industry exports 500 varieties of flowers from India to 20 countries. India is one of the major exporters of dried flowers to the tune of 7% world trade in dry flowers (Anonymous, 2016).

Bromus (*Bromus rubens*, fox tail brome) and Briza (*Briza maxima*, big quaking grass) are the important introduced ornamental dry flower grasses. These are winter season grasses commercially utilized in dry flower industry. These grasses can be grown in dry and poor textured soils and are being used commercially for dry flower arrangements. Colouring enhances the value of dried flowers because of aesthetic beautification and product diversification. Dyes are colourants or colouring substances that are added to something to change its hue or colour. Chemically dyes are

benzophenones, glycosides, quinines and flavones. At present trend throughout the world is shifting towards the use of ecofriendly and biodegradable commodities, demands for natural dyes are increasing day by day. They can be obtained from any parts of plants viz, leaves, bark flower, seed, fruits and roots etc. Dip dyeing, spray dyeing and absorption dyeing are common methods used to intensify natural colour or introduce artificial colour to plant material. Dyeing provides materials with more uniform colour, appearance, thereby increasing their saleability. However, low light and wash fastness, fading and uneven absorption of dyes are serious problems encountered in this step of dry flower making. Therefore, the study was carried out to identify suitable dyes for colouring of Briza and Bromus.

MATERIALS AND METHODS

The present investigations were carried out at Dr YS Parmar University of Horticulture and Forestry, Nauni, Solan during 2013–14. The seeds of these grasses were sown in end week of September and transplanting was done in late October, 2013. Harvesting of *Bromus rubens* was done in March, 2014 at full maturation stage when the inflorescence was green and soft (before turning purplish & spiny) whereas *Briza maxima* was harvested when colour of spikelet changed from greenish to whitish. These are easy to grow grass from seed as well as seedlings and flowering occurs in 14 to 20 weeks. The harvested grasses were tied in a bunch of 50 shoots and taken to floral craft lab for drying and dyeing.

Bunch of these grasses were hung on a bamboo hanger for air drying. Different dyes like fabric dyes (dark green, magenta pink, yellow, violet, orange, red maroon), indicator dyes (brilliant green, crystal violet, eosin yellow, metanil yellow, methylene blue and methyl orange), food dyes (green, orange, yellow and raspberry red) and biocolours (coffee, beetroot, turmeric, henna powder, wild henna, butea, punica and liliium) were used for colouring these grasses. Hence, an effort was also made to compare some of these with the synthetic dyes. Bio-colours were extracted from the parts of dye yielding plants like from the peel of *Punica granatum* var nana (darhu), flowers of *Butea monosperma* (palash), roots of *Beta vulgaris* (beet root), leaves of *Impatiens balsamina* (gulmehndi) were dried, powdered and colour was extracted by boiling the sample in water. Apart from these; coffee, henna powder and curcuma were procured from the local market. Liliium pollens were collected from the field, dried and colour was extracted with acetone. About 4 g l⁻¹ of fabric dyes, 2 g l⁻¹ of indicator dyes, 4 g l⁻¹ of food colours and 5g/100ml of bio-colours were used. Dye solution was prepared by properly mixing dyes in boiling water. Grasses were immersed in the solution for about 1-2 minutes or when it appeared it has absorbed the colour uniformly. After colour absorption these were taken out and spread over the blotting sheet in shade for drying. The colours of the dyed grasses were recorded with the help of RHS colour chart and scoring was done on the basis of colour absorption and colour intensity. The 5,4,3,2 and 1 point were given to the specimen which gave excellent, very good, good, poor and very poor colour absorption. For colour intensity 5, 3 and 1 point were given which shows high, medium and low value. Wash fastness of dyed flowers were recorded by washing the dyed flowers in distilled water and their impression with a finger was taken from each sample on white paper. The 5, 3 and 1 point were given to the specimen which gave low, medium and high impression on paper, Final evaluation was done out of a total 5 were allotted on the basis of quality parameters like colour intensity (score out of 5), colour absorption (score out of 5) and wash fastness (score out of 5) from highest to lowest order by visual observation for different dyes under study on the basis of 9-point hedonic scale as suggested by Peryam (1957) and a modified score was developed (Table 1). All the dyed samples were kept at room temperature for 10 months for checking deterioration/fading with time.

RESULTS AND DISCUSSION

The fabric dyes and indicator dyes were the best for dyeing of *Bromus rubens* and *Briza maxima*, in terms of colour intensity and colour absorption (Table 2, 3 and Plate 1,

Table 1. Score card for different quality parameters of dyes flowers (Scoring out of 5 in each parameter)

| Wash fastness | Colour absorption | | Colour intensity | | |
|-------------------|-------------------|-----------|------------------|--------|---|
| Low Impression | 5 | Excellent | 5 | High | 5 |
| Medium Impression | 3 | Very Good | 4 | Medium | 3 |
| High Impression | 1 | Good | 3 | Low | 1 |
| | | Poor | 2 | | |
| | | Very Poor | 1 | | |

2). In case of *Bromus rubens* among fabric dyes, maximum score (5) was obtained by the flowers which were dyed with Dark Green, Violet and Pink whereas minimum score (2.5) was obtained by those flowers dyed with Red Maroon. However, among indicator dyes, maximum score (5) was obtained by the flowers which were dyed with Brilliant Green, Eosin Yellow and Crystal Violet whereas minimum score (3.5) was obtained by those flowers dyed with Methyl Orange. However, in *Briza maxima*, Green, Violet and Pink among fabric dyes with maximum score (5) was obtained whereas minimum score (2.5) was obtained by those flowers dyed with Red Maroon. The result of indicator dyes in *Briza maxima* were found similar to *Bromus rubens*. The impression of indicator dyes on washing was also low on white paper indicating their good wash fastness properties (Plate 3 and 4). Similar colours were found excellent in performance for dyeing of *Lagurus ovatus* in terms of colour intensity and colour absorption (Kashyap *et al.* 2016). The results are also in agreement with the Lourdusamy *et al.* (2002), who reported that vat group of dyes scored the highest score rating values in terms of visual aesthetic qualities followed by direct and acid colours. This group had low level of colour fading on storage. Studies on bleaching and dyeing technology of hybrid tea roses and *Aerva* sp. was conducted and reported that the basic groups of dyes were the best at 3 per cent and 0.3 per cent best for bleached roses and *Aerva* flowers, respectively (Chari, 2000). Among the various dyes used, vat group was superior followed by direct and acid colours. These groups had low level of colour fading on storage. Among different fabric dyes, dark green, yellow, violet and pink gave maximum score for quality parameters after ten months of storage in both grasses. These dyes had excellent colour absorption properties and showed good colour intensity immediately after dyeing and did not faded much even after 10 months of storage

Colour intensity and colour absorption in case of food dyes were medium to high at the time of dyeing but the colours faded very fast and retention was not good after ten months in both the grasses. Maximum score (4) was obtained with green and red dyes whereas minimum was (2.5) with orange and yellow dyes in the both grasses.

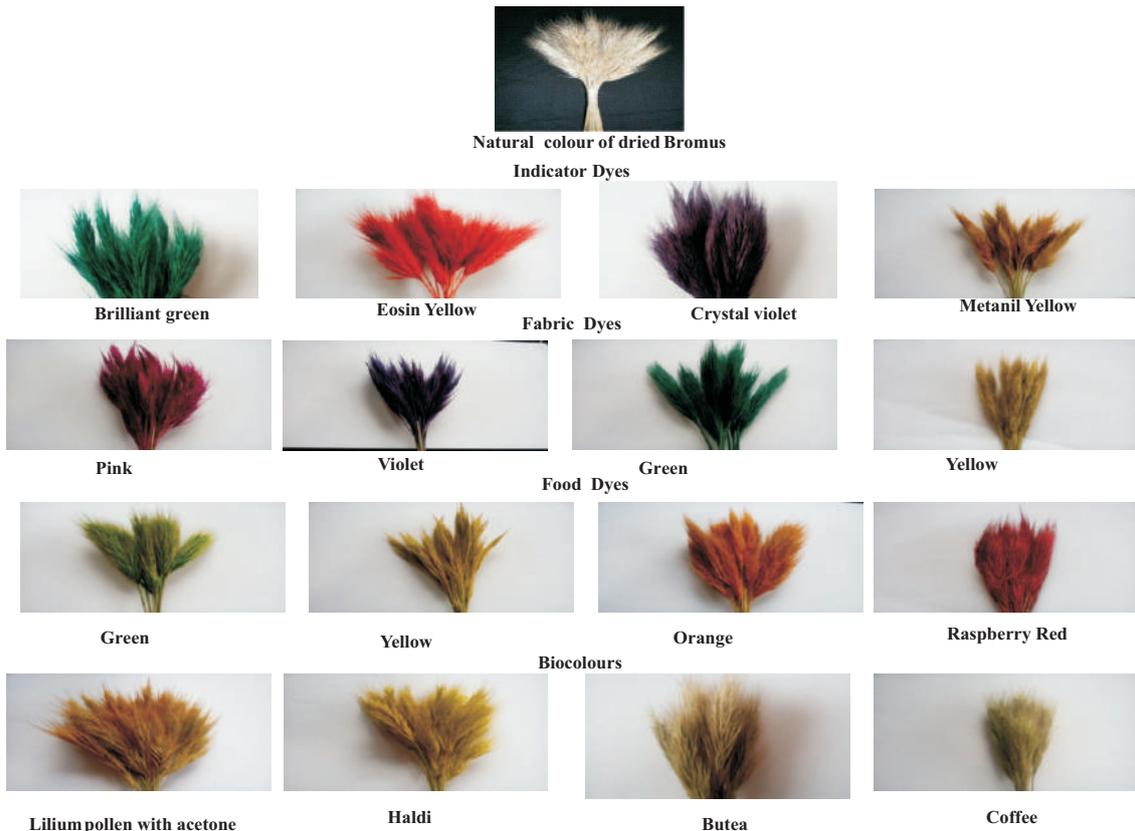


Plate 1. Dyeing of Bromus by using different dyes viz. indicator dye, fabric dye, food dye and different biocolours



Plate 2. Dyeing of Briza by using different dyes viz. indicator dyes fabric dye, food dye and different biocolours

Table 2. Effect of dyeing with various dyes/colours on *Bromus rubens*

| Type of dye | Colour intensity | | Colour absorption | Wash Fastness | Colour (RHS Colour Chart) | | Overall Score (out of 5) | |
|-----------------------|------------------|-----------------|-------------------|---------------|---------------------------|--------------------------|--------------------------|-----------------|
| | 0 hours | After 10 months | | | 0 hours | After 10 months | 0 hours | After 10 months |
| Fabric dyes | | | | | | | | |
| Dark Green | H | H | E | L | Green group 126 A | Green group 126B | 5.0 | 4.75 |
| Yellow | H | H | E | L | Yellow Green group 153 A | Yellow Green group 153 C | 4.5 | 4.0 |
| Orange | L | L | VG | L | Greyed Orange group 167C | Greyed Orange group 167C | 3.5 | 2.5 |
| Violet | H | H | E | L | Violet Blue group 95 B | Violet Blue group 95 C | 5.0 | 4.5 |
| Pink | H | H | E | M | Red Purple group 64 A | Red Purple group 64 B | 5.0 | 4.75 |
| Red Maroon | L | L | G | H | Greyed Orange group 177A | Greyed Orange group 177A | 2.5 | 1.0 |
| Food dyes | | | | | | | | |
| Orange | L | L | VG | H | Greyed Orange group 177A | Greyed Orange group 177B | 3.5 | 2.5 |
| Yellow | L | L | G | L | Yellow Green group 153C | Yellow Green group 153C | 3.0 | 2.5 |
| Green | M | M | VG | L | Yellow Green group 144A | Yellow Green group 144B | 4.0 | 3.5 |
| Red | H | M | VG | H | Greyed Purple group 184B | Red Purple group 60 C | 4.0 | 3.5 |
| Indicator dyes | | | | | | | | |
| Brilliant | H | M | E | L | Green group 126 B | Green group 126 C | 5.0 | 4.75 |
| Eosin Yellow | M | H | E | H | Red Purple 63 B | Red Purple 63 B | 5.0 | 4.75 |
| Methylene | M | L | VG | H | Blue group 102B | Blue group 103B | 4.0 | 3.5 |
| Crystal Violet | H | H | E | M | Violet Blue group 93 A | Violet blue group 93 A | 5.0 | 4.75 |
| Metanil Yellow | L | L | VG | L | Yellow Green group 153D | Yellow Green group 153D | 4.0 | 3.5 |
| Methyl Orange | L | L | VG | L | Greyed Orange group 164 | Greyed Orange group 164C | 3.5 | 2.5 |
| Biocolours | | | | | | | | |
| Coffee | L | L | P | - | - | - | 2.0 | 1.0 |
| Turmeric | H | M | VG | M | Yellow Orange group 15A | Yellow Orange group 15B | 3.5 | 2.5 |
| Henna | L | L | P | - | * Rusty Brown | - | 2.0 | 1.0 |
| Wild Henna | L | L | VP | - | * Creamish | - | 1.0 | 0.5 |
| Butea | L | L | G | - | Greyed Yellow group 162D | Greyed Yellow group 162D | 2.5 | 1.5 |
| Punica | M | L | P | - | - | - | 2.0 | 1.0 |
| Beetroot | M | L | VP | - | - | - | 1.0 | 0.5 |
| Lilium with acetone | H | M | VG | M | Yellow Green group 152C | Yellow Green group 152D | 3.5 | 3.0 |

E-Excellent, H-high, M-Medium, L-Low, G-Good, P-Poor, VP-Very poor, *- colour does not match to any of the colours of RHS Colour Chart

However, maximum score (3.5) and minimum score (2.5) was obtained with same dyes after ten months of storage. Similar results while studying the effect of same groups of dyes on *Lagurus ovatus* grass was reported by Kashyap *et*

al., 2016 that food dyes had quality but the colours fade very fast and retention of colour was poor even after ten months.

Presently there is a trend towards the use of natural dyes (biocolours) throughout the world due to ecofriendly nature of

Table 3. Effect of dyeing with various dyes/colours on *Briza maxima*

| Type of dye | Colour intensity | | Colour Absorption | Wash Fastness | Colour (RHS Colour Chart) | | Overall score (out of 5) | |
|-----------------------|------------------|-----------------|-------------------|---------------|---------------------------|--------------------------|--------------------------|---------|
| | 0 hours | After 10 months | | | 0 hours | 0 hours | After 10 months | 0 hours |
| Fabric dyes | | | | | | | | |
| Dark Green | H | M | E | L | Green group 137 B | Green group 137C | 5.0 | 4.75 |
| Yellow | H | H | E | L | Yellow group 6A | Yellow group 6A | 4.5 | 4.0 |
| Orange | M | P | VG | L | Yellow Orange group 21 B | Yellow Orange group 21 C | 3.5 | 2.5 |
| Violet | M | L | E | L | Violet Blue group 93 B | Violet Blue group 93 C | 5.0 | 4.5 |
| Pink | H | M | E | M | Red Purple group 67B | Red Purple group 67C | 5.0 | 4.75 |
| Red Maroon | P | P | G | M | Red group 45 B | Red group 46A | 2.5 | 1.0 |
| Food dyes | | | | | | | | |
| Orange | H | M | VG | H | Orange Red group 32 A | Orange Red group 32 A | 3.5 | 2.5 |
| Yellow | H | H | G | L | Yellow group 7A | Yellow group 7A | 3.0 | 2.5 |
| Green | H | M | VG | L | Green group 143 B | Green group 143 C | 4.0 | 3.5 |
| Red | H | M | VG | H | Red Purple group 60 A | Red Purple group 60 A | 4.0 | 3.5 |
| Indicator dyes | | | | | | | | |
| Brilliant Green | H | H | E | M | Green group 126 A | Green group 126 B | 5.0 | 4.75 |
| Eosin Yellow | H | H | E | L | Red group 39 A | Red group 50B | 5.0 | 4.75 |
| Methylene Blue | E | M | VG | M | Blue Green group 114 A | Blue Green group 116 A | 4.0 | 3.5 |
| Crystal Violet | H | H | E | L | Purple group 79 B | Violet group 79 B | 5.0 | 4.75 |
| Metanil Yellow | H | H | VG | L | Yellow Orange Group 23 A | Yellow Orange Group 22C | 4.0 | 3.5 |
| Methyl Orange | M | L | VG | L | Yellow Orange group 22B | Yellow Orange group 22C | 3.5 | 2.5 |
| Biocolours | | | | | | | | |
| Coffee | L | L | P | - | - | - | 2.0 | 1.0 |
| Turmeric | H | M | VG | M | Yellow Orange group 15A | Yellow Orange group 15B | 4.0 | 2.5 |
| Henna Powder | L | L | P | - | * Rusty Brown | | 2.0 | 1.0 |
| Wild Henna | L | L | VP | - | * Creamish | | 1.0 | 0.5 |
| Butea | L | L | G | - | Greyed Yellow group 162D | Greyed Yellow group 162D | 2.5 | 1.5 |
| Punica | M | L | P | - | - | - | 2.0 | 1.0 |
| Beetroot | M | L | VP | - | - | - | 1.0 | 0.5 |
| Lilium with acetone | H | M | VG | M | Yellow Green group 152C | Yellow Green group 152D | 4.0 | 3.0 |

E-Excellent, H-high, M-Medium, L-Low, G-Good, P-Poor, VP-Very poor, *- colour does not match to any of the colours of RHS Colour Chart

these colours. But there are technical drawbacks of natural dyes regarding complexity of dyeing process, which result into problem like reproducibility of shades, limited shades, inadequate fixation and fastness properties. Colouring with

turmeric and lilium pollen was found satisfactory in case of bio-colours with maximum score of 4 in both the grasses. However, colour intensity and colour absorption was very poor for other bio-colours like henna powder, gulme hndi (wild

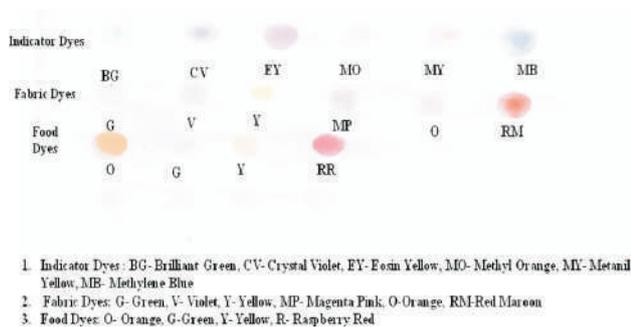


Plate 3. Wash fastness impression of different dyes in *Bromus rubens*

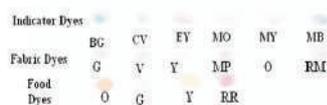


Plate 4. Wash fastness impression of different dyes in *Briza maxima*

henna), coffee, butea, punica and beetroot with a score of 2 and 1, thus cannot be recommended for dyeing. The colour of beetroot dyed samples is good at the time of dyeing but after sometimes the samples are rotten due to fungal infection. Similar results were also reported by Sangeeta *et al.*, 2017 while working on *Gomphrena globosa* with these dyes. Various types of value-added products like dry flower sticks, arrangements, bouquets, urns etc. were made out of these dried as well as dyed grass. These products are high demanded in the market (Plate 5).

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Plate 5. Different value added products made from Bromus and Briza

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Productivity and Profitability of Different Rice (*Oryza sativa*) Based Cropping Systems in Cauvery Delta Zone

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Abstract: Field experiments with nine crop sequences were conducted during 2012-2016 at Soil and Water Management Research Institute, Thanjavur, Tamil Nadu to assess productivity, profitability, land use efficiency and water use efficiency. Among the nine rice based crop sequences tested maize + blackgram-rice-blackgram + redgram cropping sequences gave the highest rice equivalent yield (16,523 kg/ha/year), system productivity (Rs.45.2 kg/ha/day), netreturns (Rs.109882 /ha/year), system profitability (Rs.301/ha/day), WUE (8.78 kg/ha mm) and B:C ratio (1.96) followed by DSR + daincha – rice – maize + blackgram. Highest land use efficiency (100%) was with rice + daincha – rice – brinjal crop sequence.

Keywords: REY, System productivity, Profitability, Net return, Cropping sequence

Indian economy largely depends on agriculture and allied sector. The share of Agriculture and allied sector in India's gross domestic product (GDP) declined to 13.9% in 2013-14 from 14.6% in 2009-10 (GOI, 2014). Food grain based cropping systems, viz., rice – wheat (10.5 m.ha), rice-rice (5.9 m ha) and coarse grain based systems (10.8 m ha) are the major contributors to national food basket in India where in about 30 important cropping systems have been identified. Out of these systems, rice + wheat is the highest contributor and together shares 65% of national food grain production. There are seven agro climatic zones of Tamil Nadu (i) North Eastern Zone (ii) North Western Zone (iii) Western zone (iv) Cauvery Delta Zone (v) Southern zone (vi) high rainfall zone (vii) high altitude and hilly zone. The Cauvery delta zone (CDZ) lies in the eastern part of Tamil Nadu, between 10°00'–11°00' N latitude and between 78° 15'–79°45 E longitude. The CDZ has a total geographical land area of 1.45 million ha which is equivalent to 11.13 percent of the state area and having humid tropical monsoon type of climate. Rice is the major crop in CDZ. The important cropping systems are rice – rice – fallow, rice – pulses, rice – sesame. The cultivation of rice in *kuruvai* depends upon the release of water from Mettur dam. In most of the years the water was not released in time. The ground water level is depleting rapidly. There is a need to change the cropping pattern and to evolve new cropping systems to meet the problem of water scarcity, which has become almost persistent (Porpavai *et al.*, 2010). Crop diversification has been recognized as an effective strategy for achieving the objectives of food security, nutritional security, income growth, poverty alleviation, employment

generation and judicious use of land and water, resources (Ray *et al.*, 2016). Hence this study was conducted to find out the productive and profitable cropping systems.

MATERIAL AND METHODS

Field experiments were conducted during 2012-2016 at Soil and Water management Research Institute, Kattuthottam, Thanjavur, to identify the productive and profitable cropping systems for Cauvery new delta zone of Tamil Nadu. The soil was sandy loam having neutral pH (6.7), low in available nitrogen (248kg ha⁻¹), high in phosphorus (26.6kg ha⁻¹) and medium in potassium (151 kg/ha). Treatments comprised of nine cropping sequences, viz., rice + daincha (10:1) –rice – brinjal, drum seeded rice (DSR) + daincha (10:1) – rice + maize + blackgram , rice + daincha (10:1) –rice – groundnut + redgram (4:1), maize + blackgram – rice – blackgram + redgram (4:1), sunflower – rice – greengram + redgram (4:1), blackgram+ redgram – rice – redgram, greengram + redgram – rice –redgram, redgram – rice – onion and daincha – rice –sunflower were evaluated to assess their production and profitability in randomized block design with three replications. Rice was the common crop grown during *rabi* in all the cropping sequences. The crops were raised under irrigated condition with recommended package of practices (Table 1) Recommended doses of N, P and K were applied to different crops through urea, single superphosphate and muriate of potash respectively. Daincha was raised for green manure purpose and incorporated at flowering stage. Economic yield of component crops was taken into account over the year and converted into rice –

equivalent yield (REY) based on prevailing market of the produces for each cropping system to compare the various systems. The cost of cultivation was calculated on the basis of prevailing market price of different inputs. System productivity in term of kg/ha/day was calculated by dividing the net returns of the cropping systems by 365 days and system profitability (Rs/ha/day) was obtained by dividing the net returns of the cropping systems by total duration of the same (Devasenapathy *et al.*, 2008). Benefit : Cost ratio of a system was expressed as net return per rupee spent. Land use efficiency was calculated as per Tomar and Tiwari (1990):

Land use efficiency (LUE) = (Sum of duration of component crops / 365) x 100%.

Irrigation requirement: Estimated by multiplying the number and area of irrigation with the depth of irrigation given to all the component crops of a particular cropping system and amount of irrigation given to the component crops of the cropping system.

Irrigation water use efficiency (kg/ha mm): For particular cropping system was calculated by dividing the total yield of the cropping system (REY) by its irrigation requirement.

RESULTS AND DISCUSSION

Productivity: Pooled analysis of four years data revealed that maize + blackgram – rice – blackgram + redgram gave the highest REY (116523) being significantly higher than other cropping systems. This might be due to higher economic yield of crops and better market price of maize, rice and blackgram. This was on par with DSR + daincha – rice – maize + blackgram and rice + daincha – rice – brinjal cropping sequences. The lowest REY of 11285 kg/ha/year was with green manure – rice – sunflower sequence. In green manure economic yield is not recorded and the biomass is

incorporated as green manure and hence the REY is low. Highest system productivity 45.2 kg/ha/day was with maize + blackgram – rice – blackgram + redgram cropping sequences and significantly superior over other cropping sequences. This is due to the higher economic yield of all the crops in the cropping sequence and was on par with DSR + daincha – rice – maize + blackgram and rice + daincha – rice – brinjal cropping sequences. This may be due to higher REY obtained in the above cropping sequences. Among all the cropping sequences the system productivity was low in daincha – rice – sunflower cropping sequence, which may be due to the lower REY recorded.

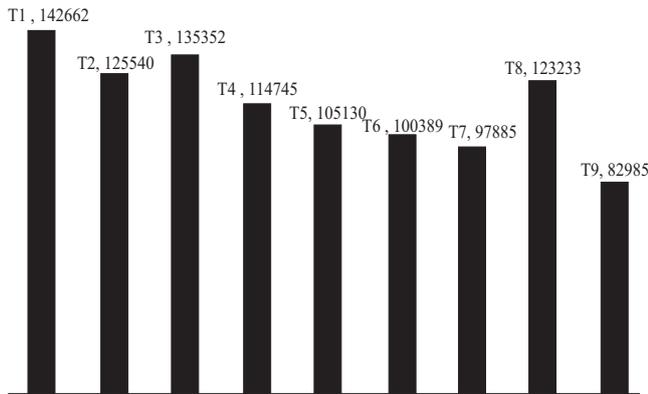
Profitability: Rice + daincha – rice – brinjal cropping sequence incurred higher cost of cultivation (Rs.1,42,662) This may be due to the higher number of labour fertilizer and plant protection chemical requirement to brinjal crop the expenditure is more in the sequence followed by rice + daincha – rice – groundnut redgram Lower cost of cultivation is recorded in daincha – rice – sunflower cropping sequence (Fig. 1). The cost of production is less in daincha crop since it is cultivated for biomass production. Highest net return of Rs. 1,09,512 was achieved in DSR + daincha – rice – maize + blackgram which was on par with maize + blackgram – rice – blackgram + redgram cropping sequence (Rs.1,09,382) but significantly superior to other systems as revealed from the results of pooled analysis data of four years. Hence maize + blackgram – rice – blackgram + redgram and DSR + daincha – rice – maize + blackgram cropping sequences was found the most remunerative owing to higher yield of maize and blackgram. Kumpawat (2001) reported that inclusion of pulses and vegetables in the system is more beneficial than cereals after cereals. Significantly higher system profitability of Rs.300/ha/day was in maize + blackgram – rice –

Table 1. Agronomic Practices of different crops

| Crop | Variety | Duration (days) | Seed rate (kg ha ⁻¹) | Spacing (cm) | Fertilizer dose | | |
|-----------|----------------|------------------------|----------------------------------|--------------|-----------------|-------------------------------|------------------|
| | | | | | N | P ₂ O ₅ | K ₂ O |
| Rice | ADT 43 | 110 (<i>Khariif</i>) | 60 | 15x10 | 150 | 50 | 50 |
| Rice | ADT 39 | 125 (<i>Rabi</i>) | 40 | 20x10 | 150 | 50 | 50 |
| Maize | Co. 6 (hybrid) | 110 | 15 | 60x25 | 135 | 62.5 | 50 |
| Sunflower | Co2 (hybrid) | 100 | 5 | 60x30 | 60 | 90 | 60 |
| Blackgram | ADT 5 | 70 | 20 | 30x10 | 25 | 50 | 25 |
| Redgram | VBN 3 | 120 | 15 | 60x20 | 25 | 50 | 25 |
| Daincha | Local | 45 | 40 | Broadcasting | – | – | – |
| Brinjal | Local | 145 | 400 gm | 75x60 | 100 | 50 | 30 |
| Groundnut | Western 45 | 105 | 125 | 30x10 | 17 | 35 | 54 |
| Greengram | Co6 | 70 | 20 | 30x10 | 25 | 50 | 25 |
| Sesame | TMV.3 | 85 | 5 | 30x30 | 35 | 23 | 23 |
| Onion | Local | 90 | 1250 | 45x10 | 100 | 50 | 100 |

Table 2. Efficiency and economics of different crop sequences (Mean of 4 years)

| Crop sequence | REY (kg ha ⁻¹ year ⁻¹) | System Productivity (kg ha ⁻¹ day ⁻¹) | Total WR (mm) of cropping sequence | WUE (kg ha ⁻¹ mm) | LUE (%) | Net returns (Rs ha ⁻¹ year ⁻¹) | System Profitability (Rs ha ⁻¹ day ⁻¹) | B:C Ratio |
|---|---|--|------------------------------------|------------------------------|---------|---|---|-----------|
| T ₁ -Rice+Daincha-Rice-Brinjal | 16472 | 45.0 | 2895 | 5.68 | 100 | 94149 | 257.6 | 1.67 |
| T ₂ -DSR+Daincha-Rice-Maize+Blackgram | 16489 | 45.0 | 2595 | 6.36 | 91.7 | 109512 | 300.0 | 1.86 |
| T ₃ – Rice+Daincha-Rice-Groundnut+Redgram | 15897 | 43.5 | 2650 | 6.00 | 91.7 | 86807 | 237.6 | 1.64 |
| T ₄ – Maize+Balckgram-Rice-Blackgram+Redgram | 16523 | 45.2 | 1880 | 8.78 | 94.5 | 109998 | 301.0 | 1.96 |
| T ₅ -Sunflower-Rice+Greengram+Redgram | 14151 | 38.7 | 1785 | 7.92 | 89.0 | 87885 | 240.7 | 1.82 |
| T ₆ – Blackgram + Redgram – Rice –Redgram | 12709 | 34.8 | 1765 | 7.20 | 94.5 | 80970 | 221.7 | 1.79 |
| T ₇ -Greengram +Redgram-Rice-Redgram | 14072 | 38.5 | 1620 | 8.68 | 89.3 | 93602 | 256.4 | 1.95 |
| T ₈ -Redgram-Rice-Onion | 13820 | 37.8 | 1860 | 7.43 | 89.0 | 68854 | 188.4 | 1.57 |
| T ₉ -Daincha (Wet.Wt) – Rice – Sunflower | 11285 | 31.0 | 1695 | 6.65 | 72.6 | 75809 | 207.6 | 1.70 |
| SEd | 695 | 1.90 | | | | | | |
| CD (p=0.05) | 1435 | 3.92 | | | | 14002 | 38.37 | |

**Fig.1.** Cost of cultivation of different cropping sequence Rs ha⁻¹

blackgram + redgram and in DSR + daincha – rice – maize + blackgram cropping sequences. The lowest system profitability was in redgram – rice – onion cropping sequences (Table 2). This may be due to the lower REY recorded by the cropping sequence. Higher B:C ratio was recorded in maize + blackgram – rice – blackgram + redgram cropping sequence. This was due to the higher REY & net returns achieved in the cropping sequence. Lower B:C ratio was recorded in redgram – rice – onion. Ray *et al.* (2016) recorded highest benefit cost ratio in rice – okra system followed by rice – lathyrus, rice – sunflower, rice – sunflower + greengram, rice – rice and rice – greengram. Kumar *et al.*, (2008) observed higher return with the inclusion of vegetable crops in rice based cropping system in eastern Uttar Pradesh. Mandal *et al.* (2002) observed higher net return in

soybean – wheat crop sequence in Central India.

Resources use efficiency: Rice + daincha – rice – brinjal cropping sequence occupied the land throughout the year having land use efficiency of 100 percent. The LUE was highest because the cropping sequence occupied the field for maximum period (365 days) compared to other cropping systems, This was followed by maize +blackgram – rice – blackgram +redgram (94.5). Jat *et al.* (2012) also reported the significantly higher LUE in rice – fenugreek – okra cropping sequence. Requirement of irrigation water (2895 mm) was higher in rice + daincha – rice – brinjal cropping sequence followed by rice + daincha – rice – groundnut + redgram (2650 mm). The irrigation water use efficiency was the highest in maize + blackgram – rice – blackgram – rice – blackgram + redgram (8.78) followed by greengram + redgram – rice – redggram (8.68) cropping sequence. This may be due to higher economic yield and lesser water requirement by the crops in the cropping sequence.

It was concluded that maize + blackgram – rice – blackgram + redgram and DSR + daincha(10:1)– rice – maize + blackgram recorded higher REY, system productivity, net returns system profitability and remunerative cropping sequence in the Cauvery delta zone.

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***In Vitro* Multiplication of *Cleopatra mandarin* from Nodal Explants**

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Abstract: The present investigation was undertaken to develop *in vitro* protocol for production of *Cleopatra mandarin*. Nodal segments cultured on Murashige and Skoog medium supplemented with BAP 0.5 mg l⁻¹ + Kin 0.5 mg l⁻¹ resulted in earliest shoot initiation and maximum number of shoots per ex-plant. Maximum shoot length was in MS media fortified with BAP 1.0 mg l⁻¹ and 0.5 mg l⁻¹ Kin. Rooting media comprising of MS media fortified with IBA 0.5 mg l⁻¹ or IBA 1.0 mg l⁻¹ resulted in 100% rooting of micro shoots. Full strength MS medium with IBA 1.0 mg/l required minimum days for root initiation. Half strength MS media supplemented with IBA 2.0 mg l⁻¹ and IBA 1.0 mg l⁻¹ resulted in maximum average number of roots per micro shoot and maximum root length respectively. The highest survival per cent (90%) of *in vitro* grown plants was in potting media containing sand, soil and vermi compost in 1:1:1 ratio.

Key words: *In vitro* propagation, *Cleopatra mandarin*, *Citrus rootstock*, Nodal segments, Nutrient status, Soil properties

Citrus rootstocks have a marked effect on vigour, precocity, productivity, fruit quality, longevity, resistance, to pests and diseases of scion varieties. Jatti khatti (*Citrus jambhiri*) and Rangpur lime (*C. limonia*) are the most commonly used rootstocks in India. *Cleopatra mandarin* (*C. reshni* Tanaka) has been recommended as a rootstock for different cultivated species of citrus and is highly compatible with sweet orange and mandarin cultivars. It is also tolerant to tristeza, exocortis, xyloporosis, salt, cold, and calcareous soils. The production of uniform plants in sufficient quantity is not possible through seeds because of cross pollination, polyembryony, shorter viability of seeds and lesser number of seeds per fruit. *In vitro* propagation ensures the availability of plant material throughout the year. Taking this into account the present investigation has been planned with objectives to develop *in vitro* protocol for production of quality planting material

MATERIAL AND METHODS

The experiment was conducted at CCS HAU Campus, Hisar during 2016-2017 during March and April. The young newly emerged shoots about 10-12 cm in length were collected during morning hours. Nodal segments explants were thoroughly washed under running tap water and thereafter washed with teepol for 10 minutes followed by washing under running tap water. These were then pre-treated with 0.4 % Bavistin + 0.2% Streptocyclin for 30 minutes followed by four times washing with double distilled

water. The nodal segments were then inoculated on MS medium supplemented with different combinations and concentrations of growth regulators viz. BAP and Kinetin. For regeneration the cultures were incubated at 25±2°C under white fluorescent light for 16 hrs photoperiod. The MS medium containing BAP and Kinetin in concentrations varying from 0.25 mg l⁻¹ to 2.0 mg l⁻¹ either alone or in combination was used for shoot induction and proliferation. The micro shoots developed were sub cultured on fresh medium for further proliferation and rooting. The micro shoots formed were transferred to rooting medium containing varying strengths of MS medium (full, half and ¼ MS) fortified with different concentrations of IBA (0.1, 0.5, 1.0 and 2.0 mg l⁻¹) for root initiation and development. The rooted plants were transferred to different potting mixtures for hardening. The per cent survival of *in vitro* raised plants in potting media was studied six weeks after transferring to the different potting mixtures.

RESULTS AND DISCUSSION

Shoot regeneration: The shoot initiation significantly took minimum (14.44) days in treatment MS + 0.5 mg l⁻¹ BAP + 0.5 mg l⁻¹ Kin (Table 1). The days required for shoot initiation increased with increasing concentrations of the cytokinins. The present results in line with Kumar *et al.*, 2014. They recorded minimum time required for bud breaking (19.50 days) with BAP 0.5 mg l⁻¹ + Kin 0.5 mg l⁻¹ in *Cleopatra mandarin* which was statistically at par with treatments MS +

Table 1. Effect of growth regulators on shoot initiation, number of shoots per explant and length of shoots from nodal segments of *Cleopatra mandarin*

| Treatments (mg/l) | Minimum number of days required for shoot initiation | Number of shoots per explant | Length of shoots (cm) |
|---------------------|--|------------------------------|-----------------------|
| Control | 16.4 | 5.3 | 1.7 |
| BAP 0.25 | 17.9 | 4.4 | 1.9 |
| BAP 0.50 | 17.4 | 6.6 | 2.1 |
| BAP 0.75 | 17.0 | 7.6 | 2.4 |
| BAP 1.00 | 15.1 | 10.0 | 3.2 |
| BAP 1.25 | 16.0 | 9.3 | 2.8 |
| BAP 1.50 | 17.8 | 8.6 | 2.4 |
| BAP 1.75 | 18.4 | 8.6 | 2.5 |
| BAP 2.00 | 19.3 | 8.3 | 2.2 |
| Kin 0.25 | 18.2 | 7.1 | 1.8 |
| Kin 0.50 | 17.0 | 8.0 | 1.9 |
| Kin 0.75 | 19.9 | 8.2 | 2.2 |
| Kin 1.00 | 22.1 | 9.4 | 3.2 |
| Kin 1.25 | 22.3 | 7.9 | 2.2 |
| Kin 1.50 | 24.7 | 7.6 | 2.2 |
| Kin 1.75 | 24.8 | 7.0 | 2.2 |
| Kin 2.00 | 24.9 | 6.1 | 2.1 |
| BAP 0.50 + Kin 0.50 | 14.3 | 12.0 | 3.2 |
| BAP 0.50 + Kin 1.00 | 15.1 | 10.9 | 2.6 |
| BAP 0.50 + Kin 1.50 | 17.3 | 9.1 | 2.2 |
| BAP 0.50 + Kin 2.00 | 20.0 | 8.2 | 2.1 |
| BAP 1.00 + Kin 0.50 | 20.7 | 8.6 | 4.8 |
| BAP 1.00 + Kin 1.00 | 21.0 | 7.2 | 3.9 |
| BAP 1.00 + Kin 1.50 | 21.8 | 8.1 | 2.8 |
| BAP 1.00 + Kin 2.00 | 21.7 | 7.9 | 1.8 |
| BAP 1.50 + Kin 0.50 | 21.3 | 8.3 | 2.6 |
| BAP 1.50 + Kin 1.00 | 21.7 | 7.7 | 2.7 |
| BAP 1.50 + Kin 1.50 | 21.6 | 7.9 | 1.8 |
| BAP 1.50 + Kin 2.00 | 23.2 | 8.1 | 1.8 |
| BAP 2.00 + Kin 0.50 | 23.6 | 7.4 | 2.5 |
| BAP 2.00 + Kin 1.00 | 23.7 | 7.3 | 1.8 |
| BAP 2.00 + Kin 1.50 | 24.4 | 6.8 | 2.0 |
| BAP 2.00 + Kin 2.00 | 25.1 | 6.8 | 1.9 |
| CD (p=0.05) | 1.41 | 1.38 | 0.43 |

Basal medium was MS

0.5 mg l⁻¹ BAP + 0.1 mg l⁻¹ Kin and MS + 1.0 mg l⁻¹ BAP. The mean time required for bud break was directly dependent on medium combinations. The maximum number of shoots per explant (12.0) was in treatment comprising of MS media fortified with BAP 0.5 mg l⁻¹ + Kin 0.5 mg l⁻¹ and was statistically at par with treatment MS + 0.5 mg l⁻¹ BAP + 0.1 mg l⁻¹ Kin. The

number of shoots obtained per explants varies with the genotypes (Carimi and De Pasquale, 2003). Similar trend was noticed with regard to number of shoot and length of shoot with increasing concentration of BAP and Kinetin up to 1.0 mg l⁻¹. It seems that high BA concentrations are toxic for *in vitro* explant growth. Similar trend was observed when these growth regulators were used in combination. A combination of 1.0 mg l⁻¹ BAP and 0.5 mg l⁻¹ Kin resulted in significantly longer shoots (4.4 cm) than all other treatments. Al-Khayri and Al-Bahrany (2001) concluded that a combination of 0.25 mg l⁻¹ BAP and 1.0 mg l⁻¹ Kin was best for shoot elongation in lime (*C. aurantifolia*).

Root regeneration: The per cent micro shoots responding to rooting was 100% in MS + 0.5 mg l⁻¹ IBA and MS + 1.0 mg l⁻¹ IBA which was statistically at par with ½ MS + 1 mg l⁻¹ IBA (Table 2). Minimum number of days (19.89 days) required for root initiation was in rooting media consisting of MS + 1.0 mg l⁻¹ IBA followed by MS + 0.1 mg l⁻¹ IBA and MS + 0.5 mg l⁻¹ IBA. Syamal *et al.* (2007) also reported minimum days (15.32) for root induction in khasi mandarin at 2.0 mg l⁻¹ IBA. Singh and Rajam (2009) reported that rooting was very fast in sweet orange under the influence of IBA (1.0 mg l⁻¹). Maximum number of roots per micro shoot (5.89) was observed in rooting media having ½ MS + 2.0 mg l⁻¹ IBA which was significantly higher than all other treatments (Table 2). Average number of roots per shoot increased as the

Table 2. Effect of rooting media on rooting parameters of *in vitro* developed micro shoots of *Cleopatra mandarin*

| Treatments (mg l ⁻¹) | Percent rooting | Minimum number of days required for root initiation | Average number of roots per micro shoot | Root length (cm) |
|----------------------------------|-----------------|---|---|------------------|
| MS+ 0.0 | 0.0 (0.00) | 0.0 | 0.0 | 0.0 |
| MS+ 0.1 | 55.6 (48.22) | 20.9 | 1.4 | 1.3 |
| MS+ 0.5 | 100.0 (90.00) | 20.9 | 3.0 | 1.4 |
| MS+ 1.0 | 100.0 (90.00) | 19.9 | 4.4 | 2.8 |
| MS+2.0 | 66.7 (54.71) | 21.7 | 4.2 | 2.2 |
| ½ MS+0.1 | 55.6 (48.22) | 23.9 | 1.7 | 1.6 |
| ½ MS+0.5 | 77.8 (66.47) | 24.0 | 2.3 | 2.2 |
| ½ MS+1.0 | 88.9 (78.23) | 22.4 | 4.3 | 4.2 |
| ½ MS+2.0 | 66.7 (54.71) | 23.0 | 5.9 | 3.9 |
| ¼ MS+0.1 | 44.4 (41.73) | 26.0 | 1.3 | 1.4 |
| ¼ MS +0.5 | 44.4 (41.73) | 24.8 | 1.6 | 1.7 |
| ¼ MS +1.0 | 55.6 (48.22) | 25.3 | 1.8 | 2.1 |
| ¼ MS + 2.0 | 66.7 (54.71) | 23.7 | 1.9 | 2.2 |
| CD (p=0.05) | 23.83 (17.89) | 1.64 | 0.74 | 0.85 |

The values given in the parenthesis are angular transformed value



Inoculated explants of Cleopatra mandarin



Bud proliferation from explant



In vitro rooting in Cleopatra mandarin



Hardened plants of Cleopatra mandarin

concentration of IBA increased. The present result was in agreement with that of Sharma *et al.* (2009). They observed that half strength MS media was more effective than full strength MS media in relation to average number of roots per micro shoot. The root length was recorded maximum (4.22 cm) in treatment comprising of ½ MS+1.0 mg l⁻¹ IBA and it was statistically at par with ½ MS+2.0 mg l⁻¹ IBA. The length of roots obtained in treatments ½ MS+1.0 mg l⁻¹ IBA and ½ MS+2.0 mg l⁻¹ IBA was significantly higher than all other treatments. Root length significantly increased with increasing concentration of IBA up to 1.0 mg l⁻¹ and higher than this had reverse effect. Similar results were obtained by Tallon *et al.* (2012) where they reported longest roots (2.7 mm) in Cleopatra mandarin in MS media supplemented with 1.0 mg l⁻¹ BAP. This may be due to genotypic differences. Half strength MS gave better results as compared to full strength MS and ¼ MS indicating that 50% reduction of major salts helps in promoting the number and length of roots

thereby increasing rooting intensity.

Survival: The survival percentage of *in vitro* raised plants was maximum (90%) in potting mixture containing sand, garden soil and vermi compost in 1:1:1 ratio followed by mixture (80%) containing sand, garden soil and FYM in 1:1:1 ratio (Table 3). Maximum per cent survival was in potting mixture containing vermi compost can be attributed to the fact that vermi compost is a finely divided, peat-like material,

Table 3. Effect of different potting mixture on survival percentage of *in vitro* raised Plantlets of *Cleopatra mandarin*

| Treatments | Potting mixture composition | Survival percentage |
|-----------------|------------------------------------|---------------------|
| PM ₁ | Sand | 50 |
| PM ₂ | Sand+ Soil (1:1) | 60 |
| PM ₃ | Sand + Soil + FYM (1:1:1) | 80 |
| PM ₄ | Sand + Soil +Vermi Compost (1:1:1) | 90 |

with high porosity, aeration, drainage, water holding capacity and microbial activity, which makes it an excellent soil conditioner (Ravimycin, 2016). The reason for better hardening in vermin compost may be due to presence of rich organic matter source providing strength and essential nutrients for survival to the *in vitro* raised plants.

CONCLUSION

Maximum shoot length was found in MS media supplemented with 1.0 mg l⁻¹ BAP and 0.5 mg l⁻¹ Kin. Rooting media comprising of full strength MS media fortified with 0.5 mg l⁻¹ IBA or 1.0 mg l⁻¹ IBA resulted in 100% rooting of micro shoots. The highest survival per cent (90%) of *in vitro* grown plants was recorded in potting media containing sand, soil and vermi compost.

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Effect of Irrigation and Mulch on Linseed (*Linum usitatissimum*) for Improving Growth, Yield and Water Extraction Pattern

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Abstract: A field experiment was conducted at Bidhan Chandra Krishi Viswavidyalaya farm, during *rabi* of 2010–11 and 2011–12 to find out the effect of irrigation and mulch on seed yield, oil yield and water use of linseed. Linseed irrigated at IW/CPE of 0.6 showed 6.72 and 17.63% higher seed yield compared to IW/CPE of 0.4 (669.02 kg ha⁻¹) and rainfed (607 kg ha⁻¹), respectively and was significantly superior. Maximum seed yield of about 707.62 kg ha⁻¹ under the treatment receiving black polythene mulch, which was about 4.33, 8.72 and 14.76% higher over the treatments receiving straw, water hyacinth both at @ 5 t ha⁻¹ and no mulch, respectively. Soil moisture extraction by the crop increased with the advancement of crop growing period and again it decreased till harvest and also increased with the increase in moisture status of the soil. Water use was highest with irrigation at IW/CPE of 0.6. Black polythene showed best performance regarding moisture conservation. Irrigation applied at IW/CPE of 0.6 maintained its superiority with highest net return and proved as best treatment. Among various mulches, black polythene was most economical followed by straw mulch @ 5 t ha⁻¹.

Keywords: Linseed, Irrigation, Mulch, Yield, Water use, Economics

Linseed (*Linum usitatissimum*) is a multipurpose crop grown in many environments for food, feed, fibre and industry. This crop has predominantly 35 to 47 per cent valuable oil, in which the most appreciated are omega-3 fatty acids. In 2014, world production of linseed was 2.65 million tonnes, led by Canada with 33% of the production. Other major producers were Kazakhstan, China and Russia. India ranked in 6th position with 141000 tonnes production (FAOSTAT 2017). Inadequate water supply for crop production is a critical limiting factor in many existing cultivated areas. Therefore, irrigation scheduling is required to determine the correct frequency and duration of watering. To retain moisture in the soil by reducing evaporation loss, the most appropriate agronomical moisture conservation practice is mulch. Mulches modify hydrothermal regime, recycles plant nutrients, promote crop development and increase yields (Poonam *et al.* 2016). Irrigation applied at different IW/CPE ratios and different mulch in areas facing water scarcity to save irrigation water for ensured higher yield was also studied by Kumar *et al.* (2015). In view of these points, the present experiment was undertaken to determine the most efficient irrigation schedule and mulch for linseed production in alluvial zone of West Bengal.

MATERIAL AND METHODS

A field experiment with linseed was conducted during the winter (*rabi*) season of 2010–12 at Research Farm, Bidhan

Chandra Krishi Viswavidyalaya, Kalyani (at 22°58' N latitude and 88°3' E longitude with an altitude of 9.75 m above the mean sea level) in West Bengal. The soil of the experimental site was alluvial and sandy loam in texture with pH 7.86, Organic carbon 0.61 %, available N, P and K was 250.12, 15.81 and 153.22 kg/ha, respectively. The moisture content at field capacity was 21.2 percent and at permanent wilting point 9.5 percent. The experiment was laid out in split plot design with three replications. Main plot treatments consisted of three levels of irrigation, I₁ : Rainfed, I₂ : Irrigation at IW/CPE of 0.4, I₃ : Irrigation at IW/CPE of 0.6 and sub-plots with four levels of mulch, M₁: No mulch, M₂: Water hyacinth @ 5 t/ha, M₃: Straw mulch @ 5 t/ha, M₄: Black polythene with 25 micron thickness. Recommended doses of N, P₂O₅ and k₂O @ 60: 30: 30 kg/ha were applied through urea, single superphosphate and muriate of potash, respectively during both the years. The full dose of phosphorus, potassium and ½ dose of nitrogen were applied as basal and remaining ½ dose of nitrogen was applied 45 DAS. Linseed 'Neela (B-67)' was sown in rows, 30 cm apart using 20 kg seeds/ha in the 2nd week of November with plot size of 5 x 3m. A pre-sowing irrigation was given for proper germination and establishment. Remaining Irrigations were applied as and when required as per treatment recommendation. One irrigation in plots under I₂ treatment and two irrigations in plots under I₃ treatment were applied. Irrigation water depth (IW) was maintained 50 mm for each irrigation with the help of

parshall flume. Irrigation was withdrawn 15 days before harvesting of the crop. For irrigation scheduling, 'Climatological approach' was followed, which involved estimation of atmospheric evaporative demand by taking ratio between 'amount of irrigation water applied (mm)' to the 'cumulative pan evaporation (CPE) (mm)'. Upon the arrival of pre-determined CPE, irrigation was applied in respective plots. The crop was harvested at maturity 3rd week of March and yield was recorded. Total rainfall during the crop growth period was 10.4 and 11.1 mm in successive years of experiment, respectively. The mean minimum and maximum temperature was 13.8-21.9°C and 26.6-34.9°C, respectively during the crop growth period. The mean relative humidity ranged from 33.6 to 95.9%. The mean pan evaporation per day ranged for 1.3 to 3.2 mm. Leaf area duration (LAD) was obtained by integrating the leaf area index over crop growth period.

$$LAD (days) = \frac{L_2 + L_1}{2} \times (t_2 - t_1) + \dots + \frac{L_{n-1} + L_n}{2} \times (t_n - t_{n-1})$$

Where, L_1 is the leaf area at time t_1 ; L_2 is the leaf area at time t_2 ; L_n is the leaf area at time t_n ; L_{n-1} is the leaf area at time t_{n-1} . Net assimilation rate (NAR) is an increase in dry weight of plant per unit leaf area per unit time. NAR was calculated from the following equation;

$$NAR = \frac{(W_2 - W_1)(\log_e L_2 - \log_e L_1)}{(t_2 - t_1)(L_2 - L_1)} \text{ gm}^{-2} \text{ day}^{-1}$$

Where, L_1 and W_1 are leaf area and dry weight of plants at time t_1 ; and L_2 and W_2 are leaf area and dry weight of plants at time t_2 . Soil moisture studies were done during the entire crop period starting from sowing to final harvesting of the crop. Soil moisture record and soil samples were collected from middle of each plot and space between crop rows corresponding to all treatments from 0-15, 15-30, 30-45 and 45-60 cm soil depths immediately before and 48 hours after each irrigation and at the same time from I₁ (rainfed) plots nearly at about 15 days interval and finally at harvest to determine the total soil moisture used up by the crop. The soil samples were dried in the oven at 105° C for 72 hours to calculate the moisture content on gravimetric basis. Volumetric moisture content was then calculated by multiplying the respective bulk density with the gravimetric moisture content. Soil moisture content was then expressed as cm of water for the calculation of total soil moisture extraction during crop growth period. The economic analysis of the experiment was carried out by taking into consideration the prevailing market price (₹/kg) of inputs used and economic produce.

RESULTS AND DISCUSSION

Growth attributes: Irrigation levels significantly influenced

the primary branches/plant, leaf area index (LAI), leaf area duration (LAD) and net assimilation rate (NAR) of linseed during both the years of experiment (Table 1). Irrigation applied at IW/CPE of 0.6 proved as superior to other irrigation levels by producing maximum primary branches /plant. About 14.99% more primary branches/plant was obtained with the application of irrigation at IW/CPE of 0.4 over rainfed. Black polythene mulch showed best performance with 6.51, 15.58 and 33.37% more primary branches/plant over straw mulch @ 5 t/ha, water hyacinth @ 5 t/ha and no mulch, respectively. Leaf area index increased with the advancement in growth of the crop and reached their maximum values at 90 DAS and thereafter declined with the increase in age. Treatment receiving irrigation at IW/CPE of 0.6 recorded the highest LAI at all growth stages where as moisture scarcity under rainfed condition maintained poor canopy coverage resulting in lower LAI values. At 90 DAS, irrigation applied at IW/CPE of 0.6 recorded about 4.50 and 24.73% higher LAI over irrigation applied at IW/CPE of 0.4 and rainfed treatment, respectively. Black polythene, straw mulch @ 5 t/ha and water hyacinth @ 5 t/ha increased 15.08, 9.55 and 4.02% LAI over no mulch. LAD values followed the same trend of LAI. The NAR value was maximum during 60 to 90 DAS from the minimum at 30 to 60 DAS and there after gradually lowered down during 90 to 120 DAS. During 60 to 90 DAS the maximum NAR of 2.87 g/m² /day was achieved with the irrigation applied at IW/CPE of 0.6 which was 12.99 and 17.14% higher over irrigation at IW/CPE of 0.4 and rainfed, respectively. About 12.76, 4.98 and 0.74% higher NAR was recorded with the application of black polythene, straw mulch @ 5 t/ha and water hyacinth @ 5 t/ha over no mulch. **This indicate that the effect of mulch was positive** to the growth attributes of the crop over no mulch and black polythene showed most efficiency. Positive influence of plastic mulch on plant growth mainly due to the modification of soil microclimate was mentioned by Lalitha *et al.* (2010).

Yield and net return: Both seed and biological yield of linseed were significantly increased with the increment in irrigation levels (Table 1). Irrigation applied at IW/CPE of 0.6 showed best performance in increasing the yield to the tune of 18.18 and 14.46% increment in seed and biological yield, respectively over rainfed treatment. Irrigation applied at IW/CPE of 0.4 registered about 9.92 and 7.78% higher seed and biological yield over rainfed crop. Improvement of soil moisture status in the root zone of a crop through irrigation favoured growth and development of the plant and thus increased height, dry matter and yield attributing characters which induces better biological yield. Favourable influence of irrigation on these attributes significantly increased yield as stated by Sharma *et al.* (2012). Different mulch treatments

Table 1. Effect of irrigation and mulch on growth attributes, yield and net return of linseed

| Treatments | Number of primary branches plant ⁻¹ | | | Leaf area index | | | Leaf area duration (Days) | | | Net assimilation rate (g m ⁻² leaf area day ⁻¹) | | | Seed yield (kg ha ⁻¹) | | | Biological yield (t ha ⁻¹) | | | Net Returns (x10 ³ /ha) | | | | | | |
|-----------------------------|--|-------|-------|-----------------|-------|-------|---------------------------|--------|------|--|-------|--------|-----------------------------------|-------|-------|--|------|----|------------------------------------|-----|----|---------|----|-----|--|
| | 2010-11 | | | 2011-12 | | | 2010-11 | | | 2011-12 | | | 2010-11 | | | 2011-12 | | | 2010-11 | | | 2011-12 | | | |
| | 30 | 60 | 90 | 120 | 30 | 60 | 90 | 120 | 30 | 60 | 90 | 120 | 30 | 60 | 90 | 120 | 30 | 60 | 90 | 120 | 30 | 60 | 90 | 120 | |
| Irrigation levels | | | | | | | | | | | | | | | | | | | | | | | | | |
| Rainfed | 3.271 | 3.370 | 0.55 | 1.49 | 1.86 | 1.11 | 124.09 | 126.71 | 1.50 | 2.45 | 2.01 | 601.87 | 612.13 | 3.15 | 3.28 | 7.27 | 7.66 | | | | | | | | |
| Irrigation at IW/CPE of 0.4 | 3.719 | 3.918 | 0.68 | 1.59 | 2.22 | 1.30 | 142.61 | 145.20 | 1.44 | 2.54 | 1.67 | 664.18 | 673.85 | 3.37 | 3.56 | 8.42 | 8.81 | | | | | | | | |
| Irrigation at IW/CPE of 0.6 | 4.232 | 4.339 | 0.73 | 1.76 | 2.32 | 1.43 | 153.26 | 156.15 | 1.45 | 2.87 | 1.72 | 709.51 | 718.47 | 3.66 | 3.70 | 9.42 | 9.74 | | | | | | | | |
| CD (p=0.05) | 0.196 | 0.185 | 0.003 | 0.005 | 0.014 | 0.020 | 1.42 | 2.59 | 0.03 | 0.06 | 0.059 | 5.510 | 3.502 | 3.805 | 2.735 | - | - | | | | | | | | |
| Mulch treatments | | | | | | | | | | | | | | | | | | | | | | | | | |
| No mulch | 3.148 | 3.279 | 0.55 | 1.51 | 1.99 | 1.12 | 128.55 | 131.05 | 1.55 | 2.43 | 1.95 | 611.92 | 621.28 | 3.18 | 3.19 | 7.40 | 7.74 | | | | | | | | |
| Water hyacinth @ 5 t/ha | 3.654 | 3.762 | 0.62 | 1.58 | 2.07 | 1.25 | 136.10 | 139.00 | 1.48 | 2.61 | 1.85 | 645.85 | 655.84 | 3.32 | 3.43 | 8.12 | 8.48 | | | | | | | | |
| Straw mulch @ 5 t/ha | 3.963 | 4.085 | 0.69 | 1.65 | 2.18 | 1.33 | 143.90 | 146.15 | 1.43 | 2.72 | 1.81 | 673.96 | 682.56 | 3.51 | 3.63 | 8.70 | 9.03 | | | | | | | | |
| Black polythene | 4.197 | 4.375 | 0.75 | 1.72 | 2.29 | 1.43 | 151.40 | 154.55 | 1.39 | 2.74 | 1.74 | 702.32 | 712.91 | 3.59 | 3.79 | 9.27 | 9.69 | | | | | | | | |
| CD (p=0.05) | 0.163 | 0.132 | 0.002 | 0.005 | 0.012 | 0.026 | 2.02 | 4.75 | 0.04 | 0.044 | 0.059 | 4.927 | 4.786 | 3.660 | 3.596 | - | - | | | | | | | | |

showed significant improvement in seed and biological yield over no mulch treatment during both the years under study. Black polythene maintained its superiority and induced about 14.63 and 15.86% seed and biological yield over control. Straw mulch @ 5 t/ha showed an increment to the tune of 9.76 and 12.09% in seed and biological yield, respectively over control and was followed by water hyacinth mulch @ 5 t/ha. Linseed irrigated at IW/CPE of 0.6 showed 11.14 and 28.25% higher net return over irrigation at IW/CPE of 0.4 and rainfed, respectively. The returns were more by 6.88, 14.22 and 25.23% with black polythene mulch over straw mulch @ 5 t/ha, water hyacinth mulch @ 5 t/ha and no mulch, respectively. Moisture conservation through mulching fetched higher net returns in linseed (Tetarwal *et. al.* 2015).

Soil moisture extraction and moisture extraction pattern: The moisture extraction by linseed was positively associated with the amount of moisture present in the soil (Table 2). Under all irrigation treatments, water withdrawal by the crop was generally maximum following irrigation which generally decreased with time. Under higher moisture stress situation rainfed plants recorded least water extraction. Soil moisture extraction by the crop increased with the advancement of growth and development and then again gradually decreased at maturity mainly due to ageing, senescence etc. Linseed irrigated at IW/CPE of 0.6 extracted maximum soil moisture throughout the entire growth period because here plants received maximum number of irrigation. The next higher value was observed with the application of irrigation at IW/CPE of 0.4 while, under rainfed treatment the least response was noticed. Mulched plots recorded lower soil moisture extraction by the crop than no mulched plots mainly due to better moisture conservation capacity of mulch. In 2010-11, rainfed linseed recorded the minimum water extraction mainly due to moisture scarcity than other two irrigation levels. Crop receiving no mulch extracted maximum soil moisture from the profile under all levels of irrigation, rainfed, irrigation at IW/CPE of 0.4 and at IW/CPE of 0.6. In 2011-2012, Treatment involving no mulch computed the maximum soil moisture extraction of 3.86 cm at 74-89 DAS and 5.01 cm at 53-68 DAS when the crop was irrigated at IW/CPE of 0.4 and 0.6, respectively.

Soil moisture extraction pattern was markedly influenced by different irrigation and mulch practices (Fig1). Linseed irrigated at IW/CPE of 0.6 extracted maximum moisture (36.55%) from top layer (0-15 cm) due to more availability of irrigation water and minimum (30.71%) was extracted under rainfed treatment. However, the reverse trend was registered in deeper soil layers viz., from 15-30, 31-45 and 45-60 cm. Usually, under dry situation crop showed a tendency to extract more moisture from deeper soil layers as compared to

Table 2. Soil moisture extraction in cm during the growth period of broad bean during 2010–11

| 2010-11 | | | | | | | | | | |
|------------------------------------|-------------------|-------|-------|-------|-------|-------|--------|---------|---------|-------|
| Rainfed | | | | | | | | | | |
| Mulch levels | Days after sowing | | | | | | | | Total | |
| | 0-15 | 15-30 | 30-45 | 45-60 | 60-75 | 75-90 | 90-105 | 105-123 | | |
| No mulch | 1.97 | 2.34 | 2.49 | 3.02 | 2.78 | 2.31 | 2.00 | 1.91 | 18.82 | |
| Water hyacinth @ 5 t/ha | 1.69 | 2.31 | 2.51 | 2.60 | 2.79 | 2.70 | 2.20 | 1.98 | 18.79 | |
| Straw mulch @ 5 t/ha | 1.76 | 2.42 | 2.42 | 2.65 | 2.88 | 2.48 | 2.15 | 1.80 | 18.56 | |
| Black polythene | 1.64 | 2.26 | 2.49 | 2.85 | 2.74 | 2.40 | 2.21 | 1.94 | 18.53 | |
| Irrigation at IW/CPE of 0.4 | 0-15 | 15-30 | 30-45 | 45-60 | 60-77 | 79-94 | 94-109 | 109-123 | Total | |
| No mulch | 1.70 | 2.25 | 2.61 | 2.87 | 2.95 | 3.79 | 3.12 | 2.47 | 21.76 | |
| Water hyacinth @ 5 t/ha | 1.67 | 2.17 | 2.68 | 2.93 | 3.16 | 3.36 | 2.73 | 2.31 | 21.01 | |
| Straw mulch @ 5 t/ha | 2.08 | 2.28 | 2.39 | 2.98 | 3.20 | 3.30 | 2.37 | 2.22 | 20.82 | |
| Black polythene | 1.91 | 2.47 | 2.52 | 2.68 | 2.71 | 3.21 | 2.73 | 2.50 | 20.73 | |
| Irrigation at IW/CPE of 0.6 | 0-15 | 15-30 | 30-45 | 45-55 | 57-72 | 72-87 | 87-104 | 106-123 | Total | |
| No mulch | 1.40 | 2.65 | 2.80 | 2.97 | 4.28 | 3.57 | 2.24 | 4.20 | 24.11 | |
| Water hyacinth @ 5 t/ha | 1.57 | 2.60 | 2.80 | 2.82 | 4.20 | 3.45 | 2.32 | 4.17 | 23.93 | |
| Straw mulch @ 5 t/ha | 1.33 | 2.31 | 2.51 | 2.69 | 4.24 | 3.64 | 2.22 | 4.32 | 23.26 | |
| Black polythene | 1.44 | 2.21 | 2.59 | 2.60 | 3.99 | 3.61 | 2.18 | 4.44 | 23.06 | |
| I_r – Rainfed | | | | | | | | | | |
| 2011-12 | | | | | | | | | | |
| | 0-15 | 15-30 | 30-45 | 45-60 | 60-75 | 75-90 | 90-105 | 105-124 | Total | |
| No mulch | 1.51 | 2.48 | 2.54 | 2.60 | 3.42 | 2.31 | 1.68 | 1.36 | 17.90 | |
| Water hyacinth @ 5 t/ha | 1.58 | 1.84 | 2.45 | 2.70 | 3.49 | 2.30 | 1.74 | 1.73 | 17.84 | |
| Straw mulch @ 5 t/ha | 1.52 | 1.80 | 2.44 | 2.65 | 3.49 | 2.42 | 1.67 | 1.61 | 17.60 | |
| Black polythene | 1.48 | 1.76 | 2.59 | 3.45 | 2.36 | 1.84 | 1.56 | 17.58 | | |
| Irrigation at IW/CPE of 0.4 | 0-15 | 15-30 | 30-45 | 45-60 | 60-77 | 79-94 | 94-109 | 109-123 | Total | |
| No mulch | 1.43 | 2.33 | 2.62 | 2.64 | 3.64 | 3.86 | 3.58 | 2.88 | 22.98 | |
| Water hyacinth @ 5 t/ha | 1.35 | 2.40 | 2.78 | 3.41 | 3.28 | 3.62 | 2.90 | 2.27 | 22.01 | |
| Straw mulch @ 5 t/ha | 1.37 | 2.08 | 2.30 | 2.96 | 3.85 | 3.38 | 2.54 | 3.02 | 21.50 | |
| Black polythene | 1.40 | 2.35 | 2.49 | 3.13 | 3.37 | 3.57 | 2.72 | 2.29 | 21.32 | |
| Irrigation at IW/CPE of 0.6 | 0-15 | 15-30 | 30-45 | 45-51 | 53-68 | 68-83 | 83-100 | 102-117 | 117-124 | Total |
| No mulch | 1.49 | 2.27 | 3.10 | 1.21 | 5.01 | 3.86 | 2.74 | 3.45 | 1.24 | 24.37 |
| Water hyacinth @ 5 t/ha | 1.45 | 2.06 | 3.12 | 1.13 | 4.92 | 3.80 | 2.58 | 3.40 | 1.21 | 23.67 |
| Straw mulch @ 5 t/ha | 1.45 | 2.19 | 2.90 | 1.52 | 4.78 | 3.63 | 2.99 | 3.06 | 1.07 | 23.59 |
| Black polythene | 1.40 | 2.11 | 2.83 | 1.00 | 4.97 | 3.69 | 3.16 | 3.21 | 1.13 | 23.50 |

wet condition, where the crop extracted more water from upper layers. This results corroborate the findings of Tatarwal et al. (2013) in Indian mustard. The maximum soil moisture

depletion (36.24%) was registered from top soil layer (0–15 cm) in no-mulch, while the least (32.77%) with black polythene mulch. This might be due to higher evaporation

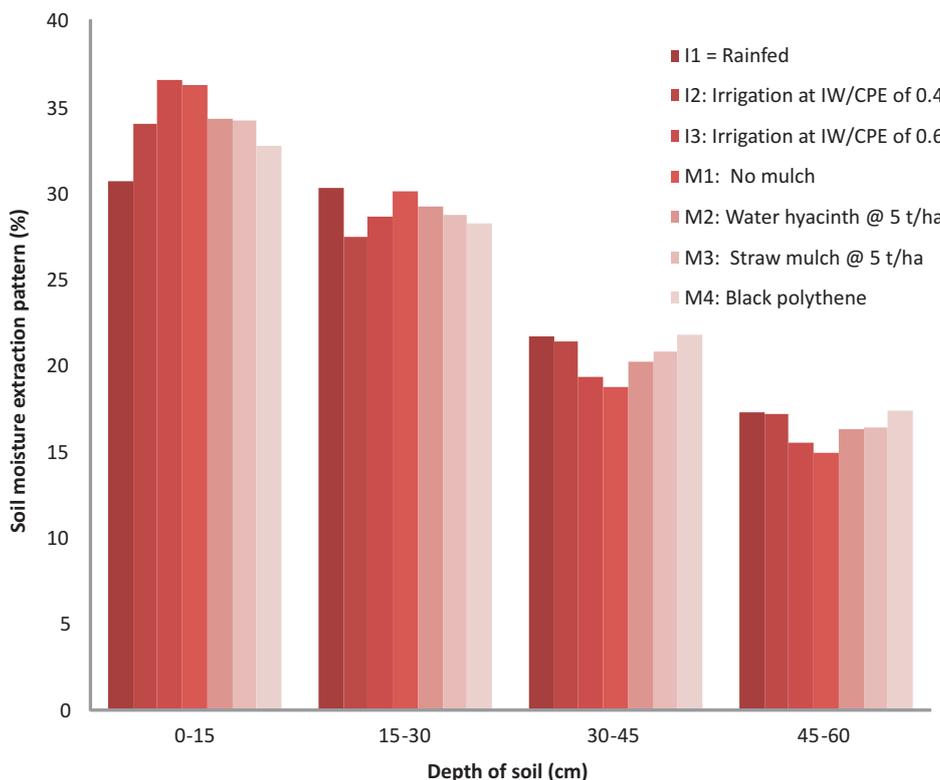


Fig. 1. Soil moisture extraction pattern (%) of linseed during (2010-12)

from top layer which was exposed to solar radiation under no mulch treatment while the evaporative loss of water was minimum with black polythene. In 15-30 cm soil layer the same trend was observed. However, the reverse trend was observed in deeper soil layer from 31-45 and 45-60 cm and the maximum depletion of soil moisture was recorded under black polythene mulch (21.73 and 17.31%) followed by straw mulch @ 5 t/ha (20.77 and 16.33%) and least with no-mulch (18.76 and 14.88%) respectively. This is in conformity with the findings of Tatarwal 2015.

Thus, linseed can be successfully grown under irrigated condition providing irrigation at IW/CPE of 0.6. Among different mulches, black polythene proved best moisture conserving material for ensuring higher productivity, profitability and water-use aspect.

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Ornamental Fish Production Sector of Maharashtra state: A Constraint Analysis

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Abstract: A study was conducted to assess the constraints faced by ornamental fish producers in Mumbai and Thane districts of Maharashtra state. A total of 30 ornamental fish producers out of 90 were taken as sample for the study and data was collected through semi-structured interview schedule. Constraints faced by them were classified as production constraints, knowledge constraints, marketing constraints and financial constraints. It was found that less water supply, less availability of live food and unsubsidized electricity supply were the main constraints. Low selling price of fish and large number of middlemen were hindering factors in marketing of ornamental fish. Also, lack of special trainings, non-availability of crop insurance schemes and less credit facility were other major constraints faced by ornamental fish producers. Constraints faced by them need to be effectively addressed by Government and policy makers. Continuous supply of water, availability of live food and supply of electricity at a rate par with agriculture sector is needed. Marketing of fish by forming marketing co-operative societies and innovative ways like mobile apps should be explored. Organization of special trainings in the field of breeding technology, live food development and health management are needed. State Government can pursue crop insurance schemes and banks / other financial institutions on offer credits.

Keywords: Ornamental fish producer, Constraints, Training, Credit, Maharashtra

With the increase in demand for ornamental fishes especially in USA, Europe and Japan, many countries in Asia have started capturing and culturing beautifully colored ornamental fishes. Developing countries play an important role and estimates shows that nearly 60 percent of the international trade in ornamental fish originates from developing countries mainly from Asia (Rani *et al.*, 2014). The entire industry, including accessories and fish feed, is estimated to be worth more than the US \$14 billion. More than 2,500 species are traded globally and some 30-35 species of freshwater fish dominate in the international market (MPEDA, 2011). India's share in ornamental fish export is negligible and mainly dominated by wild varieties of fish mainly from North East states. The domestic trade of aquarium is reported to grow at 20% annually (Kurup *et al.*, 2012). There is a vast opportunity for growth of ornamental enterprise in domestic trade. Marine Product Export development Authority (MPEDA) and National Fisheries Development Board (NFDB) with mandate to encourage the breeding and export of fish from India have named the innovative endeavor 'Rainbow Revolution' and initiated subsidy based developmental schemes in four states i.e. West Bengal, Tamilnadu, Maharashtra and Rajasthan. Self Help Group (SHG's) for women in Odisha and KAVIL (Kerala Aqua Venture International Limited) in Kerala was developed

for the development of ornamental fish enterprise for livelihood security with the ornamental fish unit (Swain *et al.*, 2013, Remeshan and Shaktivel, 2014 and Yadav and Sharma, 2017).

Ornamental fish producers have been receiving a significant amount of income from the farming activity. But, the production and income from ornamental fisheries is always susceptible to numerous problems, viz., non-availability of technical advice, special training and fetching low price to produce involvement of middlemen (Bhatkar, 2014). Few studies conducted on ornamental fish farming business in other Indian states have also revealed similar constraints i.e. West Bengal (De and Ramchandran, 2011), shortage of quality brood stock, heavy mortality and poor transportation in West Bengal (Singh and Dey, 2003) and disease outbreak due to environmental factors, lack of advance technology and market competition in Tamilnadu (Umamaheshwari *et al.*, 2016). Accordingly, a study was done with the objective of analyzing the various kinds of constraints faced by ornamental fish producers of Mumbai and Thane districts of Maharashtra state.

MATERIAL AND METHODS

Study was carried out during the period 2015-2016, in the northern coastal districts of Maharashtra, viz., Mumbai and

Thane. Primary data were collected through survey using semi-structured interview schedules and stakeholder meetings. Altogether 30 ornamental fish producers out of 90 as per MPEDA (2012) from all blocks of Mumbai and Thane districts were interviewed during the study and pilot study was conducted on 15 ornamental fish producers to list out the constraints faced by them. These constraints were further divided into production constraints (10 nos.), knowledge constraints (05 nos.), marketing constraints (07 nos.) and financial constraints (04 nos.). The producers were asked to score the constraints on 3-point scale with 2 as agree, 1 somewhat agree and 0 as disagree.

Weighted average technique was applied to analyze and rank various constraints in ornamental fish production. The weighted values taken for calculating weighted average were, agree = 2, somewhat agree = 1 and disagree = 0. Maximum and minimum score a constraint could attain were 20 and 0. The formula for weighted scale is as follows;
Weighted average = $\frac{\sum (x_1.w_1 + x_2.w_2 + x_3.w_3)}{\sum (w_1 + w_2 + w_3)}$

Where, x_1, x_2, x_3 = frequency of the respective constraints

w_1, w_2, w_3 = weighted values

RESULTS AND DISCUSSIONS

Among the production constraints, electricity supply not at subsidized rate was found critical and was ranked first by producers. Sekharan and De (2010) reported high electricity charges as the second most important constraint which inhibits the growth of ornamental fish production in India. Non-availability of adequate water supply and live food were ranked second and third respectively. Seed is considered to be the most crucial input for fish farming. Therefore, development of ornamental fish farming is highly dependent on adequate, quality and timely availability of good quality seed. Overall perception is that assured supply of quality fish seed at the time of stocking was fourth most important constraint perceived by producers in ornamental fish production in Mumbai and Thane district. Singh and Ahmad (2005) also documented that the non-availability of quality seed creates greater problems for the development of freshwater aquaculture in Bihar.

Knowledge of modern culture techniques is an important aspect to adopt ornamental fish culture. Besides knowledge, farmers also expect extension support from the Fisheries Department/ Fisheries institutes/KVK in performing fish farming activities in a better way. Invariably, both the MPEDA's beneficiaries (borrowers) and non-beneficiaries (non-borrowers) identified the lack of special trainings on ornamental fish as main constraint, non-availability of technical advice and lack of updated information also

Table 1. Production constraints perceived by producers in ornamental fish production

| Constraints | Weighted average | Rank |
|--|------------------|------|
| Electricity supply not at subsidized rates | 18.33 | 1 |
| Inadequate water supply | 16.00 | 2 |
| Non-availability of live food | 13.00 | 3 |
| Non-availability of seed in time | 11.67 | 4 |
| Low quality seed and brood stock | 9.33 | 5 |
| Vulnerability to diseases | 9.00 | 6 |
| Lack of nutritional feed | 8.00 | 7 |
| Inadequate brood stock availability | 7.33 | 8 |
| Insufficient infrastructure | 5.67 | 9 |

Table 2. Knowledge constraints perceived by producers in ornamental fish production

| Constraints | Weighted average | Rank |
|---|------------------|------|
| Less special trainings on ornamental fish | 13.33 | 1 |
| Non-availability of technical advice | 9.67 | 2 |
| Lack of latest information on ornamental fish production | 9.33 | 3 |
| Lack of technical knowledge | 9.00 | 4 |
| Non-availability of technical advice through Individual / Group / Mass contact method | 9.00 | 5 |

Table 3. Marketing related constraints perceived by producers in ornamental fish production

| Constraints | Weighted average | Rank |
|--|------------------|------|
| Low saleable price | 16.67 | 1 |
| Large no of middlemen | 16.00 | 2 |
| Unavailability of price and market information | 11.67 | 3 |
| Long marketing chain | 11.00 | 4 |
| Lack of market centers | 7.00 | 5 |
| Poor transportation facility | 3.67 | 6 |

perceived as major constraints in the ornamental fish farming business which has adversely affected the expansion of higher fish yields and incomes (Table 4). Lack of technical knowledge was ranked fourth and non-availability of technical advice through Individual / Group / Mass contact method were ranked fifth perceived constraint by ornamental fish producers. Similar constraints were documented in fish farming business by Pandey and Dewan (2006) and in ornamental fisheries by Sekharan (2010), Bhatkar (2014) and Umamaheshwari (2016).

Marketing related constraints

Involvement of middlemen is often considered as a factor which restricts the farmer in obtaining a fair price for the fish produce. In the same context, the ornamental fish producer

Table 4. Financial constraints perceived by producers in ornamental fish production

| Constraints | Weighted average | Rank |
|--|------------------|------|
| Non-availability of crop insurance schemes | 16.67 | 1 |
| Insufficient credit facility | 11.00 | 2 |
| High interest rate for the loan | 7.33 | 3 |
| Difficulty in getting credit | 6.67 | 4 |

Table 5. Category wise constraints perceived by producers in ornamental fish production

| Constraints | Weighted average | Rank |
|------------------------|------------------|------|
| Production constraints | 10.38 | 1 |
| Knowledge constraints | 10.07 | 2 |
| Marketing constraints | 10.38 | 1 |
| Financial constraints | 9.67 | 3 |

perceived low saleable price and large numbers of middlemen as first and second ranked constraints by producers in Mumbai and Thane district. Similar problems were documented by Heenatingala (2012) in Sri Lanka and Rahaman et al. (2013) in fish marketing in West Bengal. Unavailability of price and market information, long marketing chain and lack of market centers were the constraints reported in their study.

Financial constraints

The non-availability of crop insurance schemes and credit facility were the major constraints faced by ornamental fish producers of Mumbai and Thane district. The loans and crop insurance schemes were not available for ornamental fish production may be due to unorganized business activity. Similar results were reported by Sekharan (2010), De and Ramachandran (2011), Rehman (2013) and Bhatkar (2014).

The production and marketing constraints were the most persistent constraints in ornamental fish production sector of Thane and Mumbai district. Knowledge related constraints were ranked second with weighted average of 10.07 followed by financial constraints with weighted average of 9.67.

CONCLUSIONS

Study on the constraints in production of ornamental fishes in Mumbai and Thane district found that the non-availability of adequate water supply and non-availability of live food, electricity supply not at subsidized rate were the major constraint. Lack of special trainings on ornamental fish, non-availability of technical advice, lack of updated information, low saleable price, large number of middlemen, non-availability of crop insurance schemes and credit facility were the other major constraints faced by ornamental fish

producers.

The live food production farms, formation of co-operatives and Self Help Groups (SHG's) could be formed to facilitate production and marketing of ornamental fishes. Moreover, the constraints faced by the ornamental fish producers are numerous and need to be effectively addressed by government and policy makers. The State Government should encourage the ornamental fish producers and interested entrepreneurs to take up farming of aquarium fishes by extending easy credit facilities, subsidy and crop insurance scheme through the bank and other financial institutions.

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Effect of Neem Leaf Extract Incorporated Diet on Survival, Growth and Flesh Quality of Common Carp (*Cyprinus carpio*)

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Abstract: The present study was conducted to assess the efficacy of neem leaf extract (NLE) in the diet of common carp, *Cyprinus carpio* under semi-intensive culture system for 180 days. NLE was incorporated in six basal diet (rice bran 1: mustard meal 1) at different levels viz., 0.25, 0.5, 1.0, 1.5 and 2.0 g kg⁻¹ feed. Common carp fry were stocked in 80m² outdoor cemented tanks and daily fed with different diets for 180 days. During the experimental period, the water quality parameters did not vary significantly among the treatments and the values were within the range required for fish culture. Maximum survival and growth of fish (in terms of average final body weight, weight gain, specific growth rate, protein efficiency ratio) was in NLE @ 1.0 g kg⁻¹ feed. A significant increase in the flesh protein content of fish was recorded in all the NLE fed groups (0.25 to 2 g kg⁻¹ feed), with significant decline in carbohydrate content compared to control. Overall, the results revealed that the NLE improved the survival and growth of fish upto 1.0 g kg⁻¹ feed, and afterwards at higher rate the survival and growth declined.

Keywords: Aquaculture, Common carp, Neem leaf extract, Survival and growth, Flesh composition

Aquaculture is one of the fast growing food producing sectors of the world and with intensification of aquaculture system, prophylactic/therapeutic use of antibiotics and other chemicals have also increased for disease and health management, to increase the survival and improve the flesh quality of fish in aquaculture. In order to avoid economic losses, several antimicrobial and other veterinary drugs are administered regularly as additives in fish feeds, or sometimes in bath treatments (for ectoparasites and related diseases) and as injected (for bacterial infection). These are used as prophylactics, therapeutics or growth promoters (Rico *et al.*, 2013), but these chemicals have various side effects. Therefore, researchers have intensified efforts to exploit natural products such as herbs (like garlic, ginger, onion, turmeric, fenugreek, aloe, tulsi, ashwaganda or Indian ginseng, neem etc.), medicinal plants etc. for developing an alternative dietary supplement that could enhance growth, health and immune system of cultured fish. These herbs and their products are bio-degradable, safer, effective, easily prepared and inexpensive to meet the need of farmers. Beneficial effects of incorporating the medicinal plant substances in animal nutrition may include the stimulation of appetite and feed intake, the improvement of endogenous digestive enzyme secretion, activation of immune responses and antibacterial, antiviral and antioxidant actions (Citarasu, 2010).

Among the various potential herbal plants, neem *Azadirachta indica* is the most studied worldwide and is one

of the well-known indigenous plants in India. Over 140 active substances that are chemically diverse and structurally complex have been isolated from neem. These compounds are grouped under two major classes including isoprenoids (diterpenoids, triterpenoids, vilasinin type of compounds, limonoids and its derivatives) and non-isoprenoids (proteins, polysaccharides, sulphurous compounds, polyphenolics such as flavonoids and their glycosides, dihydrochalone, coumarin and tannin and aliphatic compounds) (Akhila and Rani, 1999; Biswas *et al.*, 2002). Keeping these aspects in view, the present study investigated to understand the effect of NLE on survival, growth performance and flesh quality of common carp by considering the potential benefits of neem for present day intensive aquaculture practice.

MATERIAL AND METHODS

The experiment was carried out at Guru Angad Dev Veterinary and Animal Sciences University, Ludhiana, Punjab in 80 m² outdoor cemented tanks. A 5 cm thick soil layer was spread at the bottom of each tank to hasten the decomposition process. The tube well water was used for filling and maintaining water level in the tank during culture period. All the tanks were manured with cow dung at 20,000 kg⁻¹ha⁻¹yr⁻¹ (160 kg tank⁻¹yr⁻¹). One fourth of the manure was applied 15 days prior to stocking of fish and rest in equal installments, fortnightly.

Experimental diets: For the experimental purpose, NLE was procured from the local market and six experimental

diets (D1–D6) were prepared with traditionally used basal diet (deoiled rice bran: deoiled mustard meal in 1:1 ratio, D1). NLE was incorporated at different levels, 0.25(D2), 0.5(D3), 1.0(D4), 1.5(D5) and 2.0(D6) g kg⁻¹ basal diet. Sinking pellets of different experimental diets were prepared in an electric lab pelletizer. Appropriate moisture content was provided to the feed mixture by autoclaving. Pellets were oven dried at 40 °C for 8 hours and stored in airtight plastic containers at room temperature. Proximate analysis (% dry matter basis) of different feed ingredients and prepared diets was performed as per AOAC (2000) methods (Table 1).

Stocking and feeding of fish: *C. carpio* fry were stocked @10,000 ha⁻¹ (80 fish tank⁻¹) and were fed with different diets at 5% of body weight for the first two months and 1.5% in the following four months. Water quality parameters (temperature, pH, dissolved oxygen, total alkalinity, total hardness, total ammonical nitrogen, nitrite-nitrogen, nitrate nitrogen) were analyzed at fortnightly interval as per APHA (2005). Fish sampling was carried out at monthly intervals to record total body length and weight, net weight gain (NWG), specific growth rate (SGR), feed conversion ratio (FCR) and protein efficiency ratio (PER) for all the treatments and calculated as per standard formulae. Survival and flesh quality in terms of total protein (Lowery *et al.*, 1951), lipids (Folch *et al.*, 1957), carbohydrate (Dubois *et al.*, 1965), moisture and ash contents of fish from each treatment were analyzed at the termination of the experiment.

Statistical analysis: Statistical analysis of the data was performed with a Statistical Package for the Social Sciences (SPSS v16.0).

RESULTS AND DISCUSSION

Water quality: The water temperature (15.4–33.6 °C), pH (8.98–9.40), dissolved oxygen (11.12–12.41 mg l⁻¹), total alkalinity (147–183 mg l⁻¹), total hardness (157–189 mg l⁻¹), ammonical nitrogen (0.07–0.16 mg l⁻¹), nitrite nitrogen (0.03–

0.05 mg l⁻¹), nitrate nitrogen (1.44–1.87 mg l⁻¹) were well within the range in all the treatments, recommended for carp culture and support optimum growth of carps throughout the culture period. Further differences between the treatments were not significant.

Survival of fish: After 180 days of culture, all the tanks were drained out completely to harvest the fish for calculating the percentage survival of fish in different treatments. Percentage survival in different treatments varied from 82 to 87 percent. The survival increased with increasing incorporation of NLE upto 1.0g/kg (D4) and then decreasing trend was observed. The increase in survival may be due to improved health status of the fish, which could be due to various properties of NLE such as antiseptic, insecticidal antiulcer and also superior antiviral and anti hyperglycemic activities (Chattopadhyay, 1999; Parida *et al.*, 2002). Earlier workers also observed increased survival rate in *Carassius auratus* fed on diet containing azadirachtin (Kumar *et al.*, 2012) and in Asian sea bass fed on incorporated with neem leaf meal supplemented diet at 4g kg⁻¹ feed (Talpur and Ikhwanuddin 2013).

Growth of fish: At the end of the experiment among all the treatments (including control), maximum weight gain was in D4 (119.44g) and minimum in D5 and D6 (42.11g and 42.08g) and the differences among the treatments were significant (D4>D3>D2>D1=D5=D6). Likewise, SGR was maximum in D4 (2.01) and minimum in D5(1.38) and the difference among the treatments were significant (D4>D3>D2 D1 D6 D5). Further, Among different treatments, better FCR was recorded in D4 (1.4) followed by D1 (1.5), D3 & D5 (1.8), D6 (2) and D2 (2.4), incorporation of NLE in D4 resulted in efficient utilization of feed as indicated by low FCR (1.4). Higher PER was recorded in D1 (2.48) followed by D4 (2.43), D3 (2.11), D5 (1.96), D6 (1.83) and D2 (1.50). Several reports revealed that plant extracts stimulate appetite and promote weight gain or growth, when they are

Table 1. Proximate composition (%on dry matter basis) of different feed ingredients and experimental diets

| Ingredients/feed | Crude protein (%) | Ether extract (%) | Nitrogen free extract (%) | Moisture | Ash (%) | Crude fiber (%) | Gross energy |
|---------------------------------|-------------------|-------------------|---------------------------|----------|---------|-----------------|--------------|
| Rice bran* | 15.58 | 2.23 | 47.15 | – | 11.63 | 23.41 | 302.41 |
| Mustard meal* | 35.45 | 2.84 | 27.04 | – | 9.52 | 25.15 | 337.99 |
| Neem leaf extract** | 14.90 | 2.93 | 58.54 | 10.65 | 12.93 | 0.05 | 395.55 |
| D1 (Basal diet) | 26.34 | 1.67 | 42.04 | – | 4.99 | 24.96 | 336.77 |
| D2 (0.25 g kg ⁻¹ BD) | 26.64 | 1.43 | 42.96 | – | 4.40 | 24.57 | 340.16 |
| D3 (0.5 g kg ⁻¹ BD) | 26.28 | 1.24 | 43.04 | – | 4.84 | 24.60 | 338.64 |
| D4 (1.0 g kg ⁻¹ BD) | 27.57 | 1.58 | 41.48 | – | 4.98 | 24.39 | 338.12 |
| D5 (1.5 g kg ⁻¹ BD) | 27.12 | 1.40 | 42.08 | – | 4.55 | 24.85 | 338.04 |
| D6 (2.0 g kg ⁻¹ BD) | 26.83 | 1.30 | 43.71 | – | 4.56 | 23.60 | 343.08 |

*Solvent extracted; ** % on wet basis

Table 2. Growth parameters of *C. carpio* in different treatments

| Parameters | Treatments | | | | | |
|-------------|--------------------|--------------------|--------------------|---------------------|--------------------|---------------------|
| | D1 | D2 | D3 | D4 | D5 | D6 |
| IBL (cm) | 6.10 ^b | 5.6 ^c | 6.7 ^a | 6.35 ^b | 6.20 ^b | 6.65 ^a |
| FBL (cm) | 13.1 ^d | 14.1 ^c | 15.49 ^b | 18.38 ^a | 15.43 ^b | 13.44 ^{cd} |
| Length gain | 7.03 ^c | 8.51 ^b | 8.7 ^b | 12.03 ^a | 9.23 ^b | 6.7 ^c |
| IBW (g) | 3.39 ^b | 3.38 ^b | 3.60 ^a | 3.26 ^b | 3.79 ^a | 3.72 ^a |
| FBW (g) | 45.6 ^d | 49.3 ^c | 74.9 ^b | 122.7 ^a | 45.9 ^d | 45.8 ^d |
| NWG | 42.21 ^d | 45.92 ^c | 70.42 ^b | 119.44 ^a | 42.11 ^d | 42.08 ^d |
| SGR | 1.44 ^{cd} | 1.48 ^c | 1.68 ^b | 2.01 ^a | 1.38 ^e | 1.39 ^{de} |
| PER | 1.5 | 2.4 | 1.8 | 1.4 | 1.8 | 2.0 |
| FCR | 2.48 | 1.50 | 2.11 | 2.43 | 1.96 | 1.83 |

Values with different superscripts indicate significant difference between treatments ($P < 0.05$) in a row. IBL-Initial body length, FBL-Final body length, IBW-Initial body weight, FBW-Final body weight, NWG-Net weight gain, SGR-Specific growth rate, FCR-Feed conversion ratio, PER-Protein efficiency ratio

Table 3. Flesh composition (g/100g on wet weight basis) of *C. carpio* in different treatments

| Parameter | Treatments | | | | | |
|--------------------|--------------------|--------------------|--------------------|--------------------|--------------------|--------------------|
| | D1 | D2 | D3 | D4 | D5 | D6 |
| Total protein | 14.62 ^d | 15.19 ^c | 16.54 ^b | 18.59 ^a | 16.41 ^b | 18.55 ^a |
| Total lipid | 1.93 ^{ab} | 2.04 ^a | 2.12 ^a | 2.11 ^a | 2.13 ^a | 1.66 ^b |
| Total carbohydrate | 2.63 ^a | 1.96 ^b | 1.77 ^c | 1.53 ^d | 1.83 ^c | 2.00 ^b |
| Ash | 2.36 ^a | 2.42 ^a | 2.43 ^a | 2.50 ^a | 2.52 ^a | 2.59 ^a |
| Moisture | 78.21 ^a | 77.95 ^a | 76.70 ^b | 75.25 ^c | 76.62 ^b | 74.67 ^c |

administered to cultured fish (Takaoka *et al.*, 2011, Harikrishnan *et al.*, 2012). Besides, plant extracts have also been shown to improve digestibility and availability of nutrients, resulting increased feed conversion and leading to a higher protein synthesis (Nya and Austin 2009, Citarasu 2010, Talpura and Ikhwanuddin 2013). Present study is also in agreement with Obaroh and Nzeh (2011) who observed higher body weight gain in *Oreochromis niloticus* fed with *Azadirachta indica* leaves at 1.0g kg⁻¹ diet. On the contrary, Jegede and Fagbenro (2008) observed poor growth in fish fed with neem leaf compared to control diet. Either increase or poor growth observed in different species at different levels of neem could depend on the form of neem, fish species and size and age of the fish. Further, neem might have promoted the intestinal flora and hence improved the feed digestibility and enhanced the energy utilization, which has led to the improved growth as observed the incorporation of garlic in *O. niloticus* (Khalil *et al.*, 2001).

Flesh composition of fish: The increase in total protein (TP), total lipid (TL) and ash and decrease in total carbohydrate (TC) and moisture of fish flesh was observed (Table 3). Overall effect of feeding NLE supplemented diet on

flesh quality revealed an increase in TP, TL, ash content and decline in carbohydrates and moisture content. Hitherto, research has not been performed on flesh quality of common carp with neem-supplemented diet. Most of the research performed was on immune and reproductive parameters, therefore, the present study was also focused to know the effect of NLE on flesh composition of the meat. The study showed increased lipid levels, which affect the energy production and are essential for growth and development in most of fish (Kim *et al.*, 2012). But, fish are known to utilize protein preferentially over lipid or carbohydrate as an energy source. Lee *et al.* (2014) also reported similar results in terms of increase in carcass protein and lipid with increase in incorporation of garlic powder in the diet of sterlet sturgeon and Ajiboye *et al.* (2016) in *Tilapia zillii*. However, Dedi *et al.* (2016) did not find any significant changes in the protein content of common carp fed with cinnamon leaf.

It may be concluded that the incorporation of NLE upto 1.0g kg⁻¹ in diet could help to improve the survival, growth and flesh quality of *C. carpio*. Further, as fragmented work has been performed on the effect of NLE on fish flesh, therefore the study opens a window to explore the precise mechanism involved in the biochemistry, for variation in the proximate composition of fish flesh.

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Physiological Responses of Freshwater Ornamental Fish Koi Carp, *Cyprinus carpio* (L.) in Inland Saline Water: Growth and Haematological Changes

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Abstract: Four month experimental study was carried out to assess the performance of freshwater ornamental fish, koi carp, *Cyprinus carpio* (Linnaeus) in different salinity levels w.r.t. survival, growth and haematological parameters. Inland saline water (55 ppt) collected from district Fazilka (Punjab) was used for preparation of different treatment salinities viz., 2,4,6,8,10 and 12 ppt. The pH and NH₃-N did not vary significantly and these remained in tolerable range for fish culture. The rest of the parameters (EC, TA, and TH) and ionic composition (Na⁺, K⁺, Ca²⁺, Mg²⁺, Cl⁻ and SO₄²⁻) of water differ significantly and maximum values for these parameters were observed in maximum salinity treatment (12ppt). No negative effect of salinity was observed on fish survival and growth. Hb, PCV and RBC showed significant increase with increasing salinity up to 12 ppt, whereas WBC increased significantly up to 10 ppt. The variations in haematological indices (mean corpuscular volume, mean corpuscular haemoglobin and mean corpuscular haemoglobin concentration) were in accordance with haemoglobin, packed cell volume and red blood cells. Overall results are indicative of stimulation of defense mechanism in fish for maintaining balance state of ions and water to achieve internal stability or homeostasis.

Keywords: Salinity tolerance, Homeostasis, Haematology, Koi carp, Osmoregulation

Salinity is one of the critical parameter among various abiotic factors for the overall well-being of the freshwater fish species, as it determines the level of osmoregulatory stress. Preliminary effect of salinity on fish physiology can be studied in terms of osmoregulation process as an effect of intake or loss of ions in high or low salinity in order to maintain ionic concentration of the body through major organs (gills, kidney and intestine) responsible for osmoregulation (Al-Hilali and Al-Khashali, 2016). Further, saline water tolerance in fresh water fishes appeared to vary between the species as well as with in the species having different size (Islam *et al.*, 2014).

Around 1.25 lakh ha of land in South-west districts of Punjab (Mukatsar, Ferozepur, Fazilka, Faridkot and Bathinda) is affected with underground salinity and water logging, due to which it is unfit for agriculture or any other activity. Hence, 'Aquaculture' is the most suitable option for economic utilization of these degraded lands (Dhawan *et al.*, 2010; Ansal *et al.*, 2013). Brackish water finfish/shellfish species are the most suitable species to develop these areas (Ansal *et al.*, 2013), but these could not be commercialized due to difficulties pertaining to procurement of seed from coastal states, short culture period of 6-7 months (April to October) and mortality during extreme winter (temperature <20°C) season. In view of these limitations with brackish

water species, research trials were conducted to assess the possibilities of rearing freshwater carps in low saline water in the affected districts of Punjab and semi-intensive carp poly-culture techniques have been developed with productivity range of 2.5 to 4.75 t ha⁻¹ yr⁻¹ (Dhawan *et al.*, 2010; Ansal *et al.*, 2013, 2016). The results of salinity tolerance in freshwater carps are indicative of possibility of similar tolerance level in ornamental fish too. Ornamental 'Koi carp', *Cyprinus carpio* (family – Cyprinidae) is a very popular ornamental fish and are characterized by a wide variety of colours and colour patterns and more than 100 different types of koi varieties with varied coloration pattern have already been developed, which are valued as pets. Environmental factors including salinity has been reported to alter the haematological characteristics, associated with the immune responses governing the physiological status, thus affecting the growth and physical appearance in terms of colour pattern (Akinrotimi *et al.*, 2012).

In view of above background, the experimental study was planned to check the performance of ornamental fish, koi carp, *C. carpio* (L.) in inland saline water with the objective of evaluation of salinity tolerance level and to assess the survival, growth and stress indicators in terms of haematological parameters in koi carp reared at different salinity levels.

MATERIAL AND METHODS

Collection of inland saline water (stock) and preparation of experimental salinities

Inland saline water was collected from salt affected / water logged areas of village Shajrana, district Fazilka (30° 40' 3" N and 74° 02' 5" E). Stock inland saline water (55 ppt) was analysed for its physico-chemical properties w. r. t. temperature, pH, salinity, conductivity, alkalinity, total hardness, ammonical nitrogen, and ionic composition in terms of cations [calcium (Ca²⁺), magnesium (Mg²⁺) sodium (Na⁺), potassium (K⁺)] and anions [chloride (Cl⁻) and sulphate (SO₄²⁻)]. From this stock water, different experimental salinities [2 ppt (S2), 4 ppt (S4), 6 ppt (S6), 8 ppt (S8), 10 ppt (S10) and 12 ppt (S12)] were prepared by mixing freshwater having salinity of 0 ppt (S0).

Preparation of the experimental aquaria

The experiments were carried out in glass aquaria (50 liter capacity). All the aquaria were properly cleaned before stocking of the fish. Experimental aquaria were filled with water having different salinities (0 – 12 ppt) and supplied with continuous oxygen supply through aerator.

Procurement, acclimatization and stocking of the experimental fish

Experimental fish, ornamental koi carp, *C. carpio* (Linnaeus) produced in ornamental fish culture and breeding unit of the College of Fisheries were used for the study. Fish were conditioned for one week in fiber reinforced plastic pools under indoor conditions. After proper conditioning, fish were acclimatized (gradual increase in salinity @ 1 ppt at 1-hr interval) and distributed @ 10/treatment randomly into seven (one control and six experimental) salinity treatments (0, 2, 4, 6, 8, 10, 12 ppt) in triplicate. At the time of stocking, the mean initial total length and weight of fish varied from 9–10 cm and 15.5–16.5 g respectively.

Feeding of fish: During experimental period, fish were fed twice a day (9:00 am and 4:00 pm) with commercial diet (OPTIMUM – crude protein–28%, crude fiber–4%, crude fat–3% and moisture–10%) @ 2% of fish body weight (BW) daily throughout the experimental period of four months and amount of feed was adjusted at every fortnightly sampling according to increase in fish weight.

Observations: The observation was recorded daily on fish survival and salinity. The data was recorded fortnightly w.r.t. physico-chemical parameters viz., pH, electrical conductivity (EC), total alkalinity (TA), total hardness (TH), ammonical-nitrogen (NH₃-N) and ionic composition [calcium (Ca²⁺), magnesium (Mg²⁺) sodium (Na⁺), potassium (K⁺)] and anions [chloride (Cl⁻) and sulphate (SO₄²⁻)] according to APHA (2005) and growth parameter (length and weight of fish). At termination of the experiment, growth parameters-total

length gain (TLG), net weight gain (NWG) and specific growth rate (SGR) were estimated.

TLG = Av. final total body length (cm) – Av. initial total body length (cm)

NWG = Av. Final body weight (g) – Av. initial body weight (g)

SGR (% increase in weight/day) = $\frac{\ln \text{Av. final body weight} - \ln \text{Av. initial body weight}}{\text{culture days}} \times 100$; \ln = natural logarithm

For haematological parameters, blood samples were collected from caudal peduncle vein and immediately transferred to sterile tubes. Standard hematological analysis procedures described by Blaxhall and Daisley (1973) were employed in the assessment of various blood parameters. Haemoglobin (Hb) was estimated by acid haematin method (Sahli, 1962). Packed cell volume (PCV) or haematocrit by micro capillary method. White blood cells (WBC) and red blood cells (RBC) counts were assessed by haemocytometer (Naubauer counting chamber). The haematological indices viz., mean corpuscular volume (MCV), mean corpuscular haemoglobin (MCH) and mean corpuscular haemoglobin concentration (MCHC) were calculated according to Mukherjee (1988).

Statistical analysis: Statistical analysis of the data was performed with a statistical package SPSS 16.0 for Windows, SPSS Inc., Richmond, CA, USA.

RESULTS AND DISCUSSION

Physico-chemical parameters of stock inland saline water : Mean temperature and salinity of inland saline water (stock) at the time of analysis was 33.53°C and 55 ppt, respectively. Ionic profile of water sample revealed Na⁺ and Cl⁻ as dominant cation and anion, respectively (Table 1).

Physico-chemical parameters of water: The temperature, pH and NH₃-N did not vary significantly and these remained in tolerable range for fish culture. The rest of the parameters i.e. EC, TA, TH of water varied with varying salinity levels, which can be attributed to differences with respect to ionic composition and their respective ability to conduct electric current. In accordance with ionic composition of stock inland saline water, among cations, dominant ion was Na⁺ followed by Mg²⁺, Ca²⁺ and K⁺ and among anions, dominant ion was Cl⁻ followed by SO₄²⁻ in all the treatments (Table 2).

Fish Survival: In all the treatments, 100 percent fish survival clearly depicts ability of koi carp to tolerate salinity even up to 12 ppt. Every species has their optimum salinity tolerance range depending upon its physiological conditions, which is the complex interaction of nervous system along with metabolism and physiology. Survival of fish depends on overall adapting ability to ever-changing environment

Table 1. Physico-chemical parameters of inland saline water (stock) collected from village Shajrana, district Fazilka, Punjab

| Parameters | Mean \pm SE |
|--|---------------------|
| Salinity (ppt) | 55 \pm 0.20 |
| pH | 8.18 \pm 0.04 |
| EC (mScm ⁻¹) | 20.59 \pm 0.46 |
| PA (CaCO ₃ mg l ⁻¹) | 410 \pm 20.21 |
| MOA (CaCO ₃ mg l ⁻¹) | 620 \pm 21.26 |
| TA (CaCO ₃ mg l ⁻¹) | 1030 \pm 18.78 |
| TH (CaCO ₃ mg l ⁻¹) | 9500 \pm 25.28 |
| NH ₃ -N (mg l ⁻¹) | 0.136 \pm 0.001 |
| Ca ²⁺ (CaCO ₃ mg l ⁻¹) | 1034.43 \pm 11.26 |
| Mg ²⁺ (CaCO ₃ mg l ⁻¹) | 1754.83 \pm 13.69 |
| Na ⁺ (mg l ⁻¹) | 29718.5 \pm 19.78 |
| K ⁺ (mg l ⁻¹) | 197.76 \pm 1.72 |
| Cl ⁻ (mg l ⁻¹) | 5098.97 \pm 20.28 |
| SO ₄ ²⁻ (mg l ⁻¹) | 128.55 \pm 5.23 |

Values are Mean \pm S.E.

conditions (Koedjick *et al.*, 2012). Freshwater fish produce large volume of dilute urine, which is low in salt. High concentrations of environmental calcium help reduce salt loss through gills and body surfaces in freshwater environment. Kùçùk (2013) observed 100 % survival of gold

fish (*Carassius auratus*) and crucian carp (*C. carassius*) up to salinity of 16 ppt. At 20 ppt, survival of both fish species decreased by 81.25 and 83.33 % respectively. At higher salinity, gold fish even had necrotic injuries on the body.

Fish Growth: At the end of experimental period, average final total body length (TBL) and average final body weight (TBW) differed significantly among different salinity treatments. Growth parameters in terms of Av. final TBL, Av. final TBW, TLG, NWG and SGR were significantly higher in 8 ppt, indicating no negative impact of salinity on growth of the fish all the salinity treatments as compared freshwater (S0).

Many researchers found that fishes grew better in brackish water than freshwater or sea water (Imsland *et al.*, 2001; Luz *et al.*, 2008 and Kùçùk *et al.*, 2013). There is an accepted hypothesis that iso-osmotic water decreases the use of energy for osmoregulation compared to fresh or salt water and the saved energy is used for growth. Gills and Payan (2001) reported that fish in an isotonic medium has the lowest standard metabolic rates, whereas osmoregulation in sea water appears to be energetically more expensive than in freshwater. Previous studies in different fish species indicated that the rising salinity in freshwater increases growth rate up to certain level, thereafter it declines, which indicates tolerance level of particular fish species. Although fish can survive at higher salinities, but after certain level

Table 2. Mean physico-chemical parameters of water in different salinity levels during the experimental period

| Parameters | Treatments* | | | | | | |
|--|--|---|--|---|---|---|--|
| | S0 | S2 | S4 | S6 | S8 | S10 | S12 |
| pH | 8.05 ^a (7.74-8.29) | 7.94 ^a (7.44-8.24) | 7.98 ^a (7.54-8.20) | 7.95 ^a (7.70-8.34) | 7.95 ^a (7.41-8.20) | 7.96 ^a \pm 0.05 (7.64-8.17) | 8.02 ^a (7.42-8.20) |
| EC (mScm ⁻¹) | 0.86 ^a (0.64-0.97) | 2.55 ^b \pm (2.12- 2.92) | 5.58 ^b \pm 0.07 (5.14-5.87) | 8.38 ^c \pm 0.09 (8.01-9.15) | 11.26 ^c (10.92-11.53) | 13.60 ^b (12.85-13.88) | 15.61 ^a (14.67-16.19) |
| TA (CaCO ₃ mg l ⁻¹) | 308.89 ^f (207-316.67) | 355.37 ^e (258.33-416.67) | 399.26 ^d (333.33- 440.00) | 440.00 ^c (350-486.67) | 474.44 ^{bc} (393.33- 507.40) | 507.40 ^{ab} \pm 15.36 (410-650) | 530.74 ^a \pm 16.15 (420-640) |
| TH (CaCO ₃ mg l ⁻¹) | 365.19 ^d (296.67- 496.67) | 518.22 ^f (496.67-533.33) | 1151.70 ^e (895.67- 1501.90) | 1501.90 ^d (1124-1623.33) | 1756.10 ^c (1282-1960) | 1936.7 ^b (1513.33- 2421.90) | 2421.90 ^a (1840-2716.67) |
| NH ₃ -N (mg l ⁻¹) | 0.11 ^a (0.08-0.18) | 0.09 ^a (0.07-0.14) | 0.11 ^a (0.05-0.23) | 0.13 ^a (0.01-0.16) | 0.15 ^a (0.03-0.17) | 0.03 ^a (0.01-0.07) | 0.04 ^a (0.03-0.18) |
| Ca ²⁺ (CaCO ₃ mg l ⁻¹) | 54.35 ^a (53.26-70.08) | 75.18 ^b (58.87-84.09) | 108.09 ^b (75.69-121.94) | 119.27 ^d (110.73- 134.88) | 134.88 ^c (114.93- 143.41) | 143.41 ^b (117.74-169.60) | 206.02 ^a (141.57- 295.40) |
| Mg ²⁺ (CaCO ₃ mg l ⁻¹) | 55.76 ^b (39.77-61.57) | 78.81 ^f (75.57-84.26) | 212.51 ^e (172.45- 295.40) | 295.40 ^d (210-319.63) | 349.15 ^c (244.34- 589.79) | 383.45 ^b (276.70-490.17) | 463.27 ^a (320-530.87) |
| Na ⁺ (mg l ⁻¹) | 59.52 ^a (53.66-65.13) | 202.57 ^f (112.77-280.90) | 305.98 ^e (138.47- 465.08) | 465.08 ^d (414.33- 589.79) | 589.79 ^c (423-726.33) | 752.47 ^b (667.83-831.50) | 878.82 ^a (695.17- 1092.47) |
| K ⁺ (mg l ⁻¹) | 7.57 ^a (7.23-8.06) | 10.17 ^f (9.36-10.93) | 13.51 ^e (12.90-14.60) | 35.58 ^d (31.50-38.83) | 40.96 ^c (37.33-47.83) | 47.05 ^b (40.33-60.83) | 52.89 ^a (42.83-66.50) |
| Cl ⁻ (mg l ⁻¹) | 63.68 ^a (53.32-94.98) | 154.34 ^f (79.98-303.27) | 294.57 ^e (179.96- 465.08) | 519.15 ^d (293.27- 643.40) | 643.40 ^c (417.44- 700.01) | 698.89 ^b (554.76-879.82) | 884.42 ^a (619.85- 1149.00) |
| SO ₄ ²⁻ (mg l ⁻¹) | 14.36 ^a (9.73-21.98) | 55.70 ^d (34.47-58.09) | 59.89 ^d (41.39-79.64) | 69.45 ^{cd} (51.98-89.36) | 82.94 ^c (53.43-124.38) | 104.36 ^b (74.41-188.77) | 125.69 ^a (61.41-242.67) |

* S0 = 0 ppt, S2 = 2 ppt, S4 = 4 ppt, S6 = 6 ppt, S8 = 8 ppt, S10 = 10 ppt, S12 = 12 ppt

Values with same superscripts in a row do not differ significantly (p < 0.05)

Values in parentheses represent range

growth get compromised. In present study also, growth was not compromised up to 8 ppt, thereafter it declines and get negatively affected at higher salinity of 12 ppt. Luz *et al.* (2008) observed no negative effect on growth in gold fish adapted from 0 to 2 ppt ($1.2\% \text{ day}^{-1}$), but as the salinity increased to 8 and 10 ppt, growth rate declined ($0.4\% \text{ day}^{-1}$ and $0.2\% \text{ day}^{-1}$ respectively). Likewise, Altinok and Gizzle (2001) indicated that salinity of 9 ppt affected growth of freshwater ornamental gold fish. Similar results were observed by Küçük (2013) in gold fish, *C. auratus* and crucian carp, *C. carassius*, in which both fish species tolerated salinity up to 20 ppt with 100 % survival, but growth get compromised and normal growth was recorded up to 12 ppt ($0.30\% \text{ day}^{-1}$), get too low in 16 ppt ($0.08\% \text{ day}^{-1}$) and become negative at 20 ppt ($-0.06\% \text{ day}^{-1}$). The results of the present study w.r.t. 100 % survival at 12 ppt and maximum growth at 8 ppt are in accordance to the previous studies carried out in ornamental fishes. Comparable or higher growth of freshwater fish at higher salinities ($> 0\text{ppt}$) in the previous studies by different researchers and in present study suggested that the fish were able to regulate osmotic pressure of the body fluids. Schofield *et al.* (2006 a,b) reported that gold fish can persist at $< 10\text{ppt}$ for longer period

of time as compared to higher salinity. Higher salinities result in significant muscle dehydration, which leads to adverse effect on growth, food intake and hence food conversion ratio (Luz *et al.*, 2008).

Haematological Parameters: Haematological parameters in terms of Hb, PCV and RBC showed increasing trend with increasing salinity (S0 to S12) and the differences among treatments were significant (Table 4). WBC also showed as increase up to S10, and a sharp decline was observed at 12 ppt (S12). Haematological indices such as MCV, MCH and MCHC were calculated indirectly with reference to RBC, PCV and Hb, therefore, the changes are directly linked with these parameters. MCV and MCHC showed decreasing and increasing trend with increasing salinity. The values for MCH increased with increasing salinity, but with no particular trend. However, the values for these parameters were significantly higher than control (S0). Increase in PCV or haematocrit during stress results from dehydration because of difference between the internal and external environmental ionic composition. Due to osmotic pressure, water get released in external environment (higher salinity) leading to increasing PCV percentage. The increase in RBC is the result of increasing oxygen consumption owing to increased energy requirement (Martinez *et al.*, 2002; Al

Table 3. Changes in growth parameters of koi carp, *C. carpio* (L.) in different salinity levels during the experimental period

| Parameters | Treatments* | | | | | | |
|-------------------------------|---------------------|---------------------|---------------------|---------------------|--------------------|---------------------|---------------------|
| | S0 | S2 | S4 | S6 | S8 | S10 | S12 |
| Av. Initial Total Body Length | 9.66 ^a | 9.72 ^a | 9.72 ^a | 9.68 ^a | 9.83 ^a | 9.75 ^a | 9.65 ^a |
| Av. Final Total Body Length | 10.60 ^{ab} | 10.56 ^{ab} | 10.77 ^{ab} | 10.73 ^{ab} | 10.90 ^a | 10.76 ^{ab} | 10.26 ^b |
| TLG | 0.94 ^{ab} | 0.84 ^{ab} | 1.05 ^a | 1.04 ^a | 1.07 ^a | 1.01 ^{ab} | 0.61 ^b |
| Av. Initial Body weight | 16.29 ^a | 16.15 ^a | 16.20 ^a | 16.46 ^a | 16.10 ^a | 16.36 ^a | 16.25 ^a |
| Av. Final Body weight | 18.05 ^a | 17.84 ^b | 17.82 ^{ab} | 18.13 ^a | 18.11 ^a | 18.15 ^a | 17.90 ^{ab} |
| NWG | 1.76 ^{ab} | 1.69 ^b | 1.62 ^b | 1.67 ^b | 2.01 ^a | 1.79 ^{ab} | 1.65 ^b |
| SGR | 0.08 ^{ab} | 0.08 ^{ab} | 0.07 ^b | 0.08 ^{ab} | 0.09 ^a | 0.08 ^{ab} | 0.08 ^{ab} |

See table 3 for details

TLG = Total length gain, NWG = Net weight gain, SGR = Specific growth rate

Table 4. Haematological parameters of koi carp, *C. carpio* (L.) in different salinity levels at the termination of the experiment

| Parameters | Treatments* | | | | | | |
|---------------------------------------|---------------------|---------------------|---------------------|----------------------|----------------------|----------------------|---------------------|
| | S0 | S2 | S4 | S6 | S8 | S10 | S12 |
| Hb (g %) | 1.90 ^f | 3.00 ^e | 4.23 ^d | 5.80 ^{bc} | 5.70 ^c | 6.06 ^{ab} | 6.23 ^a |
| PCV (%) | 18.83 ^c | 22.50 ^b | 25.00 ^b | 27.67 ^a | 30.00 ^a | 28.83 ^a | 29.67 ^a |
| RBC ($\times 10^6 \text{ mm}^{-3}$) | 0.71 ^e | 0.90 ^e | 1.26 ^d | 1.54 ^c | 1.81 ^{bc} | 2.01 ^b | 2.83 ^a |
| WBC ($\times 10^3 \text{ mm}^{-3}$) | 51.35 ^c | 73.01 ^b | 78.73 ^b | 94.28 ^a | 97.57 ^a | 100.89 ^a | 45.50 ^c |
| MCV (μm^3) | 269.44 ^a | 250.19 ^a | 198.36 ^b | 179.15 ^{bc} | 166.68 ^{bc} | 146.14 ^{cd} | 104.80 ^d |
| MCH (g %) | 27.27 ^{bc} | 36.50 ^a | 33.66 ^{ab} | 37.52 ^a | 31.59 ^{ab} | 30.63 ^{ab} | 22.02 ^c |
| MCHC (%) | 10.12 ^d | 15.55 ^c | 16.95 ^{bc} | 20.97 ^a | 19.06 ^{ab} | 21.05 ^a | 21.13 ^a |

Hb = haemoglobin, PCV = packed cell volume, RBC = red blood cells, WBC = white blood cells, MCV = mean corpuscular volume, MCH = mean corpuscular haemoglobin, MCHC = mean corpuscular haemoglobin concentration

Values with same superscripts in a row do not differ significantly ($p > 0.05$)

Hilali and Al-Khashali 2016). Hb increase was also in tandem with RBC, as Hb is the protein carried by RBC and playing a major role in respiration. Moreover, the increase in Hb concentration has always been considered as a vital indicator of any environmental change (Bani and Haghi, 2009). The increase in Hb concentration was also observed by Hafez and Oryan (2002) in common carp exposed to high concentration of NaCl. The increase in WBC in the present study with increasing salinity up to 10 ppt could be attributed to the increase of WBC immigration across plasma (Gomes *et al.*, 2003). It can also be explained in terms of immunity reaction due to exposure of fish to salinity stress, resulted in increased cortisol, along with RBC and WBC as a defense mechanism in fish for getting back to balance state of ions and water to achieve internal stability.

Results of experimental study in terms of survival and growth of ornamental koi carp, *C. carpio* (L.) indicated adaptive capacity of the fish in inland saline water. Although, fish was capable of adapting and growing under salinity conditions up to 12 ppt, but on the basis of results of all the parameters, 8 ppt was most appropriate. Hence, from present study, it can be concluded that freshwater ornamental koi carp, *C. carpio* can be reared in inland saline water by maintaining the salinity 8 ppt.

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Investigation of Genetic Variability for Yield and Yield Related Traits in Barley (*Hordeum vulgare* L.) Genotypes

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Abstract: The study was carried out during *rabi* season of 2014-15 at Chaudhary Charan Singh Haryana Agricultural University, Hisar, to evaluate genetic variability for yield and yield related traits in one hundred seventy barley germplasm lines (101 two rowed and 69 six rowed) and three standard check varieties (BH393 six rowed, BH946 six rowed and BH885 two rowed) in Augmented Block Design. The analysis of variance indicated significant difference among entries (ignoring blocks), checks, varieties and checks v/s varieties for all quantitative characters except harvest index in the case of checks. The mean squares due to blocks were non-significant for all the characters under study. The high magnitude of phenotypic coefficient of variation (PCV) along with genotypic coefficient of variation (GCV) was observed for number of tillers per plant followed by peduncle extrusion length. All the traits showed high heritability i.e. more than 90 per cent for majority of traits. Genetic advance as percent of mean was highest for peduncle extrusion length followed by number of tillers per plant.

Keywords: Barley, Block, Check varieties, GCV, PCV, Heritability

The most essential pre-requisite for planning and execution of a successful breeding program is the availability of desirable genetic variability for important characters in the germplasm collections of the plant species. Genetic variability is the key factor which determines the success of every breeding program. Careful management of this variability and techniques to be employed in each case with clear understanding of the extent and nature of variability leads to crop improvement. To change the genetic response of plant characters and consequently of the plant as a whole to develop improved genotypes having higher economic yield, the genetic variability for various characters available in the breeding populations or materials is systematically subjected to selection. The variability exploited in breeding programmes is derived from the naturally occurring variants and the wild relatives of crop as well as artificially developed strains and genetic stocks by human-efforts. The reservoir of variability for different characters of a plant species resulting from available natural or artificially synthesized variants or strains constitutes its germplasm. Thus, germplasm may include improved strains, primitive cultivars, wild relatives, obsolete cultivars, special genetic stocks, seeds, pollen and vegetative parts etc. The available variability in a population can be characterized by genetic parameters such as coefficients of variation, heritability and genetic advance to serve as basis for selection of desirable genotypes than existing ones. However, yield is a complex character which is controlled by association of number of components most of which are under polygenic

control. Thus the identification of important components and information about their association with yield and other traits are very useful for developing efficient breeding strategy for evolving high yielding varieties.

Barley (*Hordeum vulgare* L.) is a self-pollinated crop with basic chromosome $X = 7$ and belong to family *Poaceae*. It is the fourth most important cereal crop in the world after wheat, maize and rice (Marwat *et al.*, 2012). During the year 2013-14, the total harvested area of barley in India was 695.1 thousand hectares, with production 1830.7 thousand metric tonnes and productivity 2718 kg ha⁻¹. Haryana has the immense potential; emerge as a front running state in production as well as grain trading. The area, production and productivity of barley in Haryana state during 2013-14 was 39 thousand hectares, 153 thousand metric tonnes, 3923 kg ha⁻¹, respectively (Anonymous, 2013-14). It assumes its importance for three principle reasons namely broad adaptation, utility as a feed grain and human food combines the superior property of malt for brewing (Poehlman, 1985). It is grown in many areas where climatic conditions are not favourable for the production of other major cereals. Assessment of the extent of genetic variability within barley, is fundamental for barley breeding programs and the conservation of genetic resources, and is particularly useful as a general guide in the choice of parents for breeding hybrids. Therefore the present study was undertaken with the objective to investigate genetic variability for yield and its related traits in barley.

MATERIAL AND METHODS

The study was conducted during *rabi* season of 2014–2015 at Chaudhary Charan Singh Haryana Agricultural University, Hisar. The experimental material comprised of one hundred seventy barley germplasm lines (101 two rowed and 69 six rowed) and three standard check varieties (BH393 six rowed, BH946 six rowed and BH885 two rowed) in augmented block design in ten blocks. Checks were repeated in each block along with 17 test entries in a 2.5 m long single row plot. Row to row distance of 30 cm and plant to plant distance of 10 cm was maintained and recommended package of practices was followed to raise a good crop. Five competitive plants from each plot were randomly selected for recording observations on the ten morphological traits viz. days to flowering (75%), days to maturity (75%), plant height (cm), peduncle extrusion length (cm), number of tillers plant⁻¹, number of grains/spike, 1000 seed weight (g), grain yield/plant (g), biological yield plant⁻¹ (g) and harvest index (%). Average of the data from the sampled plant of each plot in respect of different characters was used for various statistical analyses. The augmented experimental design introduced (Federer 1956) was used for the experiment. Mean, range and coefficient of variation (CV) was also calculated for each character. Phenotypic and Genotypic coefficient of variation (PCV and GCV) for different characters was estimated as suggested by Burton (1952). Heritability in broad sense was calculated as the ratio of genotypic variance to the phenotypic variance and expressed as percentage (Falconer, 1981). Genetic advance and genetic advance as percent of mean was worked out by adopting the formula given by Johnson *et al.* (1955).

RESULTS AND DISCUSSION

Greater variability in the initial breeding material ensures better chances of producing a desired form of a crop plant. Thus, the evaluation of germplasm present in a given set of

collection for the genetic variability assumes greater significance in selection of lines for direct utilization or use in a systematic breeding plan. In the present attempt, a set of 170 (two rowed and six rowed) genotypes and three checks repeated 10 times were evaluated in an augmented design recording data on ten quantitative characters (Table 1). The mean squares due to blocks were non-significant for all the characters under study. The analysis of variance indicated significant difference ($p < 0.05$) among entries (ignoring blocks), checks, varieties and checks v/s varieties for all quantitative characters except harvest index in the case of checks. Hence, the result indicated the existence of high morphological variation for all ten characters. It suggested that we could proceed for further analysis and evaluate the genetic variability among the genotypes and checks for all the characters under study. Verma and Verma (2011), Zalata *et al.* (2011), Kumar *et al.* (2013) and Addisu and Shumet (2015) also reported significant differences for all the characters studied.

Among grain yield and its component characters, plant height possessed the highest range, followed by days to 75% flowering and 1000 seed weight. This shows that these characters are responsible for wide variation in grain yield of various genotypes (Table 2). Eshgi *et al.* (2012) and Lodhi *et al.* (2015) also reported similar results for plant height.

For adoption of suitable breeding programmes, the assessment of heritable and non-heritable components in the total variability observed is indispensable. The heritable component can be assessed by studying phenotypic coefficient of variation (PCV), genotypic coefficient of variation (GCV), heritability and predicted genetic advance. The PCV was higher than that of GCV for all the traits suggesting the role of environmental factors on various characters, which confirmed the findings of Pratap *et al.* (2012), Prasad *et al.* (2013) and Krishna *et al.* (2013).

Number of tillers per plant depicted highest PCV and

Table 1. Analysis of variance of augmented design for ten characters in barley genotypes

| Source of variation | d.f. | Mean Squares | | | | | | | | | |
|----------------------------------|------|-------------------------|------------------------|----------------------|---------------------------|----------------------|----------------------|---------------------|-------------------|----------------------------|---------------------|
| | | Days to flowering (75%) | Days to maturity (75%) | Plant height (cm) | Peduncle extrusion length | No. of tillers/plant | No. of grains/spike | 1000 seed weight | Grain yield/plant | Biological yield/plant (g) | Harvest index (%) |
| Block (eliminating Check + Var.) | 9 | 1.35 | 1.93 | 1.65 | 0.07 | 0.83 | 0.79 | 1.23 | 0.07 | 0.45 | 0.88 |
| Entries (ignoring Blocks) | 172 | 90.63 [*] | 11.80 [*] | 67.15 [*] | 3.41 [*] | 5.66 [*] | 40.58 [*] | 27.34 [*] | 1.23 [*] | 9.83 [*] | 7.54 [*] |
| Checks | 2 | 1243.30 [*] | 222.03 [*] | 558.16 [*] | 15.61 [*] | 27.90 [*] | 1069.99 [*] | 188.47 [*] | 6.68 [*] | 43.65 [*] | 3.65 |
| Varieties | 169 | 75.55 [*] | 8.10 [*] | 39.41 [*] | 3.25 [*] | 5.40 [*] | 25.14 [*] | 24.83 [*] | 1.16 [*] | 9.41 [*] | 6.34 [*] |
| Checks vs. Varieties | 1 | 333.73 [*] | 215.62 [*] | 3771.79 [*] | 6.91 [*] | 3.73 [*] | 590.74 [*] | 129.97 [*] | 2.21 [*] | 12.74 [*] | 217.81 [*] |
| Error | 18 | 2.01 | 0.85 | 4.05 | 0.11 | 0.42 | 1.06 | 1.20 | 0.05 | 0.37 | 1.23 |

* Significant at 5% probability level

GCV followed by peduncle extrusion length. Moderate PCV and GCV were found for the characters such as number of grains per spike, biological yield per plant and grain yield per plant. Lowest PCV and GCV were obtained for 1000 seed weight, days to 75% flowering, harvest index, plant height and days to 75% maturity. Similar findings were also reported by Ahmad *et al.* (2008), Singh *et al.* (2008), Mishra *et al.* (2008), Zalata *et al.* (2011), Singh *et al.* (2014) and Lodhi *et al.* (2015). The results obtained for PCV and GCV showed that there is enough possibility of further improvement in genotypes taken for present study through intermating followed by appropriate selection for these characters. The differences between PCV and GCV were relatively very small which showed least environmental influence, which was supported by the findings of Prasad *et al.* (2013). Although the GCV revealed the extent of genetic variability present in the genotypes for various traits, it does not provide full scope to assess the variation that is heritable. Heritable variation is useful for permanent genetic improvement (Singh, 2000). The GCV along with heritability estimates provide reliable estimates of the amount of genetic advance to be expected through phenotypic selection (Burton, 1952). All the traits under study showed high heritability.

The traits like days to 75% flowering, peduncle extrusion length, biological yield per plant, grain yield per plant, number of grains per spike, 1000 seed weight and number of tillers per plant showed very high heritability (97.03 to 91.38%). The remaining traits like plant height, days to 75% maturity and harvest index were highly heritable in nature (88.61 to 78.78%). Such results were reported by Sachan and Singh

(2003), Siddique *et al.* (2006), Rahim *et al.* (2010) and Riaz-Ud-Din *et al.* (2010) substantiating the present findings. The characters having high heritability estimates are of immense importance as it permits selection at phenotypic level and there would be greater correspondence between phenotypic worth and breeding values.

Genetic advance as percentage of mean is more reliable parameter than genetic advance alone. Expected genetic advance as percent of mean was found to be highest for peduncle extrusion length followed by number of tillers per plant, number of grains per spike, biological yield per plant, grain yield per plant, 1000 seed weight and days to 75% flowering, indicating that these characters can be improved better. Traits like plant height and harvest index have moderate value for genetic advance as percent of means. The character days to 75% maturity (3.78%) showed low genetic advance. Similar findings for one or more characters were also reported by Singh *et al.* (2008) and Singh *et al.* (2014). High estimates of heritability and high genetic advance were recorded for days to 75% flowering, peduncle extrusion length, biological yield per plant, grain yield per plant, number of grains per spike, 1000 seed weight and number of tillers per plant; indicates that these are simply inherited traits and most likely the heritability is due to additive gene effects and selection may be effective in early generations for these traits. Similar findings have been reported by some authors (Mishra *et al.*, 2008; Singh *et al.*, 2008; Akanksha *et al.*, 2012; Singh *et al.*, 2014). High heritability with moderate genetic advance was observed for plant height and harvest index. High heritability with low

Table 2. Mean, range, CV, LSD, heritability and GA as % mean for ten characters of barley genotypes

| Characters | Mean \pm SE (m) | Range (Min-Max) | Coefficient of Variation (%) | | Range of Parameters | | | | Heritability broad sense H ² (%) | GA as % Mean |
|--------------------------------|----------------------|--------------------|---------------------------------|-------|---------------------|------------------|------------------|------------------|--|--------------------|
| | | | PCV | GCV | LSD ₁ | LSD ₂ | LSD ₃ | LSD ₄ | | |
| | | | | | | | | | | |
| Days to flowering (75%) | 84.65 \pm 0.67 | 73.20-100.53 | 9.71 | 9.56 | 1.33 | 4.21 | 4.86 | 3.60 | 97.03 | 19.40 |
| Days to maturity (75%) | 130.20 \pm 0.22 | 121.90-136.33 | 2.08 | 1.95 | 0.87 | 2.74 | 3.16 | 2.34 | 88.37 | 3.78 |
| Plant height (cm) | 103.19 \pm 0.50 | 71.04-115.78 | 5.76 | 5.42 | 1.89 | 5.96 | 6.90 | 5.12 | 88.61 | 10.52 |
| Peduncle extrusion length (cm) | 6.96 \pm 0.14 | 3.44-11.64 | 24.50 | 24.03 | 0.31 | 0.99 | 1.13 | 0.84 | 96.23 | 48.56 |
| No. of tillers/ plant | 8.58 \pm 0.17 | 3.53-11.87 | 25.67 | 24.54 | 0.61 | 1.92 | 2.22 | 1.65 | 91.38 | 48.32 |
| No. of grains/ spike | 27.07 \pm 0.40 | 17.66-39.63 | 17.57 | 17.15 | 0.97 | 3.06 | 3.53 | 2.62 | 95.30 | 34.49 |
| 1000 seed weight (g) | 47.16 \pm 0.38 | 32.57-63.97 | 9.99 | 9.71 | 1.03 | 3.25 | 3.76 | 2.79 | 94.60 | 19.46 |
| Grain yield/ plant (g) | 7.27 \pm 0.08 | 4.19-9.55 | 14.01 | 13.68 | 0.21 | 0.65 | 0.76 | 0.56 | 95.31 | 27.50 |
| Biological yield/ plant (g) | 19.25 \pm 0.23 | 10.99-26.42 | 15.06 | 14.73 | 0.57 | 1.80 | 2.07 | 1.54 | 95.66 | 29.67 |
| Harvest index (%) | 37.86 \pm 0.19 | 30.42-43.83 | 6.36 | 5.64 | 1.04 | 3.29 | 3.78 | 2.82 | 78.78 | 10.32 |

Where;

LSD₁, LSD₂, LSD₃, LSD₄ = Least significant difference between two check means, adjusted mean of two genotypes in same block, adjusted mean of two genotypes in different block, adjusted mean of genotype and check mean,

PCV = Phenotypic coefficient of variation, GCV = Genotypic coefficient of variation, GA = Genetic Advance

genetic advance has been observed for days to 75% maturity; indicates non-additive gene effects and can be improved by intermating superior genotypes of segregating population developed from combination breeding (Prasad *et al.*, 2013)

CONCLUSION

The analysis of variance revealed highly significant differences among the entries (ignoring blocks), checks, varieties and checks v/s varieties for all the characters at genotypic level indicating a wide range of variability for further selection and improvement. There exists a very high degree of variability for all the characters in the genotypes evaluated. The magnitude of PCV was higher than their respective GCV's thereby suggesting influence of environmental factors on expression of the characters studied. The estimates of heritability and genetic advance were high for most of the characters. The character that shows high heritability with high genetic advance is controlled by additive gene action and can be improved through simple or progeny selection methods and the characters showing high heritability along with moderate or low genetic advance can be improved by intermating superior genotypes of segregating population developed from combination breeding.

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Effect of Presowing Guava Seed Treatments Influence Seedling Growth Behaviour in the Nursery

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Abstract: In the present experiment effect of different Presowing treatments on seed germination and subsequent seedling growth were examined in cv. Allahabad Safeda. The experiment was carried out at Bidhan Chandra Krishi Viswavidyalaya, Mohanpur, Nadia, India during 2013-2014 and laid out in Randomized Block Design with nine treatments and three replications. Results revealed that the highest germination success was found with NAA. Earliest germination started (7th day) as well as ceased (25th day) with NaCl. All other treatments either improved germination period, germination percentage or seedling growth behaviour, only ethephon inhibited germination, seedling growth or delayed germination. Low germination success with water + black polythene cover revealed that light plays a pivotal role in guava seed germination. Highest seedling growth rate and rate of increase in collar diameter was with water and NAA respectively. Among different Presowing treatments NAA as well as water can be recommended for an effective seed germination and seedling growth of guava.

Keywords: Seed germination, Seedling growth, Pre-sowing treatment, Guava

Although performance of fruit crops generated from seeds is variable, still raising of seedlings for rootstock purpose is very much in demand among growers due to certain advantages and is a common practice in many fruits including guava. In order to produce quality guava grafts in commercial nursery, healthy rootstock from seeds is essential. Usually guava seeds germinate poorly, unevenly and require more time to attain desired length for suitable grafting operation (Doijode, 2001). This uncertainty may be due to presence of hard seed coat that make seeds impermeable to water and gases or presence of tannins in seeds lead to difficulty of guava propagation sexually (Doijode, 2001; Ali *et al.*, 2003). A method of improving seed germination and seedling performance both in the field and in the glasshouse is through the use of pre-sowing treatments such as priming. It improves germinability, storability and better field performance with different biotic or abiotic stress tolerance. Among several methods of seed priming, hydropriming is the simplest and cost effective that eventually alleviates the environmental stresses, increase the rate of germination and crop performance even if soil moisture content is very low or in high soil salinity (Clarke *et al.*, 2001; Lutts *et al.*, 2016; Mohammadi *et al.*, 2008). Osmopriming puts many advantages including rapid and uniform seedling emergence, improved seedling growth and better crop establishment under any environmental and soil conditions (Chiu and Sung, 2002). Priming with ascorbate counteracts the negative effects of salinity stress by

changing abundance of proteins involved in metabolism, protein destination and storage (Fercha *et al.*, 2014). During hormopriming presence of growth regulators have direct impact on metabolic system of plants (Lutts *et al.*, 2016). Therefore, the study attempted to determine the best possible pre-sowing treatment from different priming agents that can maximize the germination percentage and initial seedling growth performances.

MATERIAL AND METHODS

The present experiment was carried out at Bidhan Chandra Krishi Viswavidyalaya, Mohanpur, Nadia, India during 2013-2014. Seeds of guava cv. Allahabad Safeda were extracted from well ripe freshly harvested fruits and treated with different solutions for 6 hours then dried healthy seeds were sown for the germination test in raised seed beds at a depth of 0.5 to 1 cm. The experiment was laid out in Randomized Block Design with nine treatments and three replications (Table 1) each of 50 seeds. The number of seeds germinated in each treatment was recorded every day. Germination start (days), germination cease (days), total germination period, germination percentage, mean rate of seedling height and mean rate of collar diameter were estimated for 120 days at time interval of 7 days. Analysis of variance (ANOVA) and Duncan Multiple Range Test (DMRT) (Duncan 1955) were carried out for data analysis by using MS Excel, OPSTAT and XLSTAT to explore possible treatment variation.

Table 1. Influence of pre-sowing treatments on guava seed germination and seedling growth behaviours

| Treatments | Germination start (Days) | Germination cease (Days) | Total germination period (Days) | Total germination (%) | Mean height growth rate (cm) | Mean rate of collar diameter (mm) |
|-----------------|--------------------------|--------------------------|---------------------------------|-----------------------|------------------------------|-----------------------------------|
| T ₁ | 7.00±0.58 | 25.67±1.20 | 18.67±0.67 | 49.01 d | 1.64 a | 0.32 e |
| T ₂ | 7.67±0.33 | 31.00±3.22 | 23.33±3.48 | 39.79 f | 1.23 e | 0.29 e |
| T ₃ | 8.00±1.00 | 36.33±4.63 | 28.33±3.84 | 51.92 c | 1.61 ab | 0.55 bc |
| T ₄ | 9.00±1.00 | 37.00±3.05 | 28.00±2.52 | 43.87 e | 1.64 a | 0.58 b |
| T ₅ | 8.33±0.67 | 34.33±2.33 | 26.00±1.73 | 38.61 f | 1.59 ab | 0.35 de |
| T ₆ | 14.67±1.30 | 28.33±4.33 | 14.00±3.22 | 26.55 g | 1.44 cd | 0.44 cd |
| T ₇ | 9.33±0.88 | 30.67±2.67 | 21.33±1.86 | 56.15 b | 1.65 a | 0.48 bc |
| T ₈ | 8.33±0.33 | 31.33±4.05 | 23.00±3.79 | 38.04 f | 1.39 d | 0.73 a |
| T ₉ | 7.33±0.33 | 30.00±3.51 | 22.67±3.18 | 72.59 a | 1.52 bc | 0.76 a |
| T ₁₀ | 9.33±0.88 | 34.67±1.86 | 25.33±1.20 | 39.22 f | 1.46 cd | 0.45 cd |

(T₁-NaCl 50 ppm, T₂-Citric acid 50 ppm, T₃-Ascorbic acid 50 ppm, T₄-KH₂PO₄ 50 ppm, T₅-KNO₃ 50 ppm, T₆-Ethepon 50 ppm, T₇-Water, T₈-Water with black polythene cover, T₉-NAA 50 ppm, T₁₀-Control (Seeds without any treatment))

RESULTS AND DISCUSSION

With exception to ethephon (50 ppm) priming in most of the cases markedly improved initiation of seed germination. Among all the pre sowing treatments earliest seed germination (7 days) was with NaCl (50 ppm) and germination was delayed maximum with ethephon 50 ppm (14.67 days). Seed treatment with NAA (50 ppm) also initiated early germination. Among all treatments earlier germination was observed than with water and control.

The seed germination ceased within 25.67 days with NaCl while germination was continued for 37 days with KH₂PO₄ (50 ppm). Duration to cease the seed germination of all other pre sowing treatments ranged from 28.33-36.33 days. KH₂PO₄ (50 ppm) and ascorbic acid (50 ppm) took longer duration to cease seed germination over control (34.67 days). The total duration for seed germination remained minimum in ethephon with 14 days whereas maximum in ascorbic acid with 28.33 days. Seed treatment with NaCl also minimized (18.67 days) the duration required for seed germination. Duration of seed germination in all other treatments ranged from 21.33-28 days. Lal, (2015) reported Jackfruit, seeds soaked in NAA 200 ppm significantly reduced the number of days taken for seed germination. In the present investigation water treatment and NAA (50 ppm) reduced germination period to 21.33 days and 22.67 days respectively. Maiti *et al.* (2003) reported water treatment of jackfruit seeds resulted lowest duration for seedling emergence. The highest germination success (72.59%) was in NAA and was significant ($p < 0.05$) with the following treatment that resulted enhanced germination was seed treatment with water (56.15%). Shinde *et al.* (2008) observed NAA @ 80 ppm resulted in 90% seed germination in Rangpur lime (*Citrus limonia*). Neamatollahi *et al.* (2009) reported improvement in seed germination rate with

hydropriming in cumin seeds. Total germination percentage was lowest in ethephon (50 ppm) with 26.55%. Similarly, Pampanna and Sulikeri in 2001 working with sapota cv. Kalipatti observed no significant result with ethrel treatment. Treatment with water + black polythene (38.04%), citric acid (50 ppm) (39.79%) KNO₃ (50 ppm) (38.61%) revealed statistically at per result with control (39.22%). Seed germination percentages were significantly higher in NaCl (50 ppm) 49.01% and KH₂PO₄ (50 ppm) 43.87% treatment.

There were significant difference among the treatments with respect to growth rate. Mean rate of increase in height was lowest in citric acid with 1.23 cm. Seedlings originated from seed treatment with Water resulted highest growth rate i.e. 1.65 cm and statistically on par with NaCl and KH₂PO₄ i.e. 1.64 cm. Bajehbaj (2010) evaluated the effects of NaCl priming with KNO₃ on the germination traits and seedling growth of four *Helianthus annuus* L. cultivars under salinity conditions and concluded that germination percentage of primed seeds were greater than that of un-primed seeds. Among all other treatments mean seedling growth rate ranged from 1.39-1.61 cm. Kaur *et al.*, in 2002 reported hydropriming even in drought situations increased shoot length 3-4 folds. Similarly, Srivastava *et al.* (2010) found seedling growth strengthened by hydropriming in mustard.

There were significant difference in increase rate of collar diameter among the pre-sowing treatments. Mean rate of increase in collar diameter was minimum in citric acid with 0.29 mm and maximum in NAA with 0.76 mm. Whereas in all other treatments increase rate of collar diameter ranged from 0.32-0.73 mm. Aatla and Srihari (2013) recorded that kernel pretreatment with KNO₃ @ 0.5% was highest for seedling diameter, vigor index in mango. Barche *et al.* (2008) working with papaya cv. Hybrid Mayuri reported 2% KNO₃ improved stem diameter over control. Maiti *et al.* (2003) observed that

Jackfruit seeds yielded highest stem diameter when treated with water.

According to Santos *et al.* (2015) priming and pre-soaking treatments effectively increased physiological quality of the guava accessions under study. For seed germination environmental conditions (moisture, oxygen, temperature and light) provide a temporal or spatial window for seedling emergence, development and survival (Long *et al.*, 2015). This is because treatments initiate reserve mobilization, activation of DNA and RNA synthesis and ATP production that subsequently improves uniform germination and seedling vigor (Bewley *et al.*, 2013). In the present experiment it was observed that though seed treatment with water improved germination, seed treatment with water + black polythene suppressed the positive impact of hydropriming that leads to the direction that light has a pivotal role in guava seed germination. Similarly, Sugahara and Takaki, (2004) reported darkness inhibit seed germination of guava which confirms that phytochrom B has control on guava seed germination. Seed treatment with water or salt solutions on the other hand have beneficial impacts like it softens seed coat, reduces germination period, boosts up α -amylase enzyme that increases starch hydrolysis and subsequently enhances seed germination (Afzal *et al.*, 2008). Halopriming with KNO_3 , $NaCl$ ions accumulate within seeds that increases water absorption by reducing water potential and subsequently accelerate growth, enhances germination and eventually results in high seedling quality (Basra *et al.*, 2005; Bhan and Sharma, 2011, Guo *et al.*, 2012 and Parera and Cantliffe, 2010). Ashraf and Iram (2002) and Xiao-Fang *et al.* (2000) observed either negative or no impact at all in different crops with halo priming at different concentration. In the present experiment $NaCl$ (50 ppm), KH_2PO_4 (50 ppm) resulted in improvement in seedling emergence and seedling growth but KNO_3 (50 ppm) showed improvement in seeding growth only not in germination percentage. So from the result it can be hypothesized that different halopriming agents act differently on a particular crop or a particular variety and its doses must be specified. When antioxidant like ascorbic acid is applied exogenously it improved α -amylase activity and enhance cell division efficacy of competent cell that effectively improve seed germination and seedling vigour (Kata *et al.*, 2014). When seeds imbibe ethephon it hydrolyzes in buffered condition to form ethylene; this ethylene acts as a natural germination inhibitor (Evenari, 1949 and Zhang *et al.*, 2010).

From the above experiment it can be concluded that NAA and water treatments of seeds are very effective for guava seed germination. Among all the treatments NAA (50 ppm) resulted in highest seed emergence, collar diameter and

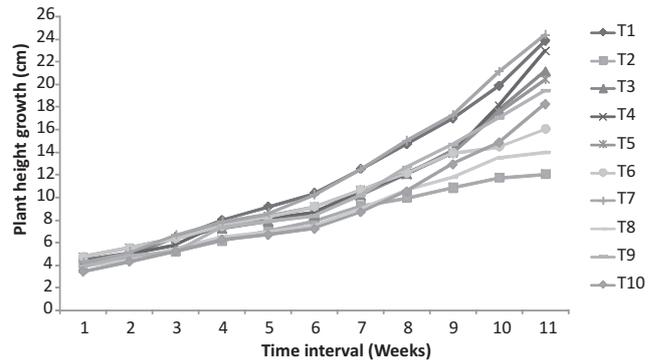


Fig. 1. Effect of pre-sowing treatments on plant height growth (cm) of guava cultivar Allahabad Safeda at the nursery stage

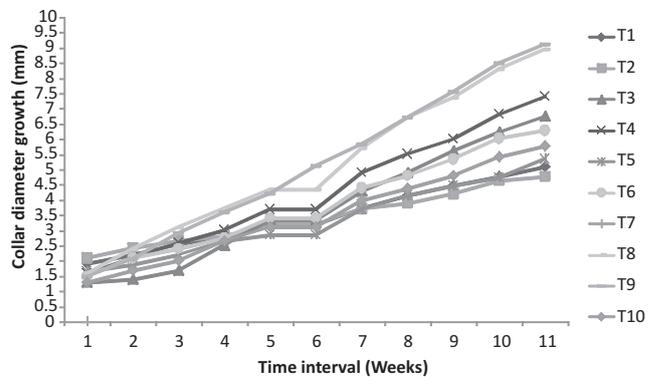


Fig. 2. Effect of pre-sowing treatments on collar diameter growth (mm) of guava cultivar Allahabad Safeda at the nursery stage

improvement in seedling growth. Ethephon exhibited inhibitory effect on all respect. The above experiment also helped to understand that light plays a pivotal role in guava seed germination.

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Genetic Variability and Interrelationships of Yield and Yield Components in Faba Bean (*Vicia faba* L.)

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Abstract: The present study was taken up at CSK HPKV, Palampur to evaluate 35 faba bean genotypes for yield, yield contributing morpho-physiological components and some biochemical traits. Wide range of variability was observed for most of the characters. High magnitude of PCV, GCV, along with high heritability and genetic advance was observed for pod yield per plant and pods per plant indicating the role of additive gene action and selection in the early generations would be valuable. Pod yield per plant had shown a positive and significant correlation at both phenotypic and genotypic levels with nodes per plant, pods per plant, branches per plant, seed yield per plant, seed size, 100-seed weight, harvest index, total soluble solids and protein content. In view of the direct and indirect contributions of component traits and correlations, selection on the basis of nodes per plant, pods per plant, branches per plant, seed yield per plant, seed size, 100-seed weight, harvest index and protein content could be considered effective for evolving high yielding genotypes.

Keywords: Correlation, Faba bean, Path analysis, Underutilized crop, Variability

Faba bean (*Vicia faba* L.; Family: Fabaceae), is one of the important legume crop of the world cultivated under both irrigated and rainfed conditions (Singh *et al.*, 2012a). It can indeed be a highly profitable crop, being capable of fixing atmospheric nitrogen and showing enhanced weed and disease control in subsequent crops (Preissel *et al.*, 2015) along with cold/frost (Sallam *et al.*, 2015), and salinity tolerance, thus helping to combat climate change. Unfortunately, in some parts of the world including India, it is still an underutilized crop and not fully exploited so far. Cultivation of faba bean in India is not widespread and confined to limited acreage in Bihar, Madhya Pradesh and some part of Uttar Pradesh (Singh *et al.*, 2012b). Probably, the non-availability of high yielding varieties with quality pods constitutes the major limiting factor of this crop. This indicated the need of variability studies in faba bean to exploit its potential against malnutrition and hidden hunger. Presence of the sufficient variability and studying such variability among different varieties enables the breeders in determining the most potential genotypes using genetic parameters like genetic coefficient of variation, heritability and genetic advance etc. Since many economic traits are quantitative in nature and highly influenced by the environment and the progress of breeding is governed by the nature of genetic and non-genetic variation. Therefore, it will be useful to partition the overall into its heritability and non heritable components. Further, the knowledge of inter-relationships among different traits is helpful because

selection of one trait may directly affect the performance of another, which is determining the components of a complex trait like yield. However, correlation studies do not provide an exact picture of the direct influence of each of the components traits towards the yield. Path coefficient proves helpful in partitioning the correlation coefficient into direct and indirect effects. Keeping this in view, the present investigation was carried out to determine the components of variability and to find out interrelationships among different characters and their direct and indirect contribution towards yield.

MATERIAL AND METHODS

The experimental material constituted thirty five genotypes along with one check collected from different parts of country. The experiment was undertaken at Vegetable Research Farm, CSK HPKV, Palampur situated at 32° 6' N latitude and 76° 3' E longitude at an elevation of 1290.8m above mean sea level. The location is characterized by humid and temperate climate with an annual rainfall of 2,500 mm of which 80% is received during June to September and represents the mid-hill zone of Himachal Pradesh. Seeds were directly sown in October, 2015 at a spacing of 25×10 cm within row to row and plant to plant, respectively. The experiment was laid out in randomized complete block design) with three replications. The standard cultural practices to raise the healthy crop were followed as per the recommendations of package of practices for vegetable

cultivation by Anonymous (2009). Observations were recorded on ten randomly selected competitive plants in each replication on various growth and yield contributory factors. The data collected were subjected to analysis of variance (Panse and Sukhatme, 1984). The parameters of variability and heritability in the broad sense were calculated as per the formulae of Burton and De Vane (1953) and Johnson *et al.* (1955). The genetic advance (GA) resulting from selection of the top 5 per cent of individuals was calculated following Burton and De Vane (1953) and Johnson *et al.* (1955). Phenotypic and genotypic coefficients of correlation were computed following Al-Jibouri *et al.* (1958). The significance of the coefficients of correlation was tested against *r* values as described by Fisher and Yates (1963) at *n* – 2 degrees of freedom, where *n* is the number of genotypes. The path coefficient analysis was done following the methods described by Dewey and Lu (1959).

Limits used for categorize magnitude of different parameters

| Component | High | Moderate | Low |
|-----------------|--------------|----------|--------------|
| GCV and PCV | More than 25 | 10-25 | Less than 10 |
| Heritability | More than 80 | 60-80 | Less than 60 |
| Genetic advance | More than 30 | 10-30 | Less than 10 |

RESULTS AND DISCUSSION

The analysis of variance revealed that mean squares due to genotypes were significant for all yield, yield contributing morpho-physiological components and quality traits (Table 1).

Phenotypic coefficient of variation was higher than genotypic coefficient of variation for all the traits indicating role of environment in the expression of characters (Table 2). The magnitude of GCV was high for pod yield per plant and pods per plant. Days to 50% flowering, nodes per plant, pod length, plant height, branches per plant, seed size and total soluble solids showed low GCV estimates. Similar estimates were also reported for pod yield per plant by Solieman and Ragheb (2014) and for pods per plant by Sheelamary and Shivani (2015). In contrary, Shrifi (2015) reported moderate PCV and GCV for pods per plant which could be due to variation in genetic material and environmental conditions.

High heritability estimates were observed for all the traits except pods per node where moderate estimates of heritability were observed. The high heritability estimates for these characters revealed the lesser influence of environment and greater role of genetic component of variation. Earlier research workers have also observed high heritability estimates in their respective studies by using different breeding material for days to 50% flowering (Sheelamary and Shivani, 2015), plant height (Toker, 2004), pod length (Shrifi, 2015), pod yield per plant (Kalia and Sood,

Table 1. Analysis of variance (ANOVA) for different traits under study

| Source | df | Mean sum of squares | | |
|------------------------------------|----|---------------------|-----------|-------|
| | | Replication | Treatment | Error |
| Characters | | 2 | 34 | 68 |
| Days to 50% flowering | | 1.31 | 42.13* | 1.18 |
| Node at which first flower appears | | 1.18 | 73.56* | 1.00 |
| Pods per node | | 0.01 | 0.11* | 0.01 |
| Nodesper plant | | 9.72 | 619.64* | 1.55 |
| Pod length (cm) | | 0.01 | 0.55* | 0.05 |
| Pods per plant | | 8.87 | 604.44* | 1.55 |
| Plant height (cm) | | 3.15 | 234.06* | 1.49 |
| Branches per plant | | 0.01 | 1.58* | 0.02 |
| Seeds per pod | | 0.01 | 0.75* | 0.05 |
| Days to maturity | | 0.12 | 482.23* | 1.87 |
| Seed yield per plant (g) | | 2.43 | 59.53* | 1.42 |
| Seed size (cm) | | 0.01 | 0.08* | 0.00 |
| 100–seed weight (g) | | 0.05 | 105.07* | 0.85 |
| Harvest index (%) | | 0.84 | 47.94* | 0.90 |
| Total soluble solids (°B) | | 0.09 | 0.81* | 0.01 |
| Ascorbic acid (mg/100g) | | 0.06 | 10.34* | 0.07 |
| Dry matter (%) | | 0.03 | 12.75* | 0.01 |
| Protein content (%) | | 0.07 | 32.90* | 0.11 |
| Pod yield per plant (g) | | 7.65 | 314.77* | 2.42 |

*Significant at P 0.05

2004), seed size (Shrifi, 2015). Similar findings for pods per node were reported by Muluaem *et al.* (2013). The high expected genetic advance expressed as per cent of mean was observed for node at which first flower appears, pods per plant, harvest index, protein content and pod yield per plant. Solieman and Ragheb (2014) have also reported high genetic advance for pods per plant, total yield per plant, pod weight, branches per plant and plant height.

High heritability along with high genetic advance was observed for node at which first flower appears, pods per plant, harvest index, protein content and pod yield per plant indicating the inheritance of these characters under the control of additive gene action and selection would be more effective for their improvement. Kalia and Sood (2004) also reported similar results for pod yield per plant. Whereas, characters namely, days to 50% flowering, nodes per plant, pod length, plant height, branches per plant, seeds per pod, days to maturity, seed yield per plant, 100–seed weight, total soluble solids, ascorbic acid and dry matter content showed same results for heritability while revealed moderate estimates in case of genetic advance. Pods per node showed moderate estimates for both these parameters indicating the scope of improvement through delayed selections for this

trait. From the results, it can be concluded that phenotypic selection would be more effective for improvement of nodes per plant, pods per plant, harvest index and pod yield per plant in early generations.

The genotypic correlation coefficients were higher than the corresponding phenotypic correlation coefficients showing the inherent association between the traits (Table 3). Pod yield per plant had shown a positive and significant correlation at both phenotypic and genotypic levels with nodes per plant, pods per plant, branches per plant, seed yield per plant, seed size, 100-seed weight, harvest index, total soluble solids and protein content. Earlier reports have also indicated significant and positive association for yield per plant with branches per plant, nodes per plant and pods per plant (Kalia and Sood, 2004; Solieman and Ragheb, 2014) through the evaluation of different breeding materials at respective locations. Therefore, for improvement of yield these traits need to be given special focus.

The correlation coefficients do not take into account extremely complex inter-relationships between various characters, path analysis was applied to partition the correlation coefficients into direct and indirect effects. The result of path analysis (Table 4) indicated that pods per plant followed by 100-seed weight, protein content, days to 50% flowering, pods per node, total soluble solids and harvest

index had maximum positive direct effects on fresh pod yield per plant at genotypic levels, while same has been observed in case of pods per plant followed by pods per plant, total soluble solids, harvest index, 100-seed weight, days to 50% flowering and dry matter at phenotypic level suggesting the importance of these traits towards fresh pod yield. The direct contribution of node at which flower appears, nodes per plant, pod length, number of branches per plant, seeds per pod, days to maturity, seed yield per plant and seed size was also substantial at both phenotypic and genotypic level. Tofiqi *et al.* (2016) has also reported that pods per plant showed maximum direct effect on yield per plant.

Highest positive direct effect of pods per plant was the main contributor of its positive correlation with pod yield per plant. Branches per plant, seed yield per plant, seed size, harvest index, total soluble solids and protein content recorded high positive indirect effect via pods per plant which sum up their respective positive direct effect thus resulting in positive correlation with pod yield per plant. High positive direct effect of 100-seed weight along with pods per plant resulted in its positive correlation with pod yield per plant. Verma *et al.* (2015) also reported the positive direct effect of 100-seed weight on seed yield via harvest index.

Based on correlation and path coefficient analysis, nodes per plant, pods per plant, branches per plant, seed yield per

Table 2. Estimates of parameters of variability for different characters in Faba bean

| Traits | Range | Population mean (mean±S.E.) | PCV (%) | GCV (%) | h^2_{bs} (%) | GA (%) |
|------------------------------------|---------------|-----------------------------|---------|---------|----------------|--------|
| Days to 50% flowering | 57.73-72.00 | 65.31±0.63 | 5.89 | 5.65 | 92.02 | 11.18 |
| Node at which first flower appears | 1.50-4.56 | 3.24±0.07 | 20.15 | 19.74 | 96.03 | 39.86 |
| Pods per node | 1.06-1.91 | 1.51±0.09 | 14.74 | 11.51 | 61.03 | 18.53 |
| Nodes per plant | 120.81-172.75 | 150.41±0.71 | 9.57 | 9.54 | 99.25 | 19.58 |
| Pod length (cm) | 5.21-7.45 | 6.43±0.043 | 6.75 | 6.65 | 97.08 | 13.51 |
| Pods per plant | 23.53-71.87 | 48.29±0.72 | 29.46 | 29.35 | 99.23 | 60.23 |
| Plant height (cm) | 91.60-123.25 | 105.65±0.70 | 8.41 | 8.33 | 98.10 | 17.04 |
| Branches per plant | 6.80-9.81 | 8.46±0.09 | 8.75 | 8.51 | 94.62 | 17.07 |
| Seeds per pod | 2.79-5.00 | 4.06±0.04 | 12.42 | 12.30 | 97.98 | 25.08 |
| Days to maturity | 181.13-216.53 | 203.39±0.76 | 6.25 | 6.22 | 98.84 | 12.74 |
| Seed yield per plant (g) | 22.88-41.93 | 31.24±0.68 | 14.59 | 14.08 | 93.15 | 28.01 |
| Seed size (cm) | 1.54-1.75 | 1.65±0.01 | 3.15 | 3.03 | 92.73 | 6.01 |
| 100-seed weight (g) | 28.21-55.59 | 40.06±0.52 | 14.89 | 14.71 | 97.60 | 29.94 |
| Harvest index (%) | 19.30-34.45 | 25.66±0.54 | 15.87 | 15.43 | 94.53 | 30.90 |
| Total soluble solids (%B) | 6.30-8.20 | 7.53±0.06 | 6.99 | 6.85 | 96.21 | 13.85 |
| Ascorbic acid (mg/100g) | 12.70-19.44 | 15.54±0.16 | 12.02 | 11.90 | 97.98 | 24.28 |
| Dry matter (%) | 10.58-18.71 | 15.02±0.07 | 13.74 | 13.72 | 99.65 | 28.22 |
| Protein content (%) | 14.78-26.34 | 21.15±0.19 | 15.71 | 15.63 | 98.91 | 32.02 |
| Pod yield per plant (g) | 21.59-66.67 | 36.52±0.94 | 28.26 | 27.93 | 97.72 | 56.89 |

S.E., PCV and GCV represents standard error, phenotypic, genotypic and environmental coefficients of variations, respectively; h^2_{bs} (%): Heritability in Broad sense; GA (%): Genetic advance (%) of mean

Table 3. Phenotypic (P) and genotypic (G) coefficients of correlation among different horticultural traits in faba bean

| Trait | Node at which first flower appears | Pods per node | Nodes per plant | Pod length (cm) | Pod per plant | Pods per plant | Plant height (cm) | Branches per plant | Seeds per pod | Days to maturity | Seed yield per plant | Seed size (cm) | 100-seed weight (gm) | Harvest index | Total soluble | Ascorbic acid (mg) | Dry matter (%) | Protein content (%) | Pod yield per plant |
|------------------------------------|------------------------------------|---------------|-----------------|-----------------|---------------|----------------|-------------------|--------------------|---------------|------------------|----------------------|----------------|----------------------|---------------|---------------|--------------------|----------------|---------------------|---------------------|
| Days to 50% flowering | P | 0.173 | 0.106 | 0.129 | -0.259 | 0.431 | | -0.172 | 0.210 | 0.196 | -0.146 | 0.124 | -0.139 | -0.054 | -0.153 | 0.165 | -0.057 | 0.093 | -0.156 |
| | G | 0.202 | 0.108 | 0.133 | -0.271 | 0.453 | | -0.172 | 0.217 | 0.206 | -0.159 | 0.133 | -0.144 | -0.051 | -0.161 | 0.172 | -0.058 | 0.106 | -0.163 |
| Node at which first flower appears | P | -0.014 | 0.057 | -0.134 | -0.112 | 0.102 | | -0.103 | 0.253 | -0.413 | -0.097 | 0.141 | 0.014 | -0.060 | 0.070 | -0.022 | -0.063 | -0.175 | -0.117 |
| | G | 0.020 | 0.056 | -0.137 | -0.115 | 0.103 | | -0.104 | 0.261 | -0.430 | -0.100 | 0.148 | 0.012 | -0.056 | 0.075 | -0.019 | -0.065 | -0.180 | -0.124 |
| Pods per node | P | 0.052 | 0.052 | 0.161 | -0.367 | 0.207 | | -0.343 | -0.023 | 0.194 | -0.284 | -0.29 | -0.313 | -0.308 | -0.039 | 0.172 | -0.028 | -0.235 | -0.374 |
| | G | 0.072 | 0.072 | 0.189 | -0.480 | 0.251 | | -0.447 | -0.018 | 0.267 | -0.391 | -0.47 | -0.413 | -0.390 | -0.062 | 0.193 | -0.028 | -0.294 | -0.484 |
| Nodes per plant | P | | | 0.235 | 0.239 | 0.506 | | 0.105 | 0.168 | 0.140 | -0.150 | 0.098 | -0.070 | 0.238 | 0.027 | -0.054 | -0.105 | 0.191 | 0.257 |
| | G | | | 0.239 | 0.240 | 0.509 | | 0.106 | 0.171 | 0.141 | -0.161 | 0.107 | -0.072 | 0.243 | 0.024 | -0.054 | -0.105 | 0.193 | 0.262 |
| Pod length (cm) | P | | | 0.023 | 0.023 | 0.124 | | -0.163 | 0.206 | 0.193 | -0.317 | 0.121 | -0.095 | 0.063 | -0.100 | 0.041 | 0.268 | 0.114 | 0.071 |
| | G | | | 0.024 | 0.024 | 0.127 | | -0.167 | 0.212 | 0.194 | -0.343 | 0.111 | -0.094 | 0.072 | -0.099 | 0.037 | 0.274 | 0.117 | 0.081 |
| Pods per plant | P | | | -0.062 | -0.062 | 0.294 | | 0.294 | -0.006 | -0.031 | 0.564 | 0.189 | 0.150 | 0.690 | 0.360 | -0.099 | -0.174 | 0.374 | 0.932 |
| | G | | | -0.064 | -0.064 | 0.308 | | 0.308 | -0.006 | -0.031 | 0.588 | 0.195 | 0.151 | 0.712 | 0.365 | -0.102 | -0.175 | 0.377 | 0.947 |
| Plant height (cm) | P | | | -0.011 | -0.011 | 0.238 | | -0.011 | 0.238 | 0.178 | -0.058 | 0.099 | 0.178 | 0.035 | 0.203 | -0.068 | -0.171 | 0.132 | 0.015 |
| | G | | | -0.008 | -0.008 | 0.242 | | -0.008 | 0.242 | 0.183 | -0.065 | 0.110 | 0.180 | 0.032 | 0.208 | -0.067 | -0.173 | 0.132 | 0.016 |
| Branches per plant | P | | | -0.002 | -0.002 | 0.182 | | -0.002 | 0.182 | 0.182 | 0.159 | -0.13 | 0.295 | 0.180 | 0.007 | 0.190 | -0.055 | -0.005 | 0.279 |
| | G | | | 0.003 | 0.003 | 0.189 | | 0.003 | 0.189 | 0.189 | 0.170 | -0.12 | 0.319 | 0.169 | -0.003 | 0.202 | -0.053 | -0.002 | 0.287 |
| Seeds per pod | P | | | -0.072 | -0.072 | 0.368 | | -0.072 | 0.368 | 0.005 | -0.072 | 0.368 | 0.043 | 0.089 | -0.021 | 0.119 | 0.126 | 0.077 | 0.060 |
| | G | | | -0.072 | -0.072 | 0.390 | | -0.072 | 0.390 | 0.005 | -0.072 | 0.390 | 0.040 | 0.096 | -0.027 | 0.124 | 0.126 | 0.076 | 0.061 |
| Days to maturity | P | | | -0.039 | -0.039 | 0.16 | | -0.039 | 0.16 | -0.039 | -0.039 | -0.16 | -0.155 | -0.038 | 0.003 | 0.123 | 0.200 | 0.124 | 0.022 |
| | G | | | -0.046 | -0.046 | 0.17 | | -0.046 | 0.17 | -0.046 | -0.046 | -0.17 | -0.154 | -0.036 | 0.004 | 0.123 | 0.200 | 0.126 | 0.020 |
| Seed yield per plant (g) | P | | | 0.286 | 0.286 | 0.336 | | 0.286 | 0.336 | 0.079 | 0.286 | 0.336 | 0.305 | 0.305 | 0.424 | 0.079 | -0.222 | 0.186 | 0.561 |
| | G | | | 0.289 | 0.289 | 0.350 | | 0.289 | 0.350 | 0.078 | 0.289 | 0.350 | 0.325 | 0.325 | 0.446 | 0.078 | -0.230 | 0.191 | 0.588 |
| Seed size (cm) | P | | | 0.374 | 0.374 | 0.085 | | 0.374 | 0.085 | 0.085 | 0.374 | 0.085 | 0.374 | 0.085 | -0.028 | -0.206 | 0.221 | -0.042 | 0.241 |
| | G | | | 0.390 | 0.390 | 0.118 | | 0.390 | 0.118 | 0.118 | 0.390 | 0.118 | 0.390 | 0.118 | -0.020 | -0.225 | 0.233 | -0.043 | 0.256 |
| 100-seed weight (g) | P | | | 0.122 | 0.122 | 0.247 | | 0.122 | 0.247 | 0.099 | 0.122 | 0.247 | 0.122 | 0.122 | 0.247 | 0.099 | -0.142 | -0.222 | 0.235 |
| | G | | | 0.124 | 0.124 | 0.255 | | 0.124 | 0.255 | 0.098 | 0.124 | 0.255 | 0.124 | 0.124 | 0.255 | 0.098 | -0.146 | -0.227 | 0.243 |
| Harvest index (%) | P | | | 0.274 | 0.274 | 0.184 | | 0.274 | 0.184 | 0.274 | 0.274 | 0.184 | 0.274 | 0.184 | 0.274 | -0.073 | -0.184 | 0.320 | 0.722 |
| | G | | | 0.279 | 0.279 | 0.191 | | 0.279 | 0.191 | 0.279 | 0.279 | 0.191 | 0.279 | 0.191 | 0.279 | -0.078 | -0.191 | 0.328 | 0.747 |
| Total soluble solids (°B) | P | | | 0.111 | 0.111 | 0.219 | | 0.111 | 0.219 | 0.111 | 0.111 | 0.219 | 0.111 | 0.111 | 0.219 | 0.111 | -0.219 | 0.382 | 0.455 |
| | G | | | 0.121 | 0.121 | 0.223 | | 0.121 | 0.223 | 0.121 | 0.121 | 0.223 | 0.121 | 0.121 | 0.223 | 0.121 | -0.223 | 0.389 | 0.470 |
| Ascorbic acid (mg/100g) | P | | | 0.024 | 0.024 | 0.085 | | 0.024 | 0.085 | 0.024 | 0.024 | 0.085 | 0.024 | 0.024 | 0.085 | 0.024 | 0.024 | 0.085 | -0.053 |
| | G | | | 0.025 | 0.025 | 0.087 | | 0.025 | 0.087 | 0.025 | 0.025 | 0.087 | 0.025 | 0.025 | 0.087 | 0.025 | 0.025 | 0.087 | -0.055 |
| Dry matter (%) | P | | | -0.030 | -0.030 | 0.198 | | -0.030 | 0.198 | -0.030 | -0.030 | 0.198 | -0.030 | -0.030 | 0.198 | -0.030 | -0.030 | 0.198 | -0.198 |
| | G | | | -0.031 | -0.031 | 0.201 | | -0.031 | 0.201 | -0.031 | -0.031 | 0.201 | -0.031 | -0.031 | 0.201 | -0.031 | -0.031 | 0.201 | -0.201 |
| Protein content (%) | P | | | 0.423 | 0.423 | 0.434 | | 0.423 | 0.434 | 0.423 | 0.423 | 0.434 | 0.423 | 0.423 | 0.434 | 0.423 | 0.423 | 0.434 | 0.423 |
| | G | | | 0.434 | 0.434 | 0.434 | | 0.434 | 0.434 | 0.434 | 0.434 | 0.434 | 0.434 | 0.434 | 0.434 | 0.434 | 0.434 | 0.434 | 0.434 |

*Significant at P 0.05; **Significant at P 0.01

Table 4. Estimates of direct and indirect effects of different traits on pod yield per plant at phenotypic (P) and genotypic (G) levels in Faba bean

| Trait | Days to 50% flowering | Node at which first flower appears | Pods per node | Nodes per plant | Pod length (cm) | Pods per plant | Plant height (cm) | Branches per plant | Seeds per pod | Days to maturity | Seed yield per plant | Seed size (cm) | 100-seed weight | Harvest index | Total soluble | Ascorbic acid (mg) | Dry matter (%) | Protein content (%) | R |
|-------|-----------------------|------------------------------------|---------------|-----------------|-----------------|----------------|-------------------|--------------------|---------------|------------------|----------------------|----------------|-----------------|---------------|---------------|--------------------|----------------|---------------------|--------|
| P | 0.0963 | -0.0060 | 0.000 | 0.005 | 0.007 | -0.19 | -0.04 | -0.0046 | 0.0038 | 0.0127 | -0.003 | 0.005 | -0.015 | -0.0062 | -0.0198 | -0.0052 | 0.0023 | 0.0065 | -0.156 |
| G | 0.1383 | -0.0098 | 0.026 | 0.006 | 0.007 | -0.20 | -0.08 | -0.0139 | 0.0016 | 0.0083 | -0.003 | 0.010 | -0.024 | -0.0058 | -0.0207 | -0.0135 | 0.0017 | 0.0148 | -0.163 |
| P | -0.0209 | 0.0276 | 0.000 | 0.002 | -0.007 | -0.08 | -0.01 | -0.0028 | 0.0045 | -0.0268 | -0.002 | 0.006 | 0.001 | -0.0068 | 0.0091 | 0.0007 | 0.0026 | -0.0121 | -0.117 |
| G | -0.0309 | 0.0440 | 0.002 | 0.003 | -0.007 | -0.08 | -0.01 | -0.0085 | 0.0019 | -0.0174 | -0.002 | 0.011 | 0.002 | -0.0064 | 0.0096 | 0.0015 | 0.0019 | -0.0250 | -0.124 |
| P | 0.0166 | -0.0004 | 0.001 | 0.002 | 0.009 | -0.26 | -0.02 | -0.0092 | -0.0004 | 0.0126 | -0.006 | -0.013 | -0.034 | -0.0352 | -0.0050 | -0.0054 | 0.0011 | -0.0163 | -0.374 |
| G | 0.0279 | 0.0009 | 0.130 | 0.004 | 0.009 | -0.36 | -0.04 | -0.0363 | -0.0001 | 0.0108 | -0.008 | -0.037 | -0.071 | -0.0442 | -0.0079 | -0.0151 | 0.0008 | -0.0408 | -0.484 |
| P | 0.0102 | 0.0016 | 0.000 | 0.050 | 0.013 | 0.175 | -0.05 | 0.0028 | 0.0030 | 0.0091 | -0.003 | 0.004 | -0.007 | 0.0272 | 0.0034 | 0.0017 | 0.0043 | 0.0133 | 0.257 |
| G | 0.0149 | 0.0025 | 0.009 | 0.060 | 0.012 | 0.180 | -0.09 | 0.0086 | 0.0013 | 0.0057 | -0.003 | 0.008 | -0.012 | 0.0276 | 0.0031 | 0.0042 | 0.0031 | 0.0268 | 0.262 |
| P | 0.0124 | -0.0037 | 0.000 | 0.0119 | 0.056 | 0.016 | -0.01 | -0.0044 | 0.0037 | 0.0126 | -0.007 | 0.005 | -0.010 | 0.0073 | -0.0130 | -0.0013 | -0.011 | 0.0080 | 0.071 |
| G | 0.0184 | -0.0060 | 0.024 | 0.014 | 0.052 | 0.018 | -0.02 | -0.0136 | 0.0016 | 0.0079 | -0.007 | 0.008 | -0.016 | 0.0082 | -0.0127 | -0.0029 | -0.008 | 0.0163 | 0.081 |
| P | -0.0250 | -0.0031 | -0.000 | 0.012 | 0.001 | 0.735 | 0.006 | 0.0079 | -0.0001 | -0.0020 | 0.013 | 0.008 | 0.016 | 0.0789 | 0.0467 | 0.0031 | 0.0071 | 0.0260 | 0.932 |
| G | -0.0375 | -0.0051 | -0.062 | 0.014 | 0.001 | 0.753 | 0.011 | 0.0250 | 0.0000 | -0.0013 | 0.013 | 0.015 | 0.026 | 0.0808 | 0.0467 | 0.0080 | 0.0052 | 0.0523 | 0.947 |
| P | 0.0415 | 0.0028 | 0.000 | 0.025 | 0.007 | -0.04 | -0.10 | -0.0003 | 0.0043 | 0.0116 | -0.001 | 0.004 | 0.019 | 0.0040 | 0.0264 | 0.0021 | 0.0070 | 0.0092 | 0.015 |
| G | 0.0627 | 0.0045 | 0.032 | 0.030 | 0.006 | -0.04 | -0.17 | -0.0007 | 0.0018 | 0.0074 | -0.001 | 0.008 | 0.031 | 0.0036 | 0.0266 | 0.0052 | 0.0051 | 0.0183 | 0.016 |
| P | -0.0166 | -0.0028 | -0.000 | 0.005 | -0.009 | 0.216 | 0.001 | 0.0268 | 0.0000 | 0.0118 | 0.003 | -0.006 | 0.032 | 0.0206 | 0.0009 | -0.0060 | 0.0023 | -0.0003 | 0.279 |
| G | -0.0238 | -0.0046 | -0.058 | 0.006 | -0.008 | 0.232 | 0.001 | 0.0811 | 0.0000 | 0.0076 | 0.003 | -0.010 | 0.055 | 0.0192 | -0.0004 | -0.0159 | 0.0016 | -0.0003 | 0.287 |
| P | 0.0202 | 0.0070 | 0.000 | 0.008 | 0.011 | -0.00 | -0.02 | -0.0001 | 0.0179 | 0.0003 | -0.001 | 0.016 | 0.004 | 0.0102 | -0.0028 | -0.0037 | -0.005 | 0.0053 | 0.060 |
| G | 0.0300 | 0.0115 | -0.002 | 0.010 | 0.011 | -0.00 | -0.04 | 0.0002 | 0.0074 | 0.0002 | -0.001 | 0.030 | 0.006 | 0.0108 | -0.0034 | -0.0098 | -0.003 | 0.0106 | 0.061 |
| P | 0.0189 | -0.0114 | 0.000 | 0.007 | 0.011 | -0.02 | -0.01 | 0.0049 | 0.0001 | 0.0650 | -0.000 | -0.007 | -0.016 | -0.0044 | 0.0004 | -0.0039 | -0.008 | 0.0087 | 0.022 |
| G | 0.0285 | -0.0189 | 0.034 | 0.008 | 0.010 | -0.02 | -0.03 | 0.0153 | 0.0000 | 0.0404 | -0.001 | -0.013 | -0.026 | -0.0041 | 0.0006 | -0.0097 | -0.005 | 0.0175 | 0.020 |
| P | -0.0141 | -0.0027 | -0.000 | -0.007 | -0.018 | 0.414 | 0.006 | 0.0043 | -0.0013 | -0.0025 | 0.023 | 0.012 | 0.036 | 0.0349 | 0.0550 | -0.0025 | 0.0091 | 0.0129 | 0.561 |
| G | -0.0220 | -0.0044 | -0.050 | -0.009 | -0.018 | 0.442 | 0.011 | 0.0138 | -0.0005 | -0.0019 | 0.022 | 0.022 | 0.060 | 0.0369 | 0.0571 | -0.0061 | 0.0068 | 0.0266 | 0.588 |
| P | 0.0119 | 0.0039 | -0.000 | 0.005 | 0.006 | 0.138 | -0.01 | -0.0036 | 0.0066 | -0.0105 | 0.006 | 0.045 | 0.040 | 0.0097 | -0.0036 | 0.0065 | -0.009 | -0.0029 | 0.241 |
| G | 0.0184 | 0.0065 | -0.061 | 0.006 | 0.005 | 0.146 | -0.01 | -0.0103 | 0.0029 | -0.0069 | 0.006 | 0.078 | 0.067 | 0.0134 | -0.0026 | 0.0176 | -0.006 | -0.0060 | 0.256 |
| P | -0.0134 | 0.0004 | -0.000 | -0.003 | -0.005 | 0.110 | -0.01 | 0.0079 | 0.0008 | -0.0101 | 0.008 | 0.016 | 0.108 | 0.0139 | 0.0321 | -0.0031 | 0.0058 | -0.0155 | 0.235 |
| G | -0.0199 | 0.0005 | -0.053 | -0.004 | -0.004 | 0.114 | -0.03 | 0.0259 | 0.0003 | -0.0062 | 0.007 | 0.030 | 0.173 | 0.0140 | 0.0326 | -0.0077 | 0.0043 | -0.0314 | 0.243 |
| P | -0.0052 | -0.0017 | -0.000 | 0.012 | 0.003 | 0.507 | -0.00 | 0.0048 | 0.0016 | -0.0025 | 0.007 | 0.003 | 0.013 | 0.1143 | 0.0355 | 0.0023 | 0.0075 | 0.0222 | 0.722 |
| G | -0.0071 | -0.0025 | -0.050 | 0.014 | 0.003 | 0.536 | -0.00 | 0.0137 | 0.0007 | -0.0015 | 0.007 | 0.009 | 0.021 | 0.1134 | 0.0358 | 0.0061 | 0.0056 | 0.0455 | 0.747 |
| P | -0.0147 | 0.0019 | -0.000 | 0.001 | -0.005 | 0.264 | -0.02 | 0.0002 | -0.0004 | 0.0002 | 0.010 | -0.001 | 0.026 | 0.0313 | 0.1297 | -0.0035 | 0.0090 | 0.0265 | 0.455 |
| G | -0.0223 | 0.0033 | -0.008 | 0.001 | -0.005 | 0.275 | -0.03 | -0.0002 | -0.0002 | 0.0002 | 0.009 | -0.001 | 0.044 | 0.0317 | 0.1279 | -0.0095 | 0.0066 | 0.0541 | 0.470 |
| P | 0.0159 | -0.0006 | 0.000 | -0.002 | 0.002 | -0.07 | 0.007 | 0.0051 | 0.0021 | 0.0080 | 0.001 | -0.009 | 0.010 | -0.0083 | 0.0144 | -0.0313 | -0.001 | 0.0059 | -0.053 |
| G | 0.0237 | -0.0008 | 0.025 | -0.003 | 0.001 | -0.07 | 0.011 | 0.0164 | 0.0009 | 0.0050 | 0.001 | -0.017 | 0.017 | -0.0088 | 0.0154 | -0.0785 | -0.000 | 0.0120 | -0.055 |
| P | -0.0055 | -0.0017 | 0.000 | -0.005 | 0.015 | -0.12 | 0.017 | -0.0015 | 0.0023 | 0.0130 | -0.005 | 0.010 | -0.015 | -0.0211 | -0.0284 | -0.0008 | -0.040 | -0.0021 | -0.198 |
| G | -0.0080 | -0.0029 | -0.003 | -0.006 | 0.014 | -0.13 | 0.030 | -0.0043 | 0.0009 | 0.0081 | -0.005 | 0.018 | -0.025 | -0.0216 | -0.0285 | -0.0020 | -0.029 | -0.0042 | -0.201 |
| P | 0.0089 | -0.0048 | -0.000 | 0.009 | 0.006 | 0.275 | -0.01 | -0.0001 | 0.0014 | 0.0081 | 0.004 | -0.001 | -0.024 | 0.0365 | 0.0495 | -0.0027 | 0.0012 | 0.0695 | 0.423 |
| G | 0.0147 | -0.0079 | -0.038 | 0.0116 | 0.006 | 0.284 | -0.02 | -0.0002 | 0.0006 | 0.0051 | 0.004 | -0.003 | -0.039 | 0.0372 | 0.0498 | -0.0068 | 0.0009 | 0.1388 | 0.434 |

Unexplained variation: (P):0.07729; (G):0.04534; *Significant at P < 0.05; r-correlation coefficient with pod yield per plant; bold values indicate direct effects

plant, seed size, 100-seed weight, harvest index and protein content could be considered as the best selection parameters for evolving high yielding genotypes.

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Assessment of Earthworm Abundance and Diversity in Wheat fields of Different Regions of Punjab

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Abstract: A study was conducted on abundance and diversity of earthworms inhabiting the wheat fields of different regions of Punjab in relation to edaphic factors (soil temperature and moisture) during November 2014–April 2015. Three species of earthworms were identified in wheat crop fields were *Metaphire posthuma*, *Lampito mauritii* and *Amyntas morrisi* belongs to family *Megascolecidae*. The prevalence of *Metaphire posthuma* and *Lampito mauritii* in all the sites represents the dominating species of Punjab. The earthworms were most abundant and active at all sites during March, whereas relative abundance declined to minimum in November. There was complete absence of earthworms in December and January. These findings exhibited great fluctuations in earthworm population over the months with the variation in the edaphic factors. Density was maximum when soil moisture was maximum and soil temperature was optimum ($> 9^{\circ}\text{C}$).

Keywords: Diversity, Sugarcane fields, Wheat fields, Edaphic factors, Earthworms

India is one of the major earthworm diverse countries with 11.1 per cent earthworm diversity of the world. Five hundred and five species and sub species of earthworm belonging to 67 genera and 10 families have been identified from the India (Julka, 2001; Kathireswari, 2016). Distribution of earthworms is usually irregular and the numbers vary in relation to the type of soil and ecological factors especially edaphic factors (Dey and Chaudhuri, 2016). They are found in all types of soils but their density and diversity are mainly controlled by environmental factors that influence their biological cycles, such as temperature, moisture, organic carbon supply. Earthworms are important soil macro fauna that have profound effects on ecosystems and have attracted a lot of interest due to their beneficial effects, especially in agriculture. The establishment of earthworm populations in an area, particularly in agricultural soil, is correlated to soil sustainability (Teng *et al.*, 2013). Earthworm feeding behavior, burrowing and casting are vital in nutrient cycling and decomposition regulation (Dechaine *et al.*, 2005). Since earthworms account for the highest biomass among tropical soil macrofauna, soil quality depends on population density, species diversity, and activity level of earthworm community (Fragoso and Lavelle, 2001). Studies pertaining to the abundance and species diversity of earthworms are scarce in agricultural fields of Punjab. Earlier, an attempt has been made by Dhiman and Battish (2006), Koul and Kocher (2016) to conduct a survey of earthworm species available in different areas of Punjab. However, literature is not available on the diversity and abundance of earthworms in the wheat

fields of Punjab. So, the present work was planned and carried out to evaluate the actual condition of the earthworm biodiversity and availability in Punjab wheat fields along with its edaphic factors. This information is very essential to take necessary steps for conserving earthworms which has a huge impact on soil fertility and environment.

MATERIAL AND METHODS

Description of sampling area: The study area was representative of Majha (Amritsar), Doaba (Shaheed Bhagat Singh (SBS) Nagar) and Malwa (Moga) regions of Punjab. Sampling was done in three villages from each district and three fields from each village (Table 1).

Surveillance: Wheat fields were surveyed during November 2014 to April 2015 at monthly intervals for collection of earthworms and soil samples. Five spots (spot area = 25 x 25 cm) per field (three replicate per field) were dug randomly upto 20 cm depth of soil and hand sorted to collect earthworms. The collected samples of earthworms with appropriate amount of soil (up to 20 cm depth) were placed in polythene bags. The soil temperature and moisture were estimated along with earthworm catch to find the relationship of these edaphic factors with population density of earthworms.

Identification of earthworms: Live worms collected from the study area were brought to laboratory for identification. For diagnostic and taxonomic characteristics, some earthworms were narcotized in 30% ethyl alcohol and then fixed in 10% formalin for 24 hours and rest was finally

preserved in 10% formalin. The morphological details were examined under binocular microscope. These earthworms were identified upto species level with the help of monographs prepared by Gates (1972) and Julka (1988). Identification of different earthworm species was further confirmed by getting them identified from ZSI (Zoological Survey of India, Solan).

RESULTS AND DISCUSSION

Population density of earthworms: During the study period, in all the three districts the earthworm count per m² was low in November (Table 1); minimum count was observed in Moga with range 1-10 earthworms per m². Earthworms were completely absent in December and January in all the districts of Punjab, when the soil temperature decreased below 9°C i.e. sub optimal level. With rise in temperature to 11°C in February the earthworm again appeared on the upper layers and their number was more than that of November (Table 1). Maximum number of earthworms were in SBS Nagar of Punjab. Density of earthworm per m² was maximum in the March in all the districts of Punjab when soil temperature was around 20 °C and percent soil moisture was also maximum. Slight decrease in earthworm abundance was observed in April when the temperature of the soil increased above 26°C and percent soil moisture decreased (Table 1).

Correlation analysis of seasonal factors and population

density of earthworms in wheat fields of Amritsar, SBS Nagar and Moga district revealed that there was significant positive correlation with soil temperature at 5°C and at 20°C (Table 2). In wheat fields among different districts maximum earthworm population was observed in SBS nagar where maximum soil moisture reached to 27.86 followed by Amritsar and least population was observed in Moga district where maximum soil moisture was observed as 27.01. Earthworm population correlates with soil edaphic factors (soil temperature and moisture). Earthworm abundance followed the trend as SBS Nagar>Amritsar>Moga.

Earthworm diversity: Three species of earthworms belonging to family Megascolecidae were identified. The identified species of earthworms were *Metaphire posthuma* (Fig. 1a), *Lampito mauritii* (Fig. 1b), *Amyntas morrisi* (Fig. 1c). At Amritsar and Moga, two species were in wheat fields (*Metaphire posthuma* and *Lampito mauritii*). In SBS Nagar in addition to these two species *Amyntas morrisi* was also collected. *Metaphire posthuma* and *Lampito mauritii* were dominating species. Species were identified and differentiated on the basis of morphological characters typical for the respective species like body colour, total no of segments, type of prostomium, type of clitellum, location of clitellum, location of spermathecae and number of pairs of spermathecae are shown in Table 3.

Metaphire posthuma is light brown in colour with 114 –116 body segments, prostomium is epilobus in shape, clitellum is

Table 1. Population studies of earthworms, variation in soil temperature and moisture in wheat fields from different regions of Punjab during November 2014 to April 2015 (Mean±SE)

| | Amritsar | | | SBS Nagar | | | Moga | | | | | |
|------------------|---|--|----------------|---------------------------|---|--|----------------|---------------------------|---|--|----------------|---------------------------|
| | Number of earthworms collected per m ² | Mean Soil temperature (°C) at different depths | | Percent soil moisture (%) | Number of earthworms collected per m ² | Mean Soil temperature (°C) at different depths | | Percent soil moisture (%) | Number of earthworms collected per m ² | Mean Soil temperature (°C) at different depths | | Percent soil moisture (%) |
| | | 5 cm | 20 cm | | | 5 cm | 20 cm | | | 5 cm | 20 cm | |
| Year 2014 | | | | | | | | | | | | |
| November | 5.9±0.88 (0-19) | 15.92 ±0.32 | 14.92 ±0.40 | 19.43 ± 0.54 | 6.18±0.91 (2-12) | 15.84 ±0.09 | 14.82 ±0.16 | 19.72 ±0.13 | 4.36±0.28 (1-10) | 17.94 ±0.06 | 16.54 ±0.14 | 20.67 ±0.16 |
| December | — | 7.05 ±0.22 | 8.84 ±0.23 | 24.93 ±0.06 | — | 6.13 ±0.36 | 6.97 ±0.08 | 25.14 ±0.03 | — | 7.743 ±0.20 | 8.42 ±0.27 | 24.47 ±0.15 |
| Year 2015 | | | | | | | | | | | | |
| January | — | 7.31 ±0.24 | 8.08 ±0.61 | 20.95 ±0.23 | — | 7.08 ±0.07 | 8.02 ±0.02 | 25.87 ±0.41 | — | 5.88 ±0.09 | 6.50 ±0.14 | 24.78 ±0.33 |
| February | 7.34±0.66 (1-30) | 11.13 ±0.20 | 11.20 ±0.10 | 23.12 ±0.06 | 9.10±0.77 (1-18) | 12.82 ±0.04 | 13.35 ±0.26 | 26.57 ±0.24 | 5.49±0.88 (1-16) | 13.70 ±0.25 | 12.59 ±0.24 | 26.79 ±0.13 |
| March | 16.21±1.05 (0-29) | 20.95 ±0.21 | 17.39 ±0.60 | 27.44 ±0.34 | 18.59±0.45 (11-29) | 21.12 ±0.03 | 19.45 ±0.29 | 27.86 ±0.05 | 7.45 ±0.96 | 24.55 ±0.30 | 23.35 ±0.27 | 27.01 ±0.06 |
| April | 7.64±1.19 (5-23) | 27.67 ±0.21 | 26.01 ±0.57 | 16.03 ±0.15 | 15.46±1.50 (5-28) | 27.89 ±0.12 | 27.28 ±0.09 | 17.17 ±0.51 | 4.49±0.81 (1-16) | 32.08 ±0.18 | 30.33 ±0.11 | 18.34 ±0.10 |

Values in parentheses indicate the range of earthworm population. No population was observed in December, 2014 and January 2015

Table 2. Variation in correlation coefficient (r) among soil temperature, moisture and population of earthworms in wheat fields of different regions of Punjab

| Districts | ST (5 cm) | ST (20 cm) | SM |
|-----------|-----------|------------|-------|
| Amritsar | 0.692** | 0.577** | 0.218 |
| SBS Nagar | 0.898** | 0.877** | 0.169 |
| Moga | 0.725** | 0.697** | 0.147 |

Critical value of r at 5% and 1 % = 0.455 and 0.575; and ** Significant at 5% and 1 %, ST = Soil temperature in°C; SM = Soil Moisture in%

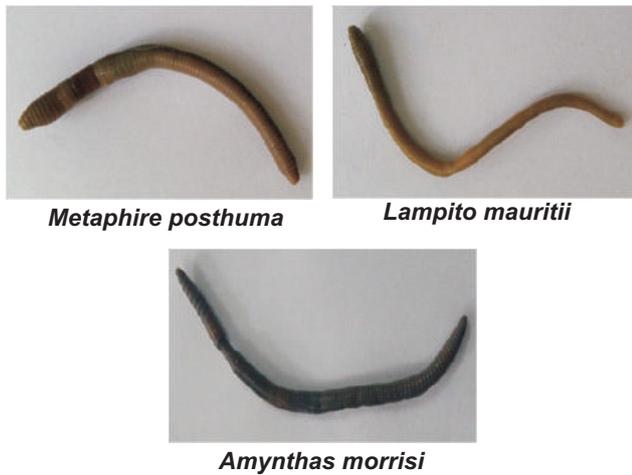


Fig. 1. Earthworm species collected from wheat crop fields of different regions of Punjab

present on 14 –17 segment and annular in shape. Spermathecae is four in number and present from 5/6 –8/9 segment. Whereas, *Lampito mauritii* is light pink in colour, body segments varied from 180 – 182, prostomium is prolobus in shape, clitellum is present between 14 –17 segment with annular shape. Spermathecae are three in number and present between 6/7 – 8/9 segments. Body colour in case of *Amynthes morrisi* was dark red with 106 to 107 total body segments, epilobus prostomium was present. Clitellum was present on 14 –16 number of segments and annular in shape. Two pairs of spermathecae were present in *Amynthes morrisi* and are present on 5/6-6/7 segments.

Various studies done in different parts of India reveal the effect of temperature and moisture content of soil on earthworm population (Goswami and Mondal, 2015; Koul

and Kocher, 2016). The earthworm population increases or decreases with an increase or decrease in temperature (Blakemore *et al.*, 2006; Koul, 2015). A number of investigators observed positive correlation between soil temperature and earthworm population density (Padamavathi, 2013; Koul, 2015). Munnoli *et al.*, (2010) reported that the activity, metabolism, growth, respiration, reproduction, fecundity and growth period from hatching to sexual maturity of earthworms are greatly influenced by temperature. A temperature range of 20–30 °C is considered ideal for most of the earthworms (Munnoli *et al.*, 2010). However, low soil temperature during December and January attributed to the reduction in earthworm population, because in winter hatching of cocoon is delayed (Timmerman *et al.*, 2006).

During the study period in the wheat fields population density was maximum during March, where moisture content was also highest. Maximum moisture in soil (50.3±1.89%) and density of earthworms was also observed in Ataurala locality of Gola block in district Gorakhpur by Kumar and Singh (2013). According to Teng *et al.* (2013) a positive correlation was observed between earthworm biomass and soil moisture content, suggesting that *M. chiliensis chiliensis* sensitive towards soil moisture content. Soil moisture content may affect the biomass of *M. chiliensis chiliensis* because water constitutes 75 –90% of their body weight. However, the moisture requirements for different species of earthworms from various regions can be quite different. Smetak *et al.* (2007) reported that relatively low soil moisture is of concern, as earthworm are particularly sensitive to moisture stress and rely on soil water to stay hydrated. Similar findings were also reported by Chaudhuri *et al.* (2008); Haokipand Singh (2012); Mohan *et al.* (2013) and Koul (2015), indicating that soil moisture significantly affects the population density of earthworms. Present study revealed that *Metaphire posthuma* and *Lampito mauritti* were present in all the districts in wheat crop fields throughout the study period, hence these are dominating species of Punjab. These results corroborates with the findings of Sathianarayanan and Khan (2006); Goswami and Mondal (2015); Deepthi and Kathireswari, (2016). Different ecosystems present in the Vatakarataluk located in

Table 3. Important morphological and anatomical features of various earthworm species found in different regions of Punjab

| Species | Body colour | Total body Segments | Prostomium | Clitellum | | Spermathecae | |
|---------------------------|-------------|---------------------|------------|------------|---------|--------------|----------|
| | | | | Segment no | Type | No of pairs | Segments |
| <i>Metaphire posthuma</i> | Light brown | 114–116 | Epilobus | 14–17 | Annular | 4 | 5/6-8/9 |
| <i>Lampito mauritti</i> | Light pink | 180–182 | Prolobus | 14–17 | Annular | 3 | 6/7-8/9 |
| <i>Amynthes morrisi</i> | Dark red | 106–107 | Epilobus | 14–16 | Annular | 2 | 5/6-6/7 |

Kozhikode District, Kerala, India which includes near coastal region, agro ecosystem, forest land and the polluted ecosystem. The study revealed that six different species of earthworms found in four different study sites and *Lampito mauritii* was the dominant of all (Deepthi and Kathireswari, 2016). In fourteen localities from different habitat in Pondicherry, *Lampito mauritii* was dominant in all the habitats (Sathianarayanan and Khan, 2006). In the present study *Lampito mauritii* was predominantly observed in all selected studied areas. Earthworm species *Lampito mauritii* can withstand in any conditions because it is a peregrine species (Deepthi and Kathireswari, 2016). It has high adaptability and natural innate immunity resistance proves to withstand against various soil climatic conditions which unfavours the growth or presence of other earthworm species in their locality. There is a great taxonomic diversity among earthworms and this variability in terms of morphological measurements has been reported by many researchers (Heethoff *et al.*, 2003; Oboh *et al.*, 2007; Vijaya *et al.*, 2012; Mohan *et al.*, 2013; Koul, 2015). Soil parameters have profound influence on the distribution of earthworm communities (Lapied *et al.*, 2009).

CONCLUSION

Maximum earthworm abundance was observed during March because of higher soil moisture and favourable temperature. Population density of earthworms varies significantly among different months, as edaphic factors (soil temperature and moisture) play a significant role in variation of earthworm density. Three species of earthworms belonging to family Megascolecidae (*M. posthuma*, *L. mauritii* and *A. morrisi*) were observed in the study sites.

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Storage Studies of Jam Prepared from Different Aonla Cultivars under Lower Foothills of Shivaliks

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Abstract: Seven aonla cultivars *i.e.* Banarsi, Chakaiya, Francis, Krishna, NA-6, NA-10 and Desi were subjected to physico-chemical analysis to assess their suitability for preparation of Jam under sub-tropical conditions of Jammu. Jam was prepared as per FPO specifications in which TSS was raised at 68° Brix by adding sugar and citric acid. Prepared Jams were stored under ambient conditions in glass containers and subjected to physico-chemical and sensory evaluation at one month interval for a period of three months. Among the cultivars, NA-7 observed the highest length, width, fruit weight, pulp weight, stone weight, pulp stone ratio, ascorbic acid, reducing and total sugar, as per the fresh analysis of aonla fruit. During storage, an increasing trend was observed with regards to TSS, reducing and total sugars while as a decreasing trend in acidity and ascorbic acid. On the basis of overall acceptability, jam prepared with cv. NA-7 ranked highest and more acceptable.

Keywords: Aonla, *Emblia officinalis*, Jam, Cultivars, Rainfed

Aonla (*Emblia officinalis* Gaertn), the Indian gooseberry is the richest source of vitamin C among all the fruits. Total area and production under aonla cultivation in India is 110 thousand hectares and 1282 thousand tonnes, respectively (Anonymous, 2014). However, in J&K state, present area under aonla cultivation is about 993.83 hectares with an annual production of 1065.24 million tonnes (Anonymous, 2015). Due to acidic and astringent taste of the fruit, its consumption in fresh form is very less and hence various products like preserve, segment in syrup, candy, squash, juice, powder etc. are made from it. Owing to better prospects of aonla in semi arid regions; hardy nature of plants, high medicinal and nutritional values, there is a possibility that it will be one of the most important fruits for the processing. Therefore, to find out a suitable cultivar of aonla fruit for processing under rainfed conditions of Jammu subtropics, this study was conducted on seven aonla cultivars as no such work has, so far, been done on the fruit in this region. Therefore, keeping these aspects in view, the present study was carried out to assess the storage stability of jam for different cultivars at ambient temperature.

MATERIAL AND METHODS

Seven aonla cultivars *viz.*, Banarsi, Chakaiya, Francis, Krishna, NA-7, NA-10 and Desi were procured from Rainfed Research Sub-Station for Sub-tropical Fruits (RRSS), Raya, SKUAST-Jammu (32° 39' N 74° 53' E 332 m amsl) during the year 2015-16 under rainfed conditions. Well matured fruits of uniform size and free from bruises were used for preparation

of jam. Selected fruits were washed thoroughly with clean water and boiled for five minutes with little amount of water for easy separation of seed and pulp (Singh and Kumar, 1995). The pulp is then fed into a warring blender for mashing into fine texture using the same boiled water. Extracted pulp was cooked along with the desired quantities of sugar and citric acid with constant stirring on a uniform flame, till the total soluble solids reached to 68 °Brix. The jam was filled hot in pre-sterilized glass bottles, cooled, sealed at room temperature. The jam prepared was analyzed at monthly interval of 0, 1, 2 and 3 months for the physico-chemical parameters and organoleptic evaluation. The physical analysis of fruit like length and width (cm) was determined by taking mean weight of 10 fruits. Pulp stone⁻¹ ratio was calculated by dividing mean pulp weight with mean stone weight of fruit. The chemical analysis of fresh fruit and product (Jam) was conducted for total soluble solids (°Brix), titratable acidity (%), reducing sugar (%), total sugar (%) and ascorbic acid (mg 100 g⁻¹). Total soluble solids (TSS) were determined as per standard procedures given by Saini *et al.*, 2001. Titratable acidity, reducing and total sugar were determined by using the standard procedures of Rangana (1986). Ascorbic acid by using 2, 6-dichlorophenol indophenol dye was determined by using the standard procedures of Ruck (1969). The aonla jam was evaluated for sensory attributes by a panel of 7-8 semi-trained judges, as described by Amerine *et al.* (1965) using a 9 point Hedonic scale system. The mean values of 7-8 semi-trained judges were considered for evaluating the quality.

RESULTS AND DISCUSSION

Physical and chemical characteristics of fresh aonla cultivars: The statistically highest length and width of aonla fruit was in NA-7 followed by *Banarsi* and *Krishna* under subtropical region of Jammu. These results are in accordance with Bakshi *et al.*, 2015 who also reported maximum length in NA-7 and minimum in Desi cultivar. NA-7 recorded maximum single fruit (40.5 g) which was followed by cultivars *Banarsi* and *Krishna*, however minimum single fruit weight was observed in desi cultivar. The difference in average fruit weight among different cultivars might be due to varietal characteristics and agro climatic conditions in which they were grown. Increase in fruit weight in NA-7 cultivar may be due to more activeness of monocarp cells which enlarge during fruit development. Kumar *et al.* (2008) also reported variation in single fruit weight of different cultivars of aonla and maximum fruit weight in NA-7 cultivar. Maximum pulp and stone weight (38.5 and 2.04 g) was recorded in cv. NA-7 followed by *Banarsi* (32.8 and 1.98 g), *Krishna* (31.8 and 1.95 g), NA-10 (30.5 and 1.90 g), Francis (29.5 and 1.86 g) and Chakaiya (27.0 and 1.82 g) while as minimum pulp weight (7.0 and 0.96 g) was found in Desi cultivar. Highest and lowest pulp stone⁻¹ ratio was found in cv. NA-7 and Desi to the tune of 18.87 and 7.29, respectively (Table 1). Similar results were also reported by Jamwal, 2000 and Kumar *et al.*, 2008.

The total soluble solids (TSS) were significantly higher in cultivar Desi which was followed by NA-10, *Krishna* and *Banarsi*. Pandita, 2015 also reported maximum TSS value (11.2 °Brix) in desi cultivar followed by *Banarsi* (9.1 °Brix) and NA-7 (8.0 °Brix) cultivars under sub-tropical conditions of Jammu region. There was not much variation with regards to acidity in different cultivars of aonla fruit; however, maximum acidity Desi cultivar followed by *Chakaiya* and NA-10 whereas minimum acidity was in cultivar NA-7 (Table 2). The present findings are in accordance with Bakshi *et al.*, 2015 in aonla fruit. The ascorbic acid content (vitamin C) of aonla cultivar varied from 532 to 756 mg 100 g⁻¹. The maximum

ascorbic acid content (756 mg 100 g⁻¹) was reported in cultivar NA-7 which was followed by *Banarsi* and *Francis* cultivars. Desi cultivar of aonla fruit registered minimum value of vitamin C content (532 mg 100 g⁻¹). The results of the present investigation are in agreement with the findings of Bakshi *et al.*, 2015 in aonla fruit under rainfed conditions of Jammu region. Similar findings were also reported by Pandita, 2015 and Singh *et al.*, 2015 in aonla fruit. Reducing sugar and total sugar were higher in cultivar NA-7 which was followed by cultivars *Banarsi*, *Krishna*, NA-10 and *Francis*. These results are in agreement with the findings of Bakshi *et al.*, 2015 in aonla fruit.

Table 2. Chemical characteristics of different cultivars of aonla fruit

| Treatments/ Cultivars | TSS (° Brix) | Acidity (%) | Ascorbic acid (mg/100g) | Reducing sugar (%) | Total sugar (%) |
|--------------------------|-----------------|----------------|-------------------------------|--------------------------|-----------------------|
| <i>Banarsi</i> | 9.1 | 2.1 | 647 | 1.35 | 8.26 |
| <i>Chakaiya</i> | 8.0 | 2.3 | 545 | 1.14 | 7.69 |
| <i>Francis</i> | 7.9 | 2.2 | 571 | 1.20 | 7.96 |
| <i>Krishna</i> | 10 | 2.1 | 645 | 1.30 | 8.16 |
| NA-7 | 8.0 | 1.9 | 756 | 2.20 | 8.54 |
| NA-10 | 10.2 | 2.2 | 566 | 1.27 | 8.10 |
| Desi | 11.2 | 2.7 | 532 | 1.10 | 7.40 |
| Mean | 9.2 | 2.2 | 609 | 1.37 | 8.02 |
| CD (p = 0.05) | 1.37 | 0.92 | 100.3 | 0.33 | 0.74 |

Changes during storage of different cultivars of Jam

Total Soluble Solids and titratable acidity: The different treatments influenced total soluble solids (TSS) of aonla fruit jam significantly at various storage periods. There was slight increase in TSS upto 30 days of storage in all the treatments. After 90 days of storage, the jam prepared with cultivar NA-7 recorded statistically highest value of TSS (70.56 °Brix), whereas lowest value of TSS (70.15 °Brix) was observed in jam prepared with Desi cultivar. The mean value of TSS during various storage periods showed an increase from

Table 1. Physical characteristics of different cultivars of aonla fruit

| Treatments/Cultivars | Length (cm) | Width (cm) | Fruit weight (g) | Pulp weight (g) | Stone weight (g) | Pulp Stone ⁻¹ ratio |
|----------------------|-------------|------------|------------------|-----------------|------------------|--------------------------------|
| <i>Banarsi</i> | 3.5 | 3.9 | 34.8 | 32.8 | 1.98 | 16.56 |
| <i>Chakaiya</i> | 2.8 | 3.4 | 28.8 | 27.0 | 1.82 | 14.83 |
| <i>Francis</i> | 3.0 | 3.4 | 31.4 | 29.5 | 1.86 | 15.86 |
| <i>Krishna</i> | 3.4 | 3.7 | 33.7 | 31.8 | 1.95 | 16.30 |
| NA-7 | 3.8 | 4.0 | 40.5 | 38.5 | 2.04 | 18.87 |
| NA-10 | 3.2 | 3.5 | 32.4 | 30.5 | 1.90 | 16.05 |
| Desi | 1.9 | 2.4 | 7.96 | 7.0 | 0.96 | 7.29 |
| Mean | 3.1 | 3.5 | 29.9 | 28.2 | 1.8 | 15.1 |
| CD (p = 0.05) | 0.44 | 0.49 | 3.42 | 2.65 | 0.59 | 2.25 |

initial value of 68.17 to 70.32 °Brix. TSS gradually increased with an increase in storage period. This might be due to conversion of polysaccharides into sugars during hydrolysis process. Hussain *et al.*, 2005 reported that TSS of mango squash prepared from some Pakistani mango varieties increased significantly after 90 days of storage. Increase in TSS with storage was also reported by Tandon *et al.*, 2003 in aonla candy and Manivasagan *et al.*, 2006 in karonda candy. The interaction effect between different treatments and storage periods was also found to be significant. Different cultivars of aonla fruit significantly influenced titratable acidity value of jam. The maximum titratable acidity (0.23 %) was reported in Desi cultivar jam and minimum in NA-7 cultivar jam at initial days of storage. A similar trend was observed in total treatment mean values (Table 3).

Reducing and total sugar: Statistically significant difference was noticed in reducing sugar content of jams prepared from different cultivars of aonla. The highest

reducing sugar content was jam prepared with NA-7 cultivar followed by Banarsi cultivar at initial day and 90 days of storage. Increment in total sugar content of aonla jam was statistically significant prepared from various cultivars during various storage periods. The total sugar content of aonla jam of about all cultivars increased significantly during subsequent storage periods from 0 to 90 days of storage. After 90 days of storage, highest total sugar content (45.96 %) was recorded in NA-7 cultivar, however lowest (40.26 %) in Desi aonla jam. Whereas, maximum increment *i.e.*, 5.5 % from 0 to 90 days of storage was noticed in aonla jam (NA-7) as compared to 3.7, 4.7 and 5.0 % in case of cultivars NA-10, Banarsi and Desi, respectively. Increase in total sugars during the subsequent storage periods might be due to conversion of polysaccharides into monosaccharides (Table 4).

Ascorbic acid and Overall acceptability: The data of ascorbic acid content in jam of various cultivars was

Table 3. Effect of treatments and storage period on total soluble solids (°Brix) and acidity (%) of jam prepared from different cultivars of aonla

| Treatments/cultivar | Total soluble solids (°Brix) | | | | | Acidity (%) | | | | |
|---------------------|------------------------------|---------|---------|---------|-------|---------------|---------|---------|---------|------|
| | 0 days | 30 days | 60 days | 90 days | Mean | 0 days | 30 days | 60 days | 90 days | Mean |
| Banarsi | 68.40 | 68.90 | 70.20 | 70.46 | 69.49 | 0.17 | 0.16 | 0.16 | 0.14 | 0.15 |
| Chakaiya | 68.00 | 68.20 | 70.14 | 70.20 | 69.13 | 0.21 | 0.21 | 0.20 | 0.20 | 0.20 |
| Francis | 68.00 | 68.20 | 70.16 | 70.24 | 69.15 | 0.20 | 0.19 | 0.17 | 0.16 | 0.18 |
| Krishna | 68.20 | 68.70 | 70.20 | 70.34 | 69.36 | 0.17 | 0.17 | 0.16 | 0.15 | 0.16 |
| NA-7 | 68.50 | 70.40 | 70.28 | 70.56 | 69.93 | 0.15 | 0.14 | 0.13 | 0.11 | 0.13 |
| NA-10 | 68.10 | 68.30 | 70.16 | 70.30 | 69.21 | 0.18 | 0.16 | 0.16 | 0.15 | 0.16 |
| Desi | 68.00 | 68.10 | 70.02 | 70.15 | 69.06 | 0.23 | 0.22 | 0.20 | 0.19 | 0.21 |
| Mean | 68.17 | 68.68 | 70.16 | 70.32 | | 0.18 | 0.17 | 0.16 | 0.15 | |
| Effects | CD (P = 0.05) | | | | | CD (P = 0.05) | | | | |
| Treatments | 0.20 | | | | | 0.03 | | | | |
| Storage | 0.15 | | | | | NS | | | | |
| Treatment X Storage | 0.40 | | | | | NS | | | | |

Table 4. Effect of treatments and storage period on reducing and total sugar (%) of jam prepared from different cultivars of aonla

| Treatments/cultivar | Reducing sugars (%) | | | | | Total sugars (%) | | | | |
|---------------------|---------------------|---------|---------|---------|-------|------------------|---------|---------|---------|-------|
| | 0 days | 30 days | 60 days | 90 days | Mean | 0 days | 30 days | 60 days | 90 days | Mean |
| Banarsi | 29.18 | 30.96 | 31.43 | 33.48 | 31.26 | 40.16 | 42.34 | 43.64 | 44.86 | 42.75 |
| Chakaiya | 25.10 | 26.42 | 28.4 | 30.24 | 27.54 | 36.42 | 38.42 | 39.26 | 40.74 | 38.71 |
| Francis | 26.16 | 27.18 | 29.64 | 31.56 | 28.63 | 38.16 | 39.42 | 40.43 | 42.10 | 40.02 |
| Krishna | 29.00 | 30.26 | 31.40 | 33.32 | 30.99 | 40.05 | 41.26 | 42.84 | 43.48 | 41.90 |
| NA-7 | 30.27 | 32.40 | 33.24 | 35.46 | 32.84 | 40.32 | 42.16 | 44.24 | 45.96 | 43.17 |
| NA-10 | 28.16 | 30.16 | 30.98 | 32.84 | 30.53 | 39.42 | 40.96 | 42.24 | 43.10 | 41.43 |
| Desi | 22.42 | 24.44 | 25.34 | 28.26 | 25.11 | 35.22 | 36.44 | 30.26 | 40.26 | 35.54 |
| Mean | 27.18 | 28.83 | 30.06 | 32.16 | | 38.53 | 40.14 | 40.41 | 42.92 | |
| Effects | CD (P = 0.05) | | | | | CD (P = 0.05) | | | | |
| Treatments | 0.08 | | | | | 0.12 | | | | |
| Storage | 0.06 | | | | | 0.09 | | | | |
| Treatment X Storage | 0.17 | | | | | 0.24 | | | | |

Table 5. Effect of treatments and storage period on ascorbic acid (mg/100 g) and overall acceptability of jam prepared from different cultivars of aonla

| Treatments/cultivar | Ascorbic acid (mg/100 g) | | | | | Overall acceptability | | | | | |
|---------------------|--------------------------|---------|---------|---------|--------|-----------------------|---------------|---------|---------|------|--|
| | 0 days | 30 days | 60 days | 90 days | Mean | 0 days | 30 days | 60 days | 90 days | Mean | |
| <i>Banarsi</i> | 139.00 | 129.20 | 117.60 | 107.40 | 123.3 | 8.07 | 7.93 | 7.80 | 7.60 | 7.85 | |
| <i>Chakaiya</i> | 135.00 | 106.40 | 98.76 | 96.40 | 109.14 | 7.33 | 7.17 | 7.10 | 6.90 | 7.13 | |
| <i>Francis</i> | 135.20 | 112.40 | 100.00 | 98.20 | 111.45 | 7.43 | 7.30 | 7.07 | 6.87 | 7.17 | |
| <i>Krishna</i> | 138.90 | 124.60 | 110.40 | 106.20 | 120.02 | 8.00 | 7.87 | 7.73 | 7.53 | 7.78 | |
| <i>NA-7</i> | 139.20 | 130.40 | 122.60 | 110.40 | 125.65 | 8.40 | 8.30 | 8.20 | 8.07 | 8.24 | |
| <i>NA-10</i> | 137.60 | 120.30 | 105.40 | 100.20 | 115.87 | 7.63 | 7.47 | 7.30 | 7.20 | 7.40 | |
| <i>Desi</i> | 138.40 | 102.40 | 92.30 | 90.80 | 105.97 | 7.27 | 7.13 | 6.97 | 6.87 | 7.17 | |
| Mean | 137.61 | 117.95 | 106.72 | 101.37 | | 7.73 | 7.60 | 7.45 | 7.29 | | |
| Effects | CD (P = 0.05) | | | | | Effects | CD (P = 0.05) | | | | |
| Treatments | 0.36 | | | | | Treatments | 0.01 | | | | |
| Storage | 0.27 | | | | | Storage | 0.02 | | | | |
| Treatment X Storage | 0.73 | | | | | Treatment X Storage | 0.03 | | | | |

statistically significant, however during different subsequent storage periods, ascorbic content decreased significantly. Statistically highest value of initial ascorbic acid was recorded in *NA-7* cultivar (139.20 mg 100 g⁻¹), which was followed by the aonla fruit jam prepared with cultivars *Banarsi*, *Krishna* and *Desi* with the values to the tune of 139.0, 138.90 and 138.40 mg 100 g⁻¹, respectively. The minimum value of ascorbic acid (135.0 mg 100 g⁻¹) was recorded in cultivar *Chakaiya* at 0 days of storage (Table 5). During the subsequent storage periods, ascorbic acid content decreased significantly. At 90 days of storage, highest ascorbic acid (110.40 mg 100 g⁻¹) was recorded *NA-7* aonla jam and the lowest (90.80 mg 100 g⁻¹) in *Desi* aonla jam. There was significant decrease for mean initial value from 137.6 to 101.4 mg 100 g⁻¹ after 90 days of storage. The decline in ascorbic acid content might be due to thermal oxidation during processing and subsequent oxidation in storage. The decreasing trend in ascorbic acid during storage was also reported by Vidhya and Narain (2011) in wood apple jam. Safdar *et al.* (2014) reported decrease in ascorbic acid content from 78.5 to 16.6 mg 100 g⁻¹ in guava leather. The data pertaining to score of overall acceptability revealed that at initial day, the highest score (8.40) was observed by aonla jam (*NA-7*); which was followed by *Banarsi* cultivar jam (8.07). The minimum value of 7.27 was recorded in *Desi* cultivar jam. After 90 days of storage, overall acceptability decreased from 8.40 to 8.07, 8.07 to 7.60 and 7.27 to 6.87 in jams of cultivars *NA-7*, *Banarsi* and *Desi*, respectively. During various storage periods, there was a significant decrease in mean score from 7.73 at initial day to 7.29 at the end of 90 days. The effect of interaction between treatment and storage period was found statistically significant. This result was in agreement with Ehsan *et al.*, 2002 who reported a decrease in overall acceptability during

storage of watermelon and lemon jam and Cherian and Cheriayan (2003) in blended papaya leather (Table 5).

CONCLUSION

Good quality aonla jam from the different cultivars could be prepared and stored at ambient temperature for 90 days with minimum damage to quality of product. With regard to sensory scores, cultivar *NA-7* is most suitable for jam preparation under sub tropical conditions of lower foothills of Shivaliks range of Himalayas.

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Thermal Indices of Pink Stem Borer, *Sesamia inferens* Walker on Maize in North-Western Plains of India

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Abstract: The biology of pink stem borer, *Sesamia inferens* was observed at different constant temperatures on maize (*Zea mays* L) and modeled their developmental rate as a function of temperature using linear regression model. Temperature has significant influence on the duration of each developmental stage. The embryonic development was completed at 63.69 degree days (DD) and the threshold of embryonic development was 12.62°C. The larval stage was completed with 535.12 DD with a developmental threshold of 8.32°C. The pupal period took 163.82 DD and the pupal development stopped at 11.27°C. *S. inferens* took 762.63 DD to complete development. In the era of climate change, this information would help to develop pest forecasting models, which in turn maximize the efficacy of pest management operations. Control measures adopted based on calendar dates by farmers should be supported by the knowledge on thermal requirements of the insect for better control.

Keywords: Degree days, Developmental threshold, Maize, *Sesamia inferens*, Thermal constant

Pink stem borer (PSB), *Sesamia inferens* Walker (Noctuidae; Lepidoptera) is an established pest of rice-wheat cropping system in the North-Western plains of India. It is a polyphagous pest attacking major graminaceous crops like rice, wheat, maize, millets and sugarcane (Selvaraj *et al.*, 2014) and is a regular pest in maize in the peninsular India (Sekhar *et al.*, 2008). Invention of new agricultural technologies has led to the cultivation of maize throughout the year in different parts of India, including the North-Western plains. Climate change is favouring the expansion in the distribution range of many pests (Sharma, 2016) and nowadays, *S. inferens* is coming up increasingly in North Indian conditions in maize during all the seasons (Singh *et al.*, 2014). Expansion in the maize area ensures continuous supply of food for *S. inferens* avoiding any dearth period throughout its generations. The yield loss due to insect pests in various crops is predicted to increase in the future due to change in climatic conditions (Sharma 2016). In general, a negative impact is observed in the maize yield with increase in temperature (Tripathi *et al.*, 2016) and is the crop having maximum yield loss for each degree rise in temperature (Zhao *et al.*, 2017). This, together with the increasing pest incidence could have larger consequences in maize production in the warming climate.

The physiology of crop plants and the associated insect pests are highly influenced by the environmental factors. Temperature is the most important climatic factor influencing the life processes (Khadioli *et al.*, 2014). Temperature

influences the abundance and establishment of a species in a region (Fand *et al.*, 2014). It sets the limits of biological activities and the temperature thresholds can be estimated for all growth stages (Roy *et al.*, 2002). Thermal indices and the temperature dependent developmental rates of insects help to understand the environmental conditions which bring them to pest status (Bahar *et al.*, 2012). Predictions on the impact of climate change on the population growth and distribution of a pest will be possible when thermal constant and developmental threshold of that pest are known (Glates *et al.*, 2017). This will also help to accurately predict the occurrence of specific growth stages of the pest in the field (Orang *et al.*, 2014), which will benefit the farmers as well as other stake holders in decision making on the timing of pest management activities. In this study thermal characteristics and thermal requirements of the PSB population collected from North-Western plains is being estimated using linear regression model.

MATERIAL AND METHODS

The experiment was conducted at Punjab Agricultural University, Ludhiana, India (30° 45' N, 75° 40' E and 247 meters above sea level) from April-August, 2015.

Rearing of pink stem borer: The larvae and pupae of PSB were collected from fields of PAU, Ludhiana and were reared on cut pieces (2–2.5-inch-long) of maize stems (about 20–25 days old) kept inside glass battery jars (10×15 cm). The jars were kept at 25±1°C and 70±5 % relative humidity (RH). The

food was changed after 2–3 days as per need until the pupae were formed. The fresh pupae were transferred to glass battery jars having 2.5 cm thick layer of sterilized moist sand at the bottom and a circular cut blotter paper with diameter just fitting in each jar over it. The freshly emerged adults in pairs were transferred to oviposition cages (30×40 cm) inside the oviposition chamber provided with 4–5 leaf stage maize seedlings of the hybrid PMH1. The eggs obtained on leaf sheath portion were kept in petri plates provided with moist cotton swabs. These neonates thus obtained had served as initial culture of *S. inferens*. Subsequently, F_1 and F_2 populations were reared in artificial diet. The F_2 population obtained was used for the experiments. For mass rearing of *S. inferens*, the green gram (*Vigna radiata* L.) based artificial diet was modified from Kumar and Siddiqui (1993) with the addition of maize grain powder. The neonates were reared in the artificial diet and the culture was maintained at $25\pm 1^\circ\text{C}$ and $70\pm 5\%$ RH.

Studies on the development of *S. inferens* at different temperatures: The leaf sheath portion containing 20 eggs of PSB were kept at 6 constant temperatures viz., 15 ± 1 , 20 ± 1 , 24 ± 1 , 28 ± 1 , 32 ± 1 and $36\pm 1^\circ\text{C}$ at $70\pm 5\%$ RH. The eggs were observed at 24 hours interval for the emergence of neonates for recording the incubation period. The neonates were observed for the larval duration and pupation. The pupae formed were kept in glass battery jars containing moist sand for adult emergence. Each observation was recorded at 24 hours interval. There were 4 replications each having 20 individuals.

Data analysis: The mean and standard error (SE) were calculated for different biological parameters studied. The developmental rate (R) for egg, larval and pupal stages were worked out as, $R = 1/D$, where D: developmental duration of the particular stage. The correlation coefficients were calculated between temperature and developmental rate of each stage and were tested using student's t test. Developmental threshold (T_o) and thermal constant (K) were

calculated by regressing their respective developmental rate on temperature (Kipyatkov and Lopatina, 2010). Regression equation, $Y = bX - a$, where, $K = 1/b$, b: Regression coefficient between development rate and temperature was worked out. T_o was obtained as the ratio of regression intercepts (a) and (b), $T_o = -a/b$. The significance of regression coefficients were tested using student's t test. These along with the coefficient of multiple determinations (R^2) were used to explain the goodness of fit of the model.

RESULTS AND DISCUSSION

Influence of temperature on the development of pink stem borer on maize:

The growth of *S. inferens* was significantly influenced at different test temperatures. The time taken to complete each developmental stage significantly reduced with increase in temperature (Table 1). The eggs remained viable at temperatures ranging from 15 to 36°C . However, incubation period varied significantly at different test temperatures and was maximum at lowest temperature of 15°C (13.38 days). As the temperature increased to 36°C , there was 81.32 per cent reduction in incubation period (2.50 days). The correlation between temperature and developmental rate of embryo was highly significant and positive (0.979). The larval and pupal stages were completed only in temperatures range of 15 to 32°C . However, at 32°C the adults emerged were malformed. The larval duration was maximum at 15°C (67.25), while it reduced 66.07 times and reached 22.83 days at 32°C . The correlation coefficient between temperature and larval developmental rate was 0.989. Similarly, the pupal duration was also affected significantly by temperature. The pupa took about 50.04 days to complete development at 15°C and this period reduced by 83.25 per cent to 8.38 days at 32°C . The correlation coefficient between temperature and developmental rate of pupa was 0.990. The total duration of immature stages was 129.92 days at 15°C and it reduced to 34.42 days at 32°C . The correlation

Table 1. Influence of temperature on the duration of pink stem borer, *S. inferens* Walker on maize under laboratory conditions

| T | Egg | | Larva | | Pupa | | Total developmental stage | |
|------|------------|-------|------------|-------|------------|-------|---------------------------|-------|
| | Mean±SE | R | Mean±SE | R | Mean±SE | R | Mean±SE | R |
| 15±1 | 13.38±0.61 | 0.075 | 67.25±0.18 | 0.015 | 50.04±0.18 | 0.020 | 129.92±0.83 | 0.008 |
| 20±1 | 9.67±0.26 | 0.103 | 51.13±0.44 | 0.020 | 19.25±0.19 | 0.052 | 76.79±0.62 | 0.013 |
| 24±1 | 7.00±0.32 | 0.143 | 31.38±0.31 | 0.032 | 12.17±0.76 | 0.082 | 55.96±0.25 | 0.018 |
| 28±1 | 4.50±0.27 | 0.222 | 27.44±0.12 | 0.036 | 9.18±0.01 | 0.109 | 40.56±0.08 | 0.024 |
| 32±1 | 3.33±0.26 | 0.300 | 22.83±0.32 | 0.044 | 8.38±0.17 | 0.119 | 34.42±0.52 | 0.029 |
| 36±1 | 2.50±0.35 | 0.400 | - | - | - | - | - | - |

CD(p<0.0001)=0.28 r=0.979** CD(p<0.0001)=0.49 r=0.989** CD(p<0.0001)=0.29 r=0.990** CD(p<0.0001)=0.39 r=0.996**

T= Temperature ($^\circ\text{C}$), R= Developmental rate (1/D), r= correlation coefficient between developmental rate and temperature, ** = Significant at 1% level

coefficient between temperature and total developmental rate of *S. inferens* was 0.996. The life cycle from egg to adult was completed in the temperature range of 15 to 32°C. The time taken by each growth stage to complete development was strongly influenced by temperature. Increase in temperature within the favourable range resulted in decrease in duration and increase in developmental rate of each growth stage. Similar observations were recorded on *S. inferens* population on maize and on rice by Selvaraj *et al.*, (2014) and Rahman and Khalequzzaman (2004), respectively. Frantinou *et al.*, (2003) has studied the thermal requirements of *S. nonagrioides* populations of Iran on artificial diet. The determination of favourable and extreme range of temperatures for *S. inferens* development will help in development of pest forecasting models.

Linear regression model and validation

Egg: The linear regression line between temperature and developmental rate for egg stage (Y_1) was $Y_1=0.0157X-0.1982$ ($Y=bX-a$) (Table 2, Fig. 1). The temperature explains 94 per cent variation in developmental rate of eggs ($R^2=0.94$). The thermal constant ($1/b$) for the egg stage was found to be 63.69 DD. The developmental threshold ($-a/b$), the temperature below which the embryonic growth ceases was found to be 12.62°C. Selvaraj *et al.*, (2014) reported slightly smaller value of thermal constant and slightly higher value of developmental threshold for egg stage from the present study. While, Rahman and Khalequzzaman (2004) reported much higher values of thermal constant and lower value of developmental threshold compared to the present study from Bangladesh population. In *S. nonagrioides*, the

developmental threshold and thermal constant are more close to that of Bangladesh population than to North Indian populations of *S. inferens*. Thus, the forecasting based on these indices should be area specific considering the prevalence of insect and its associated environment.

Larva: The linear regression model between temperature (X) and developmental rate of larva (Y_2) was found to be $Y_2=0.0019X-0.0155$. The model provided a good fit to the variation in larval development of *S. inferens* ($R^2=0.97$). The thermal constant ($1/b$) of 535.12 DD and the development threshold (a/b) of 8.32°C were for larval stage. The thermal requirements of *S. inferens* on maize in the present study are close to the findings of Rahman and Khalequzzaman (2004). While, Selvaraj *et al.*, (2014) reported the thermal constant for small larva (first three instars) and large larva (last 2 instars) separately summing up to a much higher value compared to the present study. For the larval stage, the present observations are in line with that of Frantinou *et al.*, (2003), who studied *S. nonagrioides* on artificial diet.

Pupa: The linear regression line between temperature (X) and developmental rate of pupal stage (Y_3) in maize was $Y_3=0.0061X-0.0688$ and this model explains 98 per cent variation in developmental rate of pupa ($R^2=0.98$). The thermal constant ($1/b$) and development threshold (a/b) values for the pupal stage were determined as 163.82 DD and 11.27°C, respectively. The observation of Selvaraj *et al.*, (2014) and Frantinou *et al.*, (2003) on pupal stage of *S. inferens* and *S. nonagrioides* are in line with the present study.

Total development: The total thermal constant required to

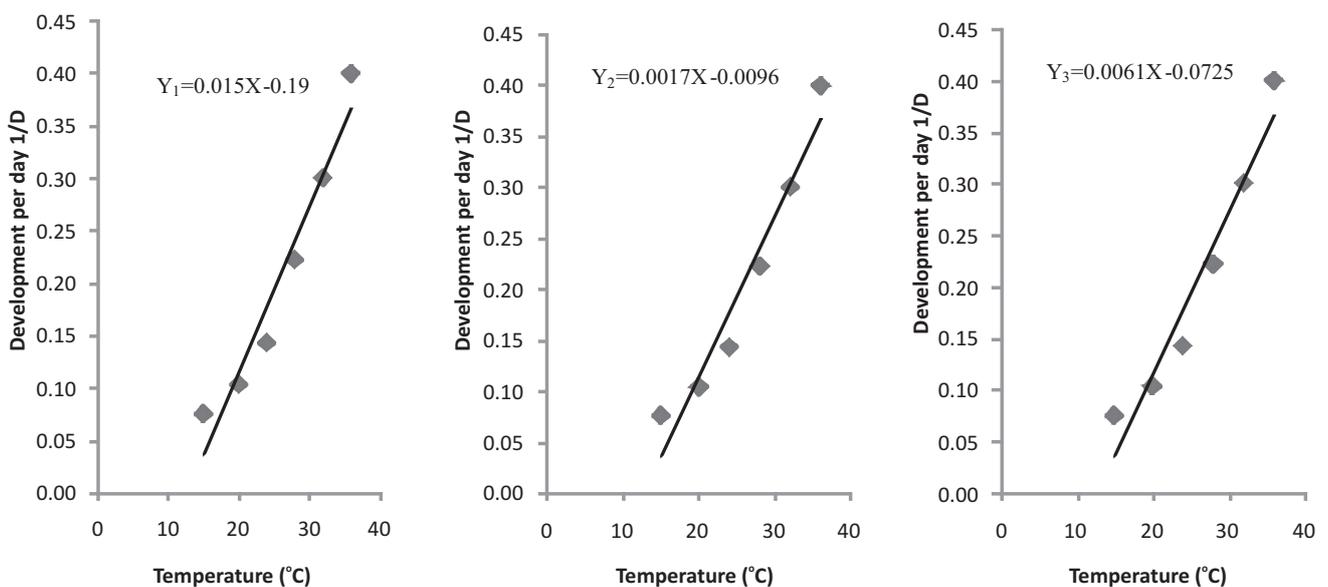


Fig. 1. Regression between temperature (X) and developmental rate (Y) of different stages of *S. inferens* on maize

Table 2. Regression equation for different developmental stages of Pink stem borer, *S. inferens* Walker on maize

| Growth stage | Regression equation (Y=bX-a) | Thermal constant in DD (K=1/b) | Threshold (°C) (T ₀ =-a/b) | R ² |
|--------------|-----------------------------------|--------------------------------|---------------------------------------|----------------|
| Egg | Y ₁ =0.0157**X-0.1982* | 63.69 | 12.62 | 0.9 |
| Larva | Y ₂ =0.0019**X-0.0155* | 535.12 | 8.32 | 0.9 |
| Pupa | Y ₃ =0.0061**X-0.0688* | 163.82 | 11.27 | 0.9 |
| Total | - | 762.63 DD | - | - |

X= Temperature, Y₁ = Developmental rate of egg, Y₂ = Developmental rate of larva, Y₃ = Developmental rate of pupa, DD = Degree Days
 Egg; F = 68.54, df = 1,3; Slope (b), p=0.0012; Intercept (a), p=0.0175; Larva; F = 136.15, df = 1,3; Slope (b), p=0.0014; Intercept (a), p=0.0292
 Pupa; F = 154.64, df = 1,3; Slope (b), p=0.0106; Intercept (a), p=0.0120

complete the development of *S. inferens* on maize was 762.63 DD. The R² values for the model for different growth stages suggest that these models well explains the relationship between developmental rate and temperature. Selvaraj *et al.*, (2014) worked out a thermal constant for total development of *S. inferens* as 874.3 DD in maize while, Rahman and Khalequzzaman (2004) reported a value of 837.95 DD in rice. Among the growth stages, the larval stage was found to be more tolerant to lower temperature as it has lower developmental threshold compared (8.32°C) to egg (12.62°C) and pupal stages (11.27°C) in the present study. Singh (2013) has also reported that *S. inferens* is multivoltine with three to four generations and overwinters as a mature larva. These observations are well explained by the findings of Sun *et al.*, (2014) that the *S. inferens* larva hibernating during winter season has specific cold tolerance strategies like reduced body water level and increased levels of low molecular weight sugars and polyols. The number of generations of multivoltine insects like *S. inferens* occurring at any locality can also be determined according to the amount of heat available during the year in that locality from the basic information on thermal requirements.

Temperature significantly influenced the biology of *S. inferens* on maize. PSB can complete development at wide range of temperatures (Orang *et al.*, 2014) and temperature significantly influences its biology. Information on thermal indices of PSB can be used more reliably to monitor and forecast the occurrence of different growth stages of the pest population causing economic damage under Punjab conditions so that, different interventions can be adopted at proper time with greater precision. This information can be used to predict the emergence of adults from the overwintering generations, completion of egg, larval and pupal stages and generation time as used in the case of different pests like codling moth, *Cydia pomonella* L.

(Lepidoptera: Tortricidae) (Howell and Neven, 2000).

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Role of Value-addition in Agrarian Farming System in Enhancing the Farmer's Income

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Abstract: India is the largest producer of fruits and second largest producer of vegetables in the world and also has a rich story of processing which is evident in many past narratives, where the use of techniques likes drying, fermentation, use of salt, sugar, spices etc. have been mentioned and are so commonly integrated in our daily life. A value chain is more about the consumer's value towards the product, rather than suppliers. So, exploring the consumer's preference would fetch a greater price. Value addition in the agrarian sector has brought the option of alternate income opportunities along with the risk minimization, better share in consumer's price, more shelf life of products and so on. We also need to look upon the challenges and opportunities so that the proper growth can be ensured. The overall view of food processing industry look promising where as we also need to look upon the wastage right from the harvesting to the consumers end.

Keywords: Value addition, Food processing industry, Cold chains

India plays a key role in providing food and nutrition to its own as well as world's increasing population. Basically, India has been an agrarian country where the tradition of farm and farming has been the saga story from traditions. India is the largest producer of fruits and second largest producer of vegetables in the world and also has a rich story of processing which is evident in many past narratives, where the use of techniques likes drying, fermentation, use of salt, sugar, spices etc. have been mentioned and are so commonly integrated in our daily life. With the advancement of time, and further increasing population and people's particular preference for the processed product along with the commercialization of farming, the scale of such product has been increased on the parallel to meet the demand. The accumulation of such indigenous knowledge and sharing of information has lead to the list of value addition products, ranging from pickles to dry fish to salted meat which have their own market potentials. There are many factors behind the unprecedented rise in such products such as increases in per capita incomes, higher urbanization, and the growing numbers of women in the workforce engender greater demand for high-value commodities, ready-prepared foods and processed products. Also a clear trend exists towards diets that include more animal products such as fish, meat and dairy products, which in turn increases the demand for feed grains (FAO, 2007). These are the favourable environments which promote ascent and flow of the processed products in the market. Given trend is well supported by the statistics as it's a well known fact that India is the world's 2nd largest producer of fruits and vegetables.

Total food grains production reached 270.10 MT in financial year 2016 (Anonymous, 2017). With all these ample resources and productivity and factors of production, it is opportune time that we should move toward promoting value addition products which sometimes can be equated with processed products in general terms. Value addition is more about the consumer pull than the suppliers push. "Value" is usually created by focusing on the benefits associated with the products or services that arise from quality, functionality, form (usefulness), place, ease of possession or availability etc., and relatively, customer value reflects the relationship between the benefits customers receive from and the price they pay for a given product. Combining the all factors of production together with the agricultural products, value addition can fetch the primary producers an additional income which came handy in the time of distress. Even going for an entrepreneurial endeavour would prove to be a supporting pillar for the farmers.

Present scenario of farmer's income

At the time when we are struggling to keep the younger generations to take agriculture as a profession, given the complex scenario of bad loans, high cost of farming and then distress sale and some other loopholes in the marketing system where the participation of farmers is still very low and they are highly dependent upon the middle man for selling their products, it became an imperative to study the different cases and reports over the income of farmers, most of which are about marginal, and small farmers. The most prime source of income is through the cultivation of crops in either the land possessed by the household or in a land leased by

them, followed by wages and salary apart from other sources. Ranganathan,(2015) reported that the growth of income from livestock was very high compared to other income sources and it has increased its share in total income of a farm household from 4 to 13 per cent. This mark the need of diversification in the field of farming and intervention of the agro food processing based on the suitability and availability of the resources available locally.

Role of value addition in diversification

Diversification plays a vital role in the minimization of the risk associated with the farming. It doesn't just include different crops but also different enterprise. This includes cultivation of fruits, flowers and vegetables, animal husbandry, sericulture, apiculture and so on. Besides giving a good return on the investment, these are best suited even for smaller farmers with limited resources. The advantage that they possess include the value addition of products which fetches the good consumer price and that is something which has been missing in case of our traditional farming. Value addition at each stage will add to the consumer satisfaction. When we talk about the value chain it include the full range of activities required to bring a product or service from conception, through the different phases of production (involving a combination of physical transformation and the input of various producer services), delivery to final consumers and final disposal after use with the concern and utility of the consumers given due care. Some of the products from the food processing industry are as following which are usually available in the market.

Relevance of value addition in terms of food processing industry

Getting more shares in the consumer's price would enhance the farm income by the farmers and for this it is require to see the areas where the value can be added in the products. The area and the markets need to be identified, with proper market study. On the similar note, today, food processing industry plays a key role in providing an employment to number of people. The Indian domestic food market is expected to grow \$344 billion by 2025 (Annapoorna, 2011 & Merchant, 2008). This increasing trend

would certainly open the employment opportunities among the farmers and promises as an income enhancing potential. Generally a food supply chain includes handling at harvest, threshing, drying, transport and distribution, storage, processing (primary processing, secondary processing, product evaluation, packaging, marketing (Parfitt *et al.* 2010). Though, there are its own strength and weakness and risk involved in the sector, particularly for the High Value Agricultural Products (HVAP) which are typically perishable, specific high-value, and are sold through specialized markets (CGIAR, 2004). They also include livestock, dairy products, fish, fruits, and vegetables. Essentially, the food industry involves the commercial movement of food from 'field to the plate of the consumer'. It has been evident that food processing industries play a crucial role in value addition by increase the shelf life and also by the reduction of post-harvest losses. We are still lagging in term of processing of the food products when compared to other countries as it has been marked that only 6 per cent of the food produced in India is properly processed which is much lower than in China (40 per cent) and Malaysia (80 per cent). According to the Ministry of Food Processing Industries, the processing levels are at mere 2 per cent in fruits and vegetables, 15 per cent in milk, 4 per cent in fish and 2 per cent in meat and poultry. The unorganized sector and small players dominate the sector and process more than 70 per cent of the industry output in volume terms and 50 per cent in value terms (Anonymous 2013). This statistics signifies scope of the processing in the agricultural field. The value addition would not just enhance the farm income, and provide employment opportunities, but also would contribute towards reduction of wastage in this sector particularly after the post harvest period of the highly perishable agricultural commodities. On one side, the preference of such highly preferred value products are creating its own market niche, while on the other side, wastage part of handling of agricultural products is something which has to be given due care. Simply with their sheer high volume and mass, the wastage sometimes accounts almost as to the total production by some other countries. One of the report suggest that Indian farming

Segments of food processing industry and products produced in India

| Sectors | Products |
|---------------------|--|
| Dairy | Whole milk powder, skimmed milk powder, condensed milk, ice cream, butter and ghee, cheese |
| Fruits & Vegetables | Beverages, juices, concentrates, pulps, slices, frozen & dehydrated products, potato wafers/ chips, etc |
| Grains & Cereals | Flour, bakeries, starch glucose, cornflakes, malted foods, vermicelli, beer and malt extracts, grain based alcohol |
| Fisheries | Frozen canned products mainly in fresh form |
| Meat & Poultry | Frozen and packed –mainly in fresh from egg powder |
| Consumer Foods | Snack food, namkeens, biscuits, ready to eat food, alcoholic and non alcoholic beverages |

(Source: Ministry of food processing, GoI, Annual report, 2004; Singh *et al.* 2012)

community incur the losses equal to 92,600 crore rupee per year. The main reason for losses has been assigned to the low level of processing of the agricultural commodities (Anonymous 2016). Along with this poor post handling, storage losses could be other reasons among the many others. Indian Council of Agricultural Research has further furnished following details regarding loss value of agriculture and allied sectors:

| Produce Loss Value | Rs. crores/annum |
|-------------------------|------------------|
| Cereals | 20,698 |
| Pulses | 3,877 |
| Oilseeds | 8,278 |
| Spices/Plantation crops | 9,325 |
| Fruits | 16,644 |
| Vegetables | 14,842 |
| Livestock | 18,987 |

Therefore, it becomes essential that the effective steps are needed to take to encourage establishment of food processing industries in all parts of the country in order to reduce agricultural wastage and improve farmers' income. (Anonymous, 2015a). One of such steps towards reducing the losses has been the establishment of Mega Food Parks all over the country, but sadly the performance and the progress has been tad slow. Standing Committee on Agriculture (2014-2015), highlighted that Ministry of Food Processing Industries have so far approved setting up of 40 Mega Food Parks in various states of the country. Out of 40 projects approved by the ministry, 21 projects have been accorded final approval and 19 projects have been accorded in-principle approval. Out of 21 projects which were accorded final approval, 5 projects are partially operational. Some of the constraints include the uneconomic viability of such projects and lack of associated infrastructure including roadways and shipping inbound and outbound logistics. Apart from capacity which we are to develop, we have some other limitation in terms of available infrastructure. According to a study conducted by National Stock Exchange Limited (NSE) in December 2010, the country needed 61.13 million MT cold storage capacities against the then available 24.29 million MT. A gap of 36.83 million MT was evaluated. The assessment was made on the basis of peak season production of fruits & vegetables and their highest market arrival in a month (Anonymous 2015b). This indicates a huge gap in the capacities to be developed and further corrective steps need to be taken in the food processing industries to stop the wastage and utilizing the resources optimally. Though the process of infrastructure building and formation is a gradual process, this would certainly help in further

strengthening the economy of the country. There is also need to prioritize the gap in different aspects like technological knowhow, training, capacity building, distribution and branding of the products. According to the World Bank (2007), the agro processing sector faces two major challenges when considering development impacts-market forces do not themselves ensure competitiveness; nor do they guarantee smallholder participation, both of which are quite essential if agricultural growth is to be linked to overall development and rural poverty reduction.

Economic viability and challenges

There are lots of different factors which are required to be look into, which affect the production, processing and distribution of the products as Horticultural production, it requires twice as much, even sometimes up to four times as much labor when compared to the production of cereal crops (Weinberger and Lumpkin, 2005). Marwaha *et al.* (2009) highlighted the challenges faced by potato processing industries as they have to make strategies to ensure round the year supply, specific breeding programme for the processing varieties, finding of low-cost alternative storage technology for the potatoes, facilities for frozen fried potato products, antioxidant rich fried products to the consumers at affordable price etc. are few to mention. Similarly, fruit processing industries have reported high energy costs inadequate technological base, cold chain and post-harvest management activities, highly unskilled labor and low remuneration for the employees making the industry unattractive as the challenges ahead of them. (Sharma *et al.* 2016). Commercial mushroom production has marked the poor supply and the increasing price of raw material, for example sawdust, poor quality of mushroom spawn, and the threat of diseases and pest attack as the major challenges and need to be addressed with the global cooperation and interaction (Rosmiza *et al* 2016). Over all, different enterprise and different agro products have different challenges which have perishability, seasonality, price fluctuation, shorter shelf life, high labor requirements, input credibility and maintaining and managing with the modern technology are some, which has found the common say. Apart from these some of the factors can be elaborated below under different sub-heading which are as follow

Technical skill and knowledge of up-to-date technology:

Technical skill or the principal know how is the very basic to the food processing and value addition. Through the up-to-date technology the cost and labor margin can be kept at the bay and also the quality can be maintained. Since value added products are more market and consumer oriented, this basic factor cannot be ignored. New technology also helps in increasing the shelf life and quality of the products. Tetra

packaging, use of suitable packaging material for fruits and vegetable has been able to keep them fresh and nutritious for the long time. Tetra packed milk can be stored for six month. So the impact of technology has been enormous on the value added products while considering their viability and quality.

Regulations: Processed food and value added products are needed to follow certain rules and regulation to have a uniformity and standard in the products. Some of these bodies are-Bureau of Indian Standard (BIS) established under the BIS Act 1986. They look after the many issues as standards formulation, product certification scheme, compulsory registration scheme, foreign manufacturers certification scheme, hall marking scheme, laboratory services, laboratory recognition scheme, sale of Indian standards, consumer affairs activities, promotional activities, training services, national & international level, information services (http://www.bis.org.in/bis_overview.asp). Similarly, The Food Safety and Standards Authority of India (FSSAI) has been established under Food Safety and Standards , 2006 which consolidates various acts & orders that have handled food related issues in various Ministries and Departments. FSSAI has been mandated to regulate the manufacturing, storage, distribution, sale and import to ensure availability of safe and wholesome food for human consumption. It would be cover various central acts like Prevention of Food Adulteration Act,1954; Fruit Products Order , 1955; Meat Food Products Order,1973; Vegetable Oil Products (Control) Order, 1947; Edible Oils Packaging (Regulation)Order 1988; Solvent Extracted Oil, De-Oiled Meal and Edible Flour (Control) Order, 1967; Milk and Milk Products Order, 1992. (<http://www.fssai.gov.in/home/safe-food-practices/introduction.html>.)

Capital Requirements: Food process in small scale industries require initial investment and but going for mass scale production need to work in some finer details like fixed cost, variable cost, wages, inputs, managerial skills, certification and quantification requirements, vertical coordination to deliver perishable products to markets or processing facilities in time, access to future markets or insurances to withstand the price and supply fluctuations. (Carter *et al.*, 1995). The challenge also include clearing the way for private investments that would bring about rapid evolution of agro-food systems, while laying down conditions that would enable the potential negative consequences to be minimized. (Henson and Cranfield, 2009).

Structure: Proper structure or making a efficient and effective hierarchy will enable to enterprise function smoothly. This will be able to put the accountability and responsibility at the right balance. On the similar note, many food processing and value added products had been

launched with much fanfare, but sadly due to no or littler market integration, there were little success. The cases have been raise in some forum expressing the concern. 'The food park should not just be a facility provider or a facilitator of infrastructure; they should also be involved in production and marketing. A small entrepreneur will find it difficult to sell the product on his own even if he sets up a unit in the park,' says Acharya Balkrishna, promoter of Patanjali Food Park, Haridwar, Uttarakhand. (<http://www.businesstoday.in/magazine/features/food-parks-in-india-fail-to-attract-corporate-investment/story/220531.html>). This statement marks the need of the hour for the formation and integration of the proper structure that would also be able to withstand all the adversity and also be able to evolve.

Opportunities and way forward

Several reports have given the suggestions and recommendations to the processing industry and same can be considered in terms of value added products also. From policy makers point of view, thrust and emphasis on developing industrial areas in raw material producing regions, thrust on small-scale industries for self-employment in micro enterprises in rural areas and promotion of supporting and subsidiary (intermediate) industries to diversify value addition activities, cost effective and adequate supply of raw material by strengthening direct linkages through suitable contract farming models, liberal credit policy to modernize processing units and encouraging formation of small industries consortia or associations for collective marketing and sales promotion are considered to be effective strategy. (Sharma *et al.*2010). Emphasis should also be given on the establishment of new agro-industrial plants in the production catchments to minimize transport cost, make use lower cost land and more abundant water supply, create employment opportunity in the rural sector and utilize process waste and by-products for feed, irrigation and manure. (Kachru, 2010). Vast geo-graphical area, range of agro-climatic zones and the resources at our disposal promises the bright future for the agro based industry to flourish and expand. We need to integrate the technologies such as electronics, material science, computer, biotechnology etc. to further strengthen the knowledge base, and for the advancement in the area. Due to globalization and opening of the market, one side the trade opportunities has been increased tremendously, while competition within and from outside the countries have been increased. Opening of global markets led to export of our products as well as developed technologies and facilitate generation of additional income and employment opportunities. (Singh *et al.* 2012) Keeping the technology and knowledge at the advance level would provide the effective edge over other

competitors. Improvement over the infrastructure, research base, grass root connection with the farmers, understanding of the basic problems, and timely availability of credits and utilization of that credit in desired area would further strengthen the farmer's position. Their share in the consumer price can be enhanced only when they themselves would participate in the whole process and this will eliminate the unnecessary middle man in the whole value chain of the processed food. Given the opportunity in the sector, this would also reduce the over dependence over the farming as a single source of income.

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Assessment of Stunting and Malnutrition among School-going Children from different Cultural Regions of Punjab, India

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Abstract: A survey was conducted to assess stunting and malnutrition through anthropometric profile of 1050 children, aged 11-17y, enrolled in urban and rural government schools of three regions of Punjab namely Majha, Doaba and Malwa. Thirty-cluster multi-stage sampling technique was used for selection of the subjects. Height-for-age and BMI-for-age z-scores were calculated and interpreted based on WHO Global Database on Child Growth and Malnutrition. Average height of the children for most of the age groups was marginally lower (92.4 to 98.7%) while the average weight was lower (78.8 to 92.8%) when expressed as percent of reference standards. The average BMI of most of the children was more than 90% of the reference standards. The results concluded that thinness was more common than stunting among Punjabi school children. Maximum stunting among children was in Majha followed by Malwa and Doaba regions, while prevalence of thinness was higher among children from Doaba region in comparison to Majha and Malwa regions.

Keywords: Height, Weight, Body mass index, Children, Punjab

The field of anthropometry encompasses a variety of human body measurements reflecting general health status, dietary adequacy and growth and development over time. Analysis of trends in children's growth at the regional or national level are imperative to put on record the changes occurring over time in physical measurements of child population. In both developed and developing countries, there is limited information on growth and nutritional status of school-age children and adolescents. The major source of this knowledge gap is the lack of an internationally agreed method for assessing growth and nutritional status during childhood and adolescence. WHO developed new growth references for school-age children and adolescents based on an international sample of ethnically, culturally and genetically diverse healthy children living under optimum conditions that are conducive to achieve a child's full genetic growth potential (WHO, 2006). The Northwest state of India, Punjab, widely acknowledged as the "Granary of India", covers the geographical area of about 1.5% of the total geographical area of the country. Socio-culturally, the state is sub-divided into three regions, namely Malwa, Majha and Doaba, with 22 districts and 145 blocks. Based on India State Hunger Index, Punjab has the lowest level of hunger in India (Menon *et al.*, 2009). Despite economic progress, Punjab lags behind in social development, particularly in the area of health of children. Rapid urbanization and industrialization result in such a transition in the state that over the years resulted in changes in occupation, economy, food consumption, dietary intake, physical activity levels and

overall lifestyle of Punjabi population. On the whole, the state has not fully translated its agricultural-led economic growth into improvements in nutritional conditions (Bhatia, 2013).

Nutrition is especially important during the school age period as it is the prime time to build up body stores of nutrients in preparation for rapid growth of adolescence (Kumari and Jain, 2005). The school is an appropriate setting to improve nutritional status of disadvantaged children and can contribute towards the national goal of promoting optimal nutrition among children (Gillespie and Haddad, 2001). Yet, school-age children are not commonly included even in national level surveys such as National Family Health Survey (NFHS) and District level household survey (DLHS) that restrict data to children below 5 years of age; the National Sample Survey Organization (NSSO), do not specify data for children and National Nutrition Monitoring Bureau (NNMB) that represents mostly rural population. Furthermore, widely recommended z-score system is not yet being used among researchers, especially in community-based studies from India, mainly due to the perceived difficulty in calculating the z-scores. Consequently, from Punjab, the studies conducted to estimate the prevalence of malnutrition, according to WHO (2007) BMI-for-age z scores are limited, especially among children more than 10 years of age. Moreover, to date, there are no studies which have dealt with regional disparity in the incidence of malnutrition among children from Punjab. In this regard, using WHO (2007) Z score system, the study attempts to measure the anthropometric profile of school-going children as the contextual determinant of stunting and

malnutrition among children from three regions of Punjab.

MATERIAL AND METHODS

Thirty-cluster multistage sampling technique was used for the selection of the subjects. A total of five districts; one each from Majha (Amritsar) and Doaba (Jalandhar) regions and three districts from Malwa region (Ludhiana, Faridkot and Patiala) of Punjab were selected targeting school-going children. In the next stage of sampling, two blocks from each district were selected. The last stage included selecting two rural and one urban government school from each block selected in order to have a total random sample size of 1050 children (210 each from Majha and Doaba region; and 630 children from Malwa region), in the age group of 11–17 years, representing the school-going children of Punjab state (Fig.1). Information related to age, gender, caste, religion, occupation, education and income of the parents was recorded through a structured questionnaire. Anthropometric measurements, i.e., height and weight of each subject were taken according to the standard procedures given by Jelliffe (1966). Age and sex specific mean height and weight of the subjects were compared with the ICMR standards (2010). Derived anthropometric indices (BMI) were calculated using the equation given by Garrow and Webster (1985). Z-scores of height-for-age (HAZ) and BMI-for-age (BAZ) were calculated using WHO Anthro Plus software (WHO, 2007a) and were interpreted based on WHO Global Database on Child Growth and Malnutrition (WHO, 2007) as shown in Table 1. The data was statistically analyzed using SPSS Windows version 16.0 (SPSS Inc., USA). For multiple comparisons between regions, analysis of variance followed by Tukey's post-hoc test was applied.

RESULTS AND DISCUSSION

Demographic and socio-economic profile: The majority of the children were Sikhs, followed by Hindus. Maximum number of children belonged to scheduled castes (SC). In comparison to other regions, Doaba region had maximum number of SC subjects, but lowest percentage of those belonging to Sikhism. Majority of the children's parents were educated up to matriculation and very few had above higher secondary education, thus indicating that number of those without any worthwhile schooling was quite substantial. Majha region had the highest and Doaba region had the least proportion of illiterate parents. The progress of literacy in the state has not only been slow but is highly iniquitous in many respects such as location, gender, region and district Brar (2016). The results further indicated that labour was the most pursued occupation of the fathers and mothers were mostly housewives. Data on monthly family income of the subjects

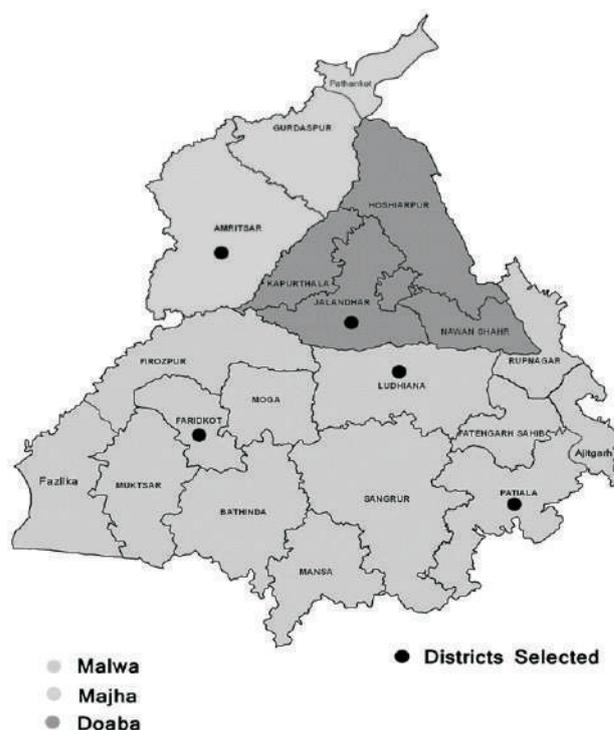


Fig. 1. Areas of three regions of Punjab

Table 1. WHO Classification for assessment of stunting and malnutrition (WHO 2007)

| z-scores | Category |
|-----------------------------|-------------------|
| Height-for-age (HAZ) | |
| -2SD to +1SD | Normal |
| < -2SD | Moderate stunting |
| < -3SD | Severe stunting |
| BMI-for-age (BAZ) | |
| -2SD to +1SD | Normal |
| < -2SD | Moderate Thinness |
| < -3SD | Severe thinness |
| > +1SD | Overweight |
| > +2SD | Obese |

showed that from Majha and Doaba region, most of the subjects were belonging to families earning Rs. 5000–10000; whereas from Malwa region, majority of the subject's families were earning up to Rs. 5000, which indicated that most of the children studied were from low socio-economic status households, earning less than Rs. 10000 per month.

Anthropometric profile: Average height of the children for most of the age groups was marginally lower i.e. 92.4 to 98.7% of ICMR (2010) standards in all the three cultural regions of Punjab, with exceptions of 11–12y old boys of Majha region and 16–17y old boys of Doaba region, with

average height of 89.3 and 101.8% of reference standards, respectively (Table 3). Similar results have been reported by Ramya and Thomas (2015) among adolescent girls from Kottayam district in Kerala; by Manna *et al.* (2011) among school children of North Bengal; and by Bisai and Mallick (2011) among Kora-Mudi children aged 2–13 years from West Bengal. Height once gained, does not alter and hence it promises to be a better standard for detection of malnutrition during growth and adolescence (WHO, 2015). The overall mean HAZ scores of school children from Majha, Doaba and Malwa region, was -1.6 vs. -1.0 vs. -1.2, respectively. A Tukey post-hoc test further revealed that significant ($p \leq 0.01$) difference in the mean HAZ scores was observed in Majha vs. Doaba and Majha vs. Malwa region; while no difference was seen in HAZ scores between Doaba vs. Malwa regions. The results showed that mean HAZ scores of the subjects from Majha region were lower than Malwa and Doaba region; thus indicating that Majha region children were more stunted than Doaba and Malwa region children. The average weight of the subjects from three regions of Punjab was almost similar, though lower (78.8 to 92.8%) than the ICMR (2010)

standards. In contrast to these results, Prabhjot *et al.* (2005) reported that children aged 6 to 15 years attending convent and public schools in Amritsar district had equal or higher average weight than well to do Indian children and NCHS standards. Similar results have been reported among children and adults aged 8–23 years from rural schools of Ludhiana district (Kahlon *et al.*, 2015). From all the regions, the average BMI of most of the children was more than 90% of the reference standards except 16–17y old boys and girls from Doaba region. Children from Majha region had higher mean BMI than children from Malwa and Doaba regions. The overall mean BAZ scores of school children from Majha, Doaba and Malwa region were -0.9 vs. -1.3 vs. -1.1, respectively. The mean BAZ scores were found to be lowest among children from Doaba region; whereas Malwa and Majha region children had almost similar BAZ scores; thus indicating that Doaba region subjects had poor nutritional status as compared to those from Majha and Malwa regions. However, a Tukey post-hoc test revealed that, significant ($p \leq 0.05$) difference was found only between Majha vs. Doaba region subjects. These findings are consistent with

Table 2. Demographic and socio-economic profile of the subjects from three regions of Punjab

| Parameter | Category | Majha (n=210) | Doaba (n=210) | Malwa (n=630) |
|----------------------------|------------------------|---------------|---------------|---------------|
| Gender | Girls | 119 (57) | 130 (62) | 364 (58) |
| | Boys | 91 (43) | 80 (38) | 266 (42) |
| Religion | Sikh | 149 (71) | 103 (49) | 458 (73) |
| | Hindu | 46 (22) | 91 (43) | 166 (26) |
| Caste | General | 47 (22) | 26 (12.4) | 169 (27) |
| | Scheduled Castes | 111 (53) | 152 (72.4) | 323 (51) |
| | Backward Castes | 52 (25) | 32 (15.2) | 138 (22) |
| Parent's education | | | | |
| Mother | No education | 100 (48) | 41 (19) | 242 (38) |
| | Up to Matric | 103 (49) | 146 (70) | 342 (54) |
| | Above higher secondary | 7 (3) | 23 (11) | 46 (7) |
| Father | No education | 61 (29) | 27 (13) | 176 (28) |
| | Up to Matric | 122 (58) | 148 (70) | 381 (60) |
| | Above higher secondary | 27(13) | 35 (17) | 73 (12) |
| Parent's occupation | | | | |
| Mother | Farming | – | 2 (1) | – |
| | Service | 5 (2) | 7 (3) | 20 (3) |
| | Labour | 39 (19) | 10 (5) | 121 (19) |
| | Self-employed | 7 (3) | 9 (4) | 27 (4) |
| | Housewife/non-working | 159 (76) | 182 (87) | 462 (73) |
| Father | Farming | 23 (11) | 14 (6) | 99 (16) |
| | Business | – | 9 (4) | 39 (6) |
| | Service | 18 (9) | 31 (15) | 70 (11) |
| | Labour | 109 (52) | 110 (52) | 327 (52) |
| | Self-employed | 44 (21) | 41 (20) | 83 (13) |
| | Any Other | 4 (2) | 4 (2) | 5 (0.8) |
| Monthly family income, Rs. | Up to 5000 | 16 (8) | 80 (38.1) | 267 (42.4) |
| | 5-10,000 | 133 (63) | 93 (44.3) | 197 (31.3) |
| | 10-20,000 | 48 (23) | 26 (12.4) | 90 (14.3) |
| | Above 20,000 | 13 (6) | 11 (5.2) | 76 (12) |

those reported by Nahar *et al.* (2009) which showed that physical growth (height and weight) of rural preschool children in two regions of Punjab i.e. sub-mountain and central plains was better than those in south western region. Similar trend of regional variation in the anthropometric measurements of children (aged 5 to 19 years) was observed by Chakrabarty and Bharati (2010) in Orissa and in the State of Jharkhand by Tigga (2013).

Regional disparity of stunting and malnutrition prevalence: Maximum stunting among children was in Majha (30%) region followed by Malwa (17%) and Doaba (9%) regions (Fig. 3). Geographical factor is considered as a

strong determinant which affects the dietary habits of children (Jelinic *et al.*, 2009). The identification of regional differences of nutritional disorders such as stunting in older children and adolescents is important for targeting high-prevalence areas for programs to prevent its complications such as psychological disorders and obesity (Kruger *et al.*, 2010). Based on BAZ scores, the prevalence of thinness was slightly higher among children from Doaba region (27%) in comparison to Majha (24%) and Malwa (23%) regions. Although the prevalence of overweight/obesity was scarce, it was higher among children from Majha region (11%), followed by Doaba (7%) and Malwa (4%) region (Fig 2). The

Table 3. Average height, weight and BMI of school children from three regions of Punjab

| Parameter | Age (years) | Gender | Majha (n=210) | Doaba (n=210) | Malwa (n=630) | ICMR (2010) |
|--------------------------|-------------|--------|---------------|---------------|---------------|-------------|
| Height (cm) | 11-12y | Girls | 136.7 | 136.8 | 140.5 | 147.8 |
| | | Boys | 132.1 | 141.8 | 140.7 | 148.0 |
| | 13-15y | Girls | 146.4 | 152.4 | 149.8 | 156.5 |
| | | Boys | 150.2 | 156.2 | 152.3 | 162.1 |
| | 16-17y | Girls | 156.9 | 154.8 | 155.1 | 160.0 |
| | | Boys | 162.0 | 172.0 | 166.8 | 169.0 |
| Weight (kg) | 11-12y | Girls | 30.5 | 30.2 | 31.3 | 37.0 |
| | | Boys | 30.5 | 31.8 | 31.6 | 36.0 |
| | 13-15y | Girls | 36.7 | 41.0 | 38.7 | 46.6 |
| | | Boys | 40.0 | 41.1 | 41.3 | 47.6 |
| | 16-17y | Girls | 45.2 | 41.7 | 44.3 | 52.0 |
| | | Boys | 50.2 | 51.0 | 51.4 | 55.4 |
| BMI (Kg/m ²) | 11-12y | Girls | 16.4 | 16.0 | 15.8 | 16.9 |
| | | Boys | 17.9 | 15.7 | 15.9 | 16.5 |
| | 13-15y | Girls | 17.2 | 17.6 | 17.2 | 19.0 |
| | | Boys | 17.9 | 16.8 | 17.8 | 18.1 |
| | 16-17y | Girls | 18.5 | 17.4 | 18.4 | 20.4 |
| | | Boys | 19.2 | 17.2 | 18.5 | 19.4 |

Table 4. Regional disparity in mean height for age (HAZ) and BMI for age (BAZ) z-scores of school children

| Parameter | Age group (years) | Gender | Majha (n=210) | Doaba (n=210) | Malwa (n=630) | F ratio |
|-----------|-------------------|--------|-------------------|-------------------|--------------------|---------------------|
| HAZ | 11-12y | Girls | -1.7 ^a | -1.7 ^a | -1.1 ^a | 3.713 ^{NS} |
| | | Boys | -2.0 ^a | -0.6 ^b | -0.8 ^b | 10.09** |
| | 13-15y | Girls | -1.8 ^a | -1.0 ^b | -1.3 ^b | 7.579** |
| | | Boys | -1.7 ^a | -0.8 ^b | -1.5 ^{ab} | 3.726* |
| | 16-17y | Girls | -0.9 ^a | -1.2 ^a | -1.1 ^a | 0.778 ^{NS} |
| | | Boys | -1.6 ^a | -0.2 ^b | -0.9 ^c | 13.409** |
| Overall | | | -1.6 ^a | -1.0 ^b | -1.2 ^b | 17.054** |
| BAZ | 11-12y | Girls | -1.0 ^a | -1.1 ^a | -1.1 ^a | 0.071 ^{NS} |
| | | Boys | -0.4 ^a | -1.2 ^b | -1.0 ^b | 1.836 ^{NS} |
| | 13-15y | Girls | -1.2 ^a | -1.0 ^a | -1.2 ^a | 0.428 ^{NS} |
| | | Boys | -0.9 ^a | -1.5 ^a | -0.9 ^a | 1.842 ^{NS} |
| | 16-17y | Girls | -1.0 ^a | -1.5 ^a | -1.1 ^a | 2.810 ^{NS} |
| | | Boys | -1.0 ^a | -1.9 ^b | -1.2 ^{ab} | 3.162* |
| Overall | | | -0.9 ^a | -1.3 ^b | -1.1 ^{ab} | 3.287* |

* ** significant at 5 and 1%,^{NS} Non-significant

Means sharing same superscript in a row are not significantly different from each other (Tukey's HSD)

most likely explanation for these region specific disparities could be the heterogeneous nature of population, differences

in socio-economic conditions, diverse culture, food habits and level of development that are expected to be associated

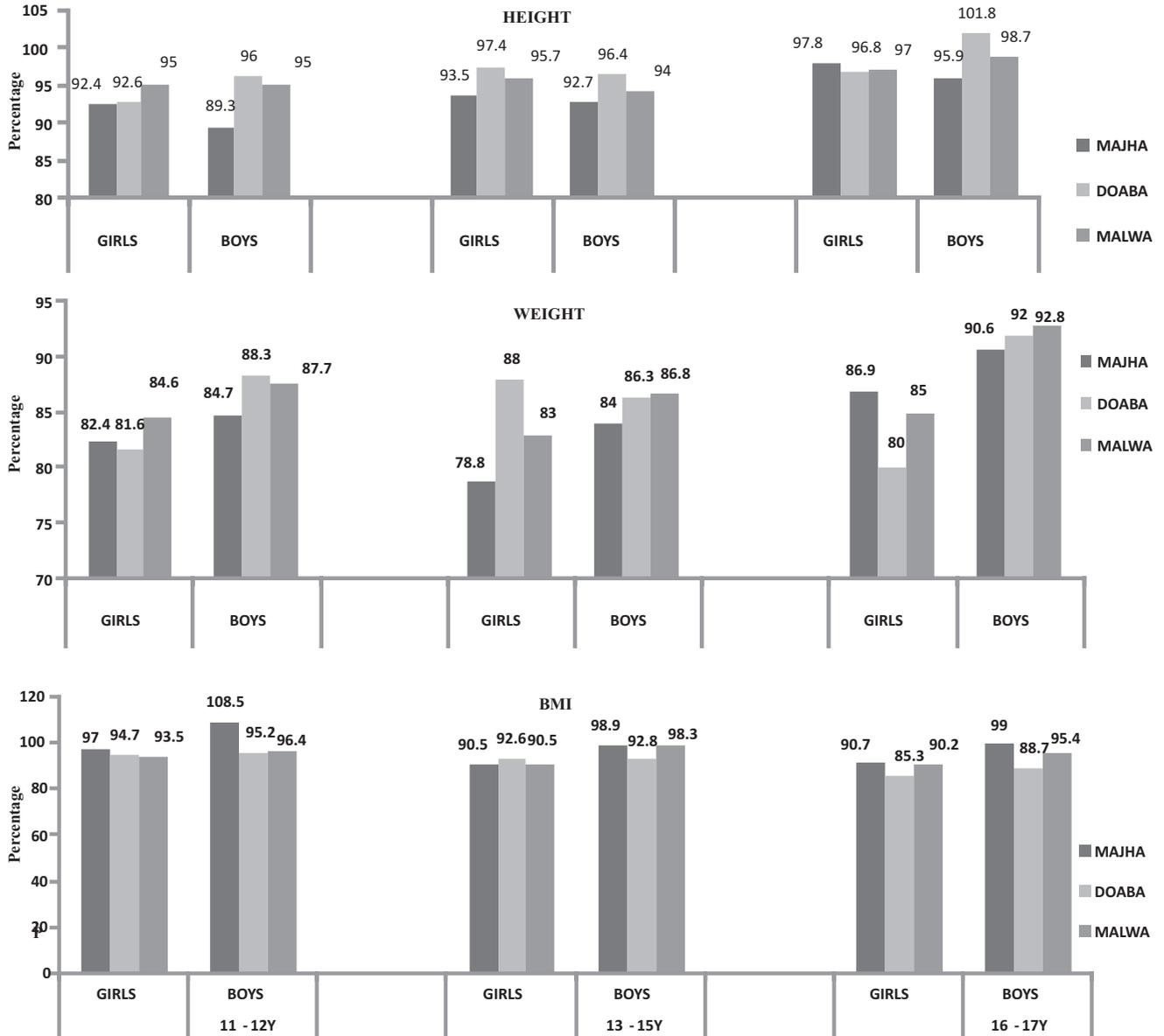


Fig. 2. Average height, weight and body mass index (BMI) as percent of reference standards of school children belonging to three regions of Punjab

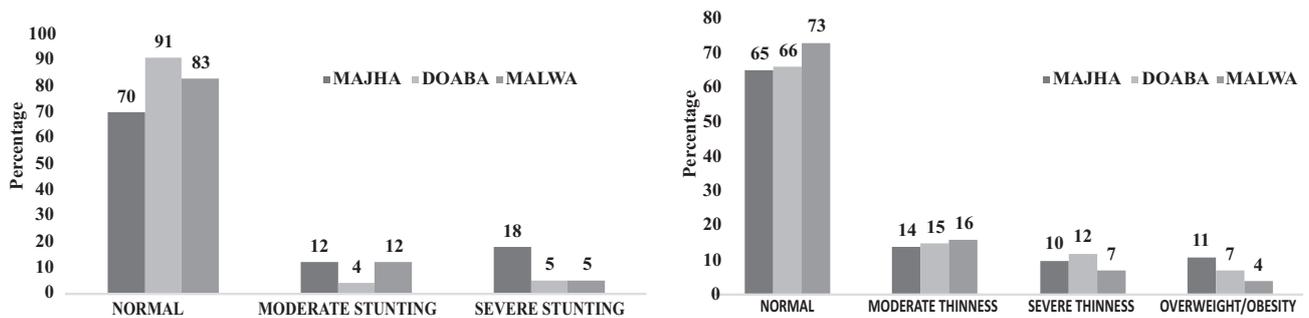


Fig. 3. Prevalence of stunting and malnutrition among school children from three regions of Punjab, on the basis of z scores

with child malnutrition. Understanding the nature and the underlying factors behind health disparities within and across the regions would help in designing effective intervention measures to improve population health outcomes (Sharaf and Rashad, 2015). Although, the study results revealed regional disparity in the nutritional status of the children, they were not as widely prevalent as compared to those reported in other states of India (Arnold *et al.*, 2009; Tarozzi and Mahajan, 2006; NNMB-3, 2012; NFHS-4, 2015-16; Ponmuthusaravanan and Ravi, 2016).

CONCLUSION

The average height of the children for most of the age groups was marginally lower in all the three cultural regions of Punjab. Thinness was more common than stunting among Punjabi school children. Maximum stunting among children was found in Majha followed by Malwa and Doaba regions. The average weight of the subjects from three regions of Punjab was lower than the reference standards. Prevalence of thinness was higher among children from Doaba region in comparison to Majha and Malwa regions. The findings of the study provide health indicators for policy makers in designing effective intervention measures to improve child population health outcomes.

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