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Simulation of Nitrogen Uptake, Nitrogen Utilization Efficiency and Yield of Wheat under Tillage, Residue and Nitrogen Management using DSSAT-CERES-Wheat Model

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Abstract: Crop Simulation Models (CSMs) serve as effective tools for taking decisions about optimization of resource use provided they are calibrated and validated in a particular agro-climatic region. Therefore, the experiment was conducted to simulate the influence of tillage, residue and nitrogen interaction on grain and biomass yield, nitrogen uptake and nitrogen utilization efficiency of HD-2967 cultivar of wheat in a sandy-loam soil of Indo-gangetic plains using CERES – Wheat model of DSSAT. The model was calibrated and validated with the field experiment data of the years 2014-15 and 2015-16, respectively. The results showed that the N uptake increased but N utilization Efficiency decreased with increase in N levels. The effect of tillage and crop residue mulch on grain and biomass yield of wheat was not significant but it increased with increase in the N levels. During stress free season (2014-15), irrigated wheat crop responded upto 120 kg N/ha while under temperature and water stress (2015-16), the crop responded upto 180 kg N/ha. Crop simulation model DSSAT could satisfactorily simulate grain yield (R^2 = 0.759), biomass yield (R^2 = 0.728) and N uptake(R^2 = 0.883) in wheat.

Keywords: Wheat, No tillage, Conventional tillage, Nitrogen uptake, Nitrogen utilization efficiency, DSSAT 4.6 model

Wheat (*Triticum aestivum* L.) is the second most important cereal crop after rice in India and the HD-2967 cultivar is widely adopted in the Indo-gangetic plain region. Nitrogenous fertilizers play a key role in improving the yield of wheat but it must be used judiciously. However, farmers usually resort to application of high dose of nitrogenous fertilizers to increase the wheat production, which ultimately increase the production cost with concomitant deterioration of water and soil quality. Improved use efficiency of nitrogenous fertilizers can be achieved by studying the peak requirement period of nitrogen by the wheat crop so that the nitrogenous fertilizer application can match with this period to facilitate its efficient utilization and minimum loss to the ecosystem. So, the crop management practices should be such that maximum amount of available soil N is supplied to crop during that period (Ebrayi *et al.*, 2007).

Tillage practices influence the nutrient and water dynamics and their utilization by crops by altering physical, chemical and biological properties of soil. So optimum synergistic combination of water, nutrient and tillage should be found out for different cropping systems, soil types and agro-climatic regions to enhance the overall input use efficiency. However, excessive and indiscriminate tillage practices under conventional tillage practices such as deep moldboard plowing, ridging, etc. can cause loss of soil organic carbon, degradation of soil structure, and extensive wind–water erosion leading to deterioration of soil health and low input use efficiency. Most, if not all, of these impeding factors could likely to be mitigated substantially by replacing conventional tillage with conservation tillage, or at least reduced tillage. Conservation agriculture includes practices which minimize the soil disturbance, provide soil cover through crop residues, mulch or cover crops, and crop rotations for attaining higher productivity and minimizing adverse environmental impacts. N uptake, contributing significantly to crop yield, is influenced by tillage and residue management practices. So, to improve the nitrogen use efficiency, management practices need to be standardized under different agro-climatic conditions.

Soil and plant system is very complex because there are numerous interacting factors, which affect the desired end result. So, to study how to manage, which factor and to what extent through field experiments, is a difficult and time-consuming task. However, crop simulation models has made this task easy as it considers the combined influence of several factors and improves our understanding on their interactions. Crop simulation models are developed to simulate the performance of a particular cultivar, sown at any time, in any soil and in any climate because of their generic nature. These models can help in accomplishing the goal of efficient management of these interacting factors by defining a minimum set of soil, weather, management and genetic information, which needs to be provided by the user (Jones and Ritchie, 1990) and can serve as useful tools in taking critical decisions with respect to efficient use of inputs *viz*., water, nutrient, tillage for achieving the goal of sustainable agricultural intensification. The Decision Support System for Agro-technology Transfer (DSSAT) is an assemblage of various models, which links the decision support system with crop simulation models (Ngwira *et al.*, 2014). This model was developed by International Benchmark Sites Network for Agro-technology Transfer (IBSNAT) project and is under continuous revisions. DSSAT 4.6 has algorithms which can simulate the influence of conservation agricultural practices such as crop residue cover and tillage on soil surface properties and plant development (DSSAT 4.6 manual). In India, there are many studies for using this model under different fertilizer doses, irrigation water management, different sowing time, *etc.* but no work has yet been done so far on applicability of this model under different tillage and residue condition. Keeping this in view, the present study was undertaken to calibrate and validate DSSAT 4.6 crop model for simulation of nitrogen uptake, nitrogen utilization efficiency, grain and biomass yield of wheat under conventional and no-tillage system in the presence and absence of residues with three different levels of nitrogen.

MATERIAL AND METHODS

Field experiments were conducted in the MB-4C farm of ICAR-Indian Agricultural Research Institute, New Delhi (28^0 35'N latitude, 77^0 12'E longitude and at an altitude of 228.16 m above mean sea level) with wheat as a test crop during the years 2014-15 and 2015-16.

Climate: New Delhi has sub-tropical semi-arid climate with dry hot summer and brief severe winter. The average monthly minimum and maximum temperature in January (the coldest month) ranged between 5.9°C and 19.9°C, respectively. The corresponding temperature in May (the hottest month) ranged between 24.4°C and 38.6°C, respectively. The average annual rainfall is 651 mm, out of which, 75% is received through south-west monsoon during July to September. The weather condition during crop growth period of the years 2014-15 and 2015-16 are presented in Table 1.

Soil: The soil of the experimental site was sandy loam (Typic Haplustept) of Gangetic alluvial origin, very deep (>2 m), flat and well drained. Detailed soil physico-chemical characteristics were determined before initiating the experiment and the data are presented in Table 2. It showed that the soil was mildly alkaline, non-saline, low in soil organic C (Walkley and Black C) and available N and medium in available P and K content. The soil (0–15 cm) has bulk density 1.58 Mg/m^3; hydraulic conductivity (saturated) 1.01 cm/h, saturated water content 0.41 m^3/m^3, EC 1:2.5 soil/water suspension, 0.36 dS m^{-1}; organic C, 4.2 g kg^{-1}; total N, 0.03%; available (Olsen) P, 7.1 kg ha^{-1}; available K, 281 kg ha^{-1}; sand, silt and clay, 64.0, 6.8 and 19.2%, respectively. The bulk

Table 1. Monthly weather condition during wheat growth during the year 2014-15 and 2015-16

Parameter	Maximum temperature.		Minimum temperature		Maximum R.H. (%)		Minimum R.H. (%)		Sunshine hours		Rainfall (mm)		Evaporation (mm)	
Month	2014–15	2015–16	2014–15	2015–16	2014–15	2015–16	2014–15	2015–16	2014–15	2015–16	2014–15	2015–16	2014–15	2015–16
November	28.3	28.1	10.6	11.9	84.3	90.3	37.6	47.4	5.7	2.4	0	2.2	3.1	3.4
December	20.6	22.6	6.7	6.1	93.8	93.9	59.0	49.7	4.4	3.5	26.4	0.0	2.1	2.8
January	16.9	20.7	6.8	6.5	96.0	95.9	68.8	59	2.3	2.4	35.8	0.0	1.9	2.5
February	24.6	24.6	10.6	8.1	91.9	88.7	48.0	53	5.1	5.7	0	0.0	2.6	3.0
March	27.2	30.8	13.1	13.7	90.8	88.2	51.0	54	6.9	6.8	201.8	0.6	3.7	5.1
April	33.9	38.7	19.2	19.1	76.6	67.7	43.4	45	7.2	7.8	51.8	0.0	6.8	8.2

Table 2. Physico-chemical properties of the soil at the experimental site

Depth (cm)	Bulk density (Mg m^{-3})	pH	EC (dS m^{-1})	Saturated hydraulic conductivity (cm h^{-1})	SOC (gkg^{-1})	Particle size distribution (%)			Soil texture	Soil moisture constants (cm^3/cm^3)	
						Sand	Silt	Clay		0.033 MPa	1.5 MPa
0-15	1.58	7.1	0.46	1.01	4.2	64.00	16.80	19.20	SL	0.254	0.101
15-30	1.61	7.2	0.24	0.82	2.2	64.40	10.72	24.88	SCL	0.269	0.112
30-60	1.64	7.5	0.25	0.71	1.6	63.84	10.00	26.16	SCL	0.283	0.129
60-90	1.71	7.5	0.25	0.49	1.2	59.84	10.00	30.16	SCL	0.277	0.110
90-120	1.72	7.7	0.30	0.39	1.1	53.68	13.44	32.88	SCL	0.247	0.097

density varied from 1.58 Mg m^{-3} in the 0–15 cm layer to 1.72 Mg m^{-3} in the 90–120 cm layer. Available soil moisture content ranged from 24.6–28.3% (0.033 MPa) to 9.7–12.9 % (1.50 MPa) in different layers of 0–120 cm soil depth.

Experimental details: The field experiments were conducted during *rabi* season of 2014–15 and 2015–16 at ICAR–IARI Research Farm to study the effects of tillage, residue and nitrogen management on nitrogen uptake and nitrogen utilization efficiency in HD–2967 cultivar of wheat (*Triticum aestivum* L.). The treatments comprising of two levels of tillage as main plot factor [Conventional tillage (CT) and No Tillage (NT)], two levels of residue as subplot factors (maize residue @ 5t ha^{-1} (R_+) and without residue (R_0), and three levels of Nitrogen as sub–sub plot factors (60, 120 and 180 kg ha^{-1}, representing 50% –N_{60}, 100% –N_{120} and 150% –N_{180} of the recommended dose of nitrogen for wheat, respectively) were evaluated in a split–split plot design with three replications. The sub–subplot size was 4.5 × 5 m. Wheat crop (cv. HD 2967) was sown on 16th and 28th November in 2014 and 2015, respectively, by a tractor drawn seed drill (at a depth of 4–5 cm) with a row spacing of 22.5 cm at a seed rate of 100 kg ha^{-1} and harvested on 17th April 2015 and 5th April 2016, respectively. In conventional tillage treatment, the plot was ploughed once with disc plough and once with duck–foot tine cultivator followed by leveling and sowing by seed drill. In no tillage treatments, the seed was directly sown using an inverted T type no–till seed drill. Maize residue was applied manually at the rate of 5 t ha^{-1} under R_+ treatment after CRI stage. All the plots received standard dose of P and K and five irrigations at critical growth stages.

Total nitrogen content in plant: Nitrogen content in the grain and straw samples was determined by Micro–Kjeldhal method (AOAC, 1970).

Nitrogen uptake, nitrogen utilization efficiency and grain protein content: Nitrogen uptake in grain and straw was determined by multiplying the N concentration with the corresponding dry grain and straw biomass, respectively. The total N uptake in plant was determined by summation of N uptake in grain and straw.

Plant N uptake (kg ha^{-1}) = (% N content in plant/100) × dry matter (kg ha^{-1})

N utilization efficiency (NUtE) = [Grain yield (kg ha^{-1})] / [Total N uptake (kg ha^{-1})]

The protein content in grain was measured by grain analyzer from Foss Tecator AB (Infratec™ model 1241) through the spectroscopic investigations of the grain samples.

DSSAT Model calibration and validation: The Decision Support System for Agrotechnology Transfer (DSSAT) is a decision support system that embodies several process–based computer models that simulate physiological behavior of plant as influenced by local weather and soil conditions, crop management practices and genetic coefficients to predict growth, development and yield. The CSMs, apart from predicting crop yield, also simulate dynamics of resources like water, nitrogen and carbon, and environmental impact, such as nitrogen leaching. DSSAT also includes an economic tool that calculates gross profit based on harvested yield and by–products, the price of the harvested products, and the cost of inputs. International Benchmark Sites Network for Agro–technology Transfer (IBSNAT) – a project under international network of scientists developed the Decision Support System for Agro–technology Transfer (DSSAT) model, which is undergoing continuous revisions (IBSNAT, 1993; Tsuji, 1998; Uehara, 1998; Jones *et al.*, 1998). This model also provides variety of management options like irrigation and fertilizer management, type of tillage, type of residue applied, etc. which is generally absent in many crop simulation models. Thus, this model is very useful for taking management decisions, comparing various management options and risk assessment. CERES–Wheat (incorporated within the DSSAT version 4.6, Jones *et al.*, 2003) is a dynamic mechanistic model that calculates phenological development and growth with daily time step in response to environmental factors like soil and climate, and management factors like crop variety, fertilization, planting conditions, irrigation, etc. Input requirements for CERES–Wheat include weather and soil conditions, plant characteristics and crop management (Hunt *et al.*, 2001). The following input parameters were provided during calibration and validation of model.

Weather data: Daily weather data parameters like maximum and minimum temperature, rainfall, solar radiation, relative humidity, evaporation, bright sunshine hours and wind speed of the desired location was required for creating a weather file to run the DSSAT model.

Crop data: Crop name, variety, number of seeds sown per square meter, number of plants per square meter, single seed weight, harvest index, biomass, harvested grain and straw yield and maximum leaf area index was required.

Soil data: Surface slope, permeability and drainage class, soil texture, thickness of soil layer, bulk density, saturated hydraulic conductivity, and soil organic carbon, soil moisture status at field capacity and permanent wilting point, pH, EC, ammonical and nitrate nitrogen content of soil is needed. All these data should be provided layer wise to the model prior to start of simulation.

Management data: Inputs on crop management practices include date of start of simulation, sowing/transplanting time, tillage type, seed rate, depth of sowing, irrigation date and amount of irrigation applied; date, amount and type of fertilizer and manure application, kind and amount of residue applied, tillage implements used, method and time of harvesting *etc.*

The model was calibrated with the data collected from field experiments on wheat crop for the year 2014–15 and validated this model with the independent data set collected from the field experiment on wheat during the 2015–16 to simulate the nitrogen uptake, nitrogen utilization efficiency, grain and biomass yield of wheat under different tillage, residue and nitrogen management systems.

Statistical analysis and evaluation of model : All the data were statistically analyzed using analysis of variance (ANOVA) as applicable to split-split plot design using SAS software. The significance of the treatment effects was determined using F-test and the difference between the means was estimated by using least significance difference at 5% probability level.

The observed and model predicted data were evaluated using the parameters like prediction error (PE), coefficient of determination (R^2), root mean square error (RMSE), coefficient of residual mass (CRM), index of agreement (d index) (Willmott, 1981), mean systematic error (MSEs) and mean unsystematic error (MSEu).

Prediction error, $PE = ((P_i - O_i)/O_i) \times 100$

where, P_i is predicted value, O_i is observed value. Prediction is considered to be excellent if this value is close to zero.

The coefficient of determination (R^2) gives an indication of the quality of trend conformity, with values of R^2 = 1.0 indicating perfect fit, and lower values indicating less agreement of data. The root mean square error (RMSE) was used to calculate the closeness between the estimated and measured results.

$$RMSE = \sqrt{\frac{1}{n}\sum_{i=1}^{n}\left(P_i - O_i\right)^2}$$

The normalized RMSE is expressed as RMSE as a percentage over the observed mean value.

nRMSE = (RMSE/ Ō) × 100

where P_i is predicted value, O_i is observed value, Ō is observed mean and n is number of samples. nRMSE (%) shows the relative difference between the predicted and observed data. The prediction is considered excellent, good, fair and poor if the nRMSE is < 10 %, 10–20 %, 20–30 %, > 30 %, respectively (Jamieson *et al.*, 1991).

Coefficient of residual mass (CRM) statistics gives the degree to which the prediction is over or under estimated. Positive value of CRM indicates that the model underestimates the measured or observed value where as a negative value of CRM indicates a tendency to overestimate.

$$CRM = \frac{\sum_{i=1}^{n}(O_i - P_i)}{\sum_{i=1}^{n} O_i}$$

Index of agreement $$d = 1 - \frac{\sum_{i=1}^{n}(P_i - O_i)^2}{\sum_{i=1}^{n}\left(\left|P_i'\right| + \left|O_i'\right|\right)^2}$$

where, $P_i' = P_i - \bar{O}$; $O_i' = O_i - \bar{O}$

Mean systematic error

$$MSEs = \frac{1}{n}\sum_{i=1}^{n}\left(\hat{P}_i - O_i\right)^2$$

Mean unsystematic error

$$MSEu = \frac{1}{n}\sum_{i=1}^{n}\left(P_i - \hat{P}_i\right)^2$$

where, P_1= Estimated P_i , determined by fitting a linear equation between P_i and O_i.

RESULTS AND DISCUSSION

Weather: During the year 2015–16, the crop experienced higher maximum temperature during December, January, March and April by 9.7, 22.4, 13.2 and 14.2%, respectively than that of the year 2014–15 (Table 1). During the year 2014–15, the crop received total rainfall of 315.8 mm whereas during the year 2015–16, the crop received only 2.8 mm of rainfall. The month of March was the wettest for the year 2014–15 with the rainfall of 201.8 mm. The average bright sunshine hours during November and December in 2015–16 were less than that of 2014–15. This indicates that the crop was under temperature and water stress during the year 2015–16 compared to the year 2014–15. This stress reduced the crop duration in the year 2015–16 (130 days) by 23 days as compared to the stress free season of the year 2014–15 (153 days).

Grain yield of wheat: The grain yield of wheat as influenced by tillage, residue and nitrogen management for the year 2014–15 and 2015–16 is presented in the Table 3. During the year 2014–15, grain yield of wheat ranged from 3291 kg ha^{-1} (NT R_0 N_{60}) to 4884 kg ha^{-1} (NT R_0 N_{180}) with an average value of 4282 kg ha^{-1} whereas during the year 2015–16, the grain yield of wheat ranged from 2412 kg ha^{-1} (CT R_+ N_{60}) to 3833 kg ha^{-1} (NT R_+ N_{180}) with an average value of 3158 kg ha^{-1}. There was reduction in the grain yield and biomass yield of wheat by 35.6 and 24.5%, respectively during the year 2015–16 than that of the year 2014–15. This may be attributed to the lower rainfall received and higher maximum temperature

Table 3. Grain and biomass yield of wheat as influenced by tillage, residue and nitrogen management

Treatment	Grain yield (kg ha^{-1})		Biomass yield (kg ha^{-1})	
	2014–15	2015–16	2014–15	2015–16
Effect of tillage				
CT	$4439^{A\#}$	3096^{A}	11106^{A}	8467^{A}
NT	4125^{A}	3220^{A}	10633^{A}	8992^{A}
Effect of residues				
R_0	4319^{A}	3143^{A}	10649^{A}	8687^{A}
R_+	4245^{A}	3173^{A}	11090^{A}	8772^{A}
Effect of nitrogen				
N_{60}	3727^{B}	2636^{C}	8800^{B}	7388^{C}
N_{120}	4429^{A}	3241^{B}	11672^{A}	8837^{B}
N_{180}	4691^{A}	3598^{A}	12137^{A}	9963^{A}
Effect of Tillage ×Residue × Nitrogen				
CTR_0N_{60}	4016^{a}	2836^{a}	9765^{a}	7905^{a}
CTR_0N_{120}	4406^{a}	3187^{a}	11532^{a}	8556^{a}
CTR_0N_{180}	4680^{a}	3592^{a}	11160^{a}	9479^{a}
CTR_+N_{60}	4034^{a}	2412^{a}	9347^{a}	6801^{a}
CTR_+N_{120}	4659^{a}	3203^{a}	12137^{a}	8370^{a}
CTR_+N_{180}	4841^{a}	3343^{a}	12695^{a}	9693^{a}
NTR_0N_{60}	3291^{a}	2592^{a}	6603^{a}	7324^{a}
NTR_0N_{120}	4639^{a}	3028^{a}	12137^{a}	8434^{a}
NTR_0N_{180}	4884^{a}	3622^{a}	12695^{a}	10422^{a}
NTR_+N_{60}	3568^{a}	2702^{a}	9486^{a}	7522^{a}
NTR_+N_{120}	4011^{a}	3544^{a}	10881^{a}	9989^{a}
NTR_+N_{180}	4359^{a}	3833^{a}	11997^{a}	10259^{a}
LSD (T)	NS	NS	NS	NS
LSD (R)	NS	NS	NS	NS
LSD (N)	445.8*	322.6*	517.3*	579.7*
LSD (T×R×N)	NS	NS	NS	NS

#Values in a column followed by same letters are not significantly different at $p<0.05$ as per DMRT ; The uppercase letters and the lower case letters are used for comparing main plot and subplot effects, respectively;* Significant at $p<0.05$

experienced by the crop during 2015–16 than that of 2014–15 resulting in decreased crop duration and, hence, reduced yield. Neither the tillage treatment nor the crop residue mulch significantly influenced grain yield of wheat in both the years of study. This may be attributed to the fact that the experiment was only two years old. However this result also depicts that even conversion from conventional to no-tillage system would not affect the yield of wheat crop significantly. The, farmers could successfully adopt no-tillage system with residue application in sandy loam soil and save fuel, labour, implements and money. However, Ghosh *et al.* (2015) reported that under five years of conservation agriculture in a sandy-loam soil having maize – wheat rotation, the equivalent yield of wheat was 47% higher than that of conventional agriculture. Increase in nitrogen levels significantly increased the grain yield of wheat in both the years of study. This finding is in agreement with Lopez-Bellido *et al.*(1998). Application of 180 kg N ha^{-1} significantly increased the grain yield of wheat by 25.8 % and 36.5% than that of 60 kg N ha^{-1} during the year 2014–15 and 2015–16, respectively. Although application of 180 kg N ha^{-1} significantly increased the grain yield of wheat by 11% than that of 120 kg N ha^{-1} during the year 2015–16, but these treatments were statistically at par during the year 2014–15. Effect of tillage, residue and nitrogen interaction was not significant in grain yield of wheat during both the years of study.

Biomass yield of wheat: The above ground biomass yield of wheat at harvest as influenced by tillage, residue and nitrogen management for the year 2014–15 and 2015–16 followed the similar trend as that of grain yield of wheat (Table 3). During the year 2014–15, the above ground biomass yield of wheat at harvest ranged from 6603 (NT R_0N_{60}) to 12695 kg ha^{-1} (NT R_0 N_{180} and CT R_+ N_{180}) with an average value of 10869 kg ha^{-1} whereas during the year 2015–16, the biomass yield of wheat ranged from 6801 (CT R_+ N_{60}) to 10422 kg ha^{-1} (NT R_0 N_{180}) with an average value of 8730 kg ha^{-1}. The effect of tillage and crop residue mulch was not significant on biomass yield of wheat during both the years of study. Application of 180 kg N ha^{-1} significantly increased the biomass yield of wheat by 37.9 and 34.9% than that of 60 kg N ha^{-1} during the year 2014–15 and 2015–16, respectively. Application of 180 kg N ha^{-1} significantly increased the biomass yield by 12.7% than that of 120 kg N ha^{-1} during the year 2015–16, but these two treatments were statistically at par during the year 2014–15 with respect to biomass yield of wheat. During both the years of study, effect of tillage, residue and nitrogen interaction was not significant for the biomass yield of wheat.

During high rainfall year (2014–15), the grain and biomass yield of wheat under CT was higher than that of NT by 7.6 and 2.7 % whereas during low rainfall year (2015–16), grain and biomass yield of wheat under NT was higher than that of CT by 4 and 6.2%, respectively but these differences were not statistically significant. This finding is in agreement with Lopez-Bellido*et al.* (1998). This shows that the crop under no-tillage system can be one of the adaptive mechanisms to mitigate the effects of climate variability.

Nitrogen concentration in grain, straw and grain protein content of wheat: Nitrogen concentration in wheat grain ranged from 1.65 (CT R_0 N_{60}) to 2.11 % (NT R_0 N_{180}) with a mean value of 1.86% during the year 2014–15 whereas during the year 2015–16, it ranged from 1.49 (CT R_0 N_{60}) to 2.38 % (NT R_+ N_{180}) with a mean value of 2.01 % (Table 4).

Effect of tillage, residue and nitrogen interaction was not significant on N concentration of wheat grain during both the years. During the year 2014–15, effect of nitrogen levels was not significant on grain N concentration whereas during the year 2015–16, nitrogen concentration in grain increased significantly with the increase in N levels. Application of 180 kg N ha^{-1} significantly increased the N concentration in grain by 15.7 and 37.2 % than that of 120 kg N ha^{-1} and 60 kg N ha^{-1}, respectively. This may be due to the nitrogen dilution effect due to higher biomass production in 2014–15 than that of 2015–16 (Lopez-Bellido *et al*., 1998).

Nitrogen concentration in wheat straw ranged from 0.33 (CT R_+ N_{60}) to 0.49% (CT R_0 N_{120}) with a mean value of 0.41% during the year 2014–15 whereas during the year 2015–16, it ranged from 0.35 (CT R_0 N_{60}) to 0.61 % (CT R_+ N_{180}) with a mean value of 0.46 %. Effect of tillage, residue and nitrogen management interaction was not significant on N concentration of wheat straw during both the years. During the year 2014–15, effect of nitrogen levels was not significant on wheat straw N concentration whereas during the year 2015–16, nitrogen concentration in wheat straw increased significantly with the increase in nitrogen levels. Application of 180 kg N ha^{-1} significantly increased the nitrogen concentration in wheat straw by 22.8 and 59.0 % than that of 120 and 60 kg N ha^{-1}, respectively.

Protein concentration in wheat grain ranged from 9.98 (NT R_0 N_{60}) to 12.7 % (NT R_0 N_{180}) with a mean value of 11.49 % during the year 2014–15 whereas during the year 2015–16, it ranged from 10.93 (NT R_+ N_{60}) to 14.1 % (NT R_0 N_{180}) with a mean value of 12.4 %. This may be attributed to the dilution

Table 4. Nitrogen concentration in grain and straw of wheat and grain protein concentration as influenced by tillage, residue and nitrogen management

Treatment	Grain N concentration (%)		Straw N concentration (%)		Grain protein concentration (%)	
	2014–15	2015–16	2014–15	2015–16	2014–15	2015–16
			Effect of tillage			
CT	1.83^{A}	1.93^{A}	0.41^{A}	0.49^{A}	11.43^{A}	12.38^{A}
NT	1.89^{A}	2.08^{A}	0.40^{A}	0.44^{B}	11.54^{A}	12.57^{A}
			Effect of residues			
R_0	1.86^{A}	1.97^{A}	0.42^{A}	0.47^{A}	11.47^{A}	12.52^{A}
R_+	1.86^{A}	2.05^{A}	0.39^{A}	0.46^{A}	11.50^{A}	12.42^{A}
			Effect of nitrogen			
N_{60}	1.76^{A}	1.69^{C}	0.37^{A}	0.36^{C}	10.42^{C}	11.16^{C}
N_{120}	1.80^{A}	2.01^{B}	0.46^{A}	0.46^{B}	11.66^{B}	12.39^{B}
N_{180}	2.02^{A}	2.32^{A}	0.40^{A}	0.57^{A}	12.38^{A}	13.87^{A}
			Effect of tillage ×residue × nitrogen			
CTR_0N_{60}	1.65^{a}	1.49^{a}	0.38^{a}	0.35^{a}	10.51^{a}	10.97^{a}
CTR_0N_{120}	1.92^{a}	1.96^{a}	0.49^{a}	0.51^{a}	11.90^{a}	12.37^{a}
CTR_0N_{180}	1.96^{a}	2.24^{a}	0.41^{a}	0.58^{a}	12.24^{a}	13.87^{a}
CTR_+N_{60}	1.80^{a}	1.68^{a}	0.33^{a}	0.37^{a}	10.56^{a}	11.60^{a}
CTR_+N_{120}	1.73^{a}	1.87^{a}	0.47^{a}	0.49^{a}	11.36^{a}	11.80^{a}
CTR_+N_{180}	1.92^{a}	2.33^{a}	0.39^{a}	0.61^{a}	12.02^{a}	13.67^{a}
NTR_0N_{60}	1.76^{a}	1.77^{a}	0.37^{a}	0.35^{a}	9.98^{a}	11.13^{a}
NTR_0N_{120}	1.76^{a}	2.01^{a}	0.47^{a}	0.44^{a}	11.51^{a}	12.70^{a}
NTR_0N_{180}	2.11^{a}	2.33^{a}	0.41^{a}	0.56^{a}	12.70^{a}	14.10^{a}
NTR_+N_{60}	1.84^{a}	1.82^{a}	0.39^{a}	0.35^{a}	10.63^{a}	10.93^{a}
NTR_+N_{120}	1.80^{a}	2.19^{a}	0.39^{a}	0.40^{a}	11.87^{a}	12.70^{a}
NTR_+N_{180}	2.08^{a}	2.38^{a}	0.37^{a}	0.51^{a}	12.56^{a}	13.83^{a}
LSD (T)	NS	NS	NS	0.04	NS	NS
LSD(R)	NS	NS	NS	NS	NS	NS
LSD(N)	NS	0.10*	NS	0.05	0.34*	0.46*
LSD(T×R×N)	NS	NS	NS	NS	NS	NS

[#]Values in a column followed by same letters are not significantly different at p<0.05 as per DMRT;The uppercase letters and the lower case letters are used for comparing main plot and subplot effects, respectively; * Significant at p<0.05

effect because of higher grain yield recorded during stress-free season (2014–15) than that of temperature and water stress season (2015–16) as stated by Lopez-Bellido *et al*. (1998). Effect of tillage, residue and nitrogen interaction was not significant on grain protein content during both the years. However, grain protein concentration increased significantly with increase in the N levels during both the years. Several workers also reported increased levels of wheat grain protein at higher levels of nitrogen application (Fowler *et al.,* 1990; Abderrazak *et al*., 1995; Li-Hong *et al.*, 2007).

Total nitrogen uptake: The nitrogen uptake by wheat grain and straw during the year 2014–15 ranged from 69.82 (NT R_0 N_{60}) to 135.42 kg ha^{-1} (NT R_0 N_{180}) with a mean value of 107.61 kg ha^{-1} whereas during the year 2015–16, nitrogen uptake by wheat grain and straw ranged from 57.09 (CT R_+ N_{60}) to124.10 kg ha^{-1} (NT R_+ N_{180}) with a mean value of 90.49 kg ha^{-1} (Table 5). Neither tillage nor crop residue mulch significantly influenced the nitrogen uptake by wheat grain and straw during both the years of study. However, nitrogen uptake by wheat grain and straw increased significantly with increase in the nitrogen levels.

Application of 180 kg N ha^{-1} significantly increased the nitrogen uptake by wheat grain and straw by 47.5 and 94.8 % than that of 60 kg N ha^{-1} during the year 2014–15 and 2015–16, respectively. During the year 2014–15, there was no significant difference between 120 kg N ha^{-1} and 180 kg N ha^{-1} with respect to total nitrogen uptake by wheat grain and straw whereas during the year 2015–16, application of 180 kg N ha^{-1} significantly increased the nitrogen uptake by wheat grain and straw by 32.2 % than that of 120 kg N ha^{-1}. Application of 120 kg N ha^{-1} significantly increased the total nitrogen uptake by wheat grain and straw by 34.4 and 47.4 % than that of 60 kg N ha^{-1} during the year 2014–15 and 2015–16, respectively. The increase in N uptake with increase in the nitrogen levels was due to higher biomass production and higher nitrogen concentration in grain and straw at higher nitrogen levels. Pandey *et al.* (2001) reported significant increase in the N uptake by wheat with increasing nitrogen levels under Sahelian environment. During both the years, effect of tillage, residue and nitrogen interaction was not significant on nitrogen uptake by wheat grain and straw.

Nitrogen utilization efficiency by wheat: Neither tillage nor crop residue mulch significantly influenced NUtE by wheat (Table 5). However, NUtE by wheat decreased with increase in nitrogen levels during both the years of study. This may be attributed to the losses of nitrogen at higher level of N application and also due to the fact that yield of wheat didnot increase in the same proportion as that of increase in nitrogen application. Similar results have been reported by

Table 5. Total Nitrogen uptake and nitrogen utilization efficiency of wheat as influenced by tillage, residue and nitrogen management

Treatment	Total N uptake (kg ha^{-1})		N Utilization Efficiency	
	2014–15	2015–16	2014–15	2015–16
Effect of tillage				
CT	109.78^{A}	87.45^{A}	41.4^{A}	37.2^{A}
NT	105.44^{A}	93.53^{A}	40.4^{A}	35.5^{A}
Effect of residues				
R_0	108.79^{A}	89.14^{A}	41.2^{A}	37.0^{A}
R_+	106.43^{A}	91.83^{A}	40.6^{A}	35.7^{A}
Effect of nitrogen				
N_{60}	84.53^{B}	61.39^{C}	44.4^{A}	42.9^{A}
N_{120}	113.61^{A}	90.48^{B}	40.0^{AB}	36.0^{B}
N_{180}	124.69^{A}	119.59^{A}	38.2^{B}	30.2^{C}
Effect of tillage ×residue×nitrogen				
CTR_0N_{60}	88.83^{a}	60.33^{a}	45.5^{a}	47.3^{a}
CTR_0N_{120}	119.30^{a}	90.30^{a}	37.0^{a}	35.7^{a}
CTR_0N_{180}	119.73^{a}	115.20^{a}	40.0^{a}	31.5^{a}
CTR_+N_{60}	89.90^{a}	57.10^{a}	44.9^{a}	42.1^{a}
CTR_+N_{120}	116.67^{a}	85.20^{a}	41.0^{a}	38.0^{a}
CTR_+N_{180}	124.23^{a}	116.57^{a}	39.8^{a}	28.7^{a}
NTR_0N_{60}	69.80^{a}	62.47^{a}	47.3^{a}	41.7^{a}
NTR_0N_{120}	119.67^{a}	84.07^{a}	40.9^{a}	36.0^{a}
NTR_0N_{180}	135.43^{a}	122.50^{a}	36.4^{a}	29.7^{a}
NTR_+N_{60}	89.60^{a}	65.67^{a}	40.0^{a}	40.3^{a}
NTR_+N_{120}	98.80^{a}	102.37^{a}	41.2^{a}	34.4^{a}
NTR_+N_{180}	119.37^{a}	124.10^{a}	36.5^{a}	30.9^{a}
LSD (T)	NS	NS	NS	NS
LSD (R)	NS	NS	NS	NS
LSD (N)	20.00*	6.68*	4.8*	2.7*
LSD	NS	NS	NS	NS

#Values in a column followed by same letters are not significantly different at p<0.05 as per DMRT ;The uppercase letters and the lower case letters are used for comparing main plot and subplot effects, respectively; * Significant at p<0.05

many workers (Bandyopadhyay *et al.*, 2009; Chakraborthy *et al.*, 2010; Pradhan *et al.,* 2013 and Pradhan *et al.,* 2014). Nitrogen Utilization Efficiency by wheat ranged from 36.4 (NT R_0 N_{180}) to 47.3 kg grain kg^{-1} N uptake (NT R_0 N_{60}) with a mean value of 40.9 kg grain kg^{-1} N uptake during the year 2014–15 whereas during the year 2015–16, it ranged from 28.7 (CT R_+ N_{180}) to 47.3 kg grain kg^{-1} N uptake (CT R_0 N_{60}) with a mean value of 36.4 kg grain kg^{-1} N uptake. During the year 2014–15, application of 60 kg N ha^{-1} significantly increased the NUtE by 16.4% than that of 180 kg N ha^{-1}, whereas there was no significant difference between 60 kg N ha^{-1} and 120 kg N ha^{-1}

dose with respect to NUtE. However, during the year 2015–16, application of 60 kg N ha^{-1} significantly increased NUtE of wheat by 18.9 and 41.9 % than that of 120 kg N ha^{-1} and 180 kg N ha^{-1}, respectively. During the year 2015–16, application of 120 kg N ha^{-1} significantly increased NUtE by 19.3 % than that of 180 kg N ha^{-1}. During both the years, effect of tillage, residue and nitrogen management interaction was not significant on NUtE by wheat.

Calibration of DSSAT 4.6 model for the HD-2967 cultivar of wheat: DSSAT model was calibrated using yield data, maximum LAI, harvest index and flowering days values for the year 2014–15. Local soil and weather parameters, initial conditions of experiment and management practices were used for running the model. The genetic coefficients were estimated using the best fit method *i.e.* by iteratively varying the values of the coefficients to produce a close match (within 10%) between simulated and measured grain and biomass yield. The seven critical genetic coefficients and some ecotype coefficients for the model have been calibrated (Table 6).

Validation of DSSAT model to predict grain and biomass yield of wheat: The model was validated with an independent dataset generated from the field experiment on tillage, residue and nitrogen interaction during the year 2015–16 (Table 7 and 8). During the validation, the mean observed grain yield of wheat was 3158 kg ha^{-1} as against mean simulated grain yield of 3009 kg ha^{-1}. The prediction error ranged from 22.0 % (CT R_+ N_{180}) to –22.7 % (NT R_+ N_{60}) with a mean value of –5.6%. The evaluation of the DSSAT model with respect to grain yield showed that observed grain yield of wheat accounted for 75.9% variation in the simulated grain yield of wheat. The RMSE between the observed and simulated grain yield of wheat was 412 kg ha^{-1}, which accounted for 13% of the mean observed grain yield of wheat, which indicates fair agreement between the observed and simulated grain yield of wheat (Fig. 1). RMSEs and RMSEu were 66.2 and 98.8 kg ha^{-1}, respectively (Table 11). Higher RMSEu indicates higher unsystematic error i.e. error in experimentation than the systematic error *i.e.* error in the

Table 6. Genotype and ecotype coefficients for wheat (*cv* HD2967) calibrated for DSSAT model

Parameter	Acronym	Value
Genotype coefficients		
Days, optimum vernalizing temperature, required for vernalization	P1V	09.87
Photoperiod response (% reduction in rate/10 h drop in pp)	P1D	93.71
Grain filling (excluding lag) phase duration (°C.d)	P5	500.3
Kernel number per unit canopy weight at anthesis (number/g)	G1	13.46
Standard kernel size under optimum conditions (mg)	G2	46.80
Standard, non–stressed mature tiller weight (including grain) (g dry weight)	G3	1.900
Interval between successive leaf tip appearances (°C.d)	PHINT	100.0
Ecotype coefficients		
Duration of phase end juvenile to terminal spikelet (PVTU)	P1	410
Duration of phase terminal spikelet to end leaf growth (TU)	P2	230
Duration of phase end leaf growth to end spike growth (TU)	P3	150
Duration of phase end spike growth to end grain fill lag (TU)	P4	150
Vernalization effect (fr)	VEFF	0.2
Minimum grain N (%)	GN%MN	1.4
Standard grain N (%)	GN%S	2.4
PAR extinction coefficient	KCAN	0.90
Area of standard first leaf (cm^2)	LA1S	2.5
PAR conversion to dm ratio, after last leaf (g/MJ)	PARU2	3.0
PAR conversion to dm ratio, before last leaf stage (g/MJ)	PARUE	3.0
Final leaf senescence ends	LSPHE	6.0
Tiller production starts	TIL#S	3.5
Specific leaf area, standard first leaf (cm^2/g)	SLAS	450
Tiller initiation (rate) factor	TIFAC	1.5
Tillering phase end stage (growth stage)	TIPHE	2.5

Table 7. Validation of the DSSAT model to simulate grain yield of wheat for the year 2015-16

Treatment	Observed grain yield (kg ha^{-1})	Simulated grain yield (kg ha^{-1})	Prediction error (%)
CTR_0N_{60}	2836	2195	-22.6
CTR_0N_{120}	3187	3150	-1.2
CTR_0N_{180}	3592	3928	9.4
CTR_+N_{60}	2412	2195	-9.0
CTR_+N_{120}	3343	3170	-1.0
CTR_+N_{180}	3203	4077	22.0
NTR_0N_{60}	2592	2094	-19.2
NTR_0N_{120}	3028	2928	-3.3
NTR_0N_{180}	3622	3530	-2.5
NTR_+N_{60}	2702	2088	-22.7
NTR_+N_{120}	3544	3024	-14.7
NTR_+N_{180}	3833	3725	-2.8
Mean	3158	3009	-5.6

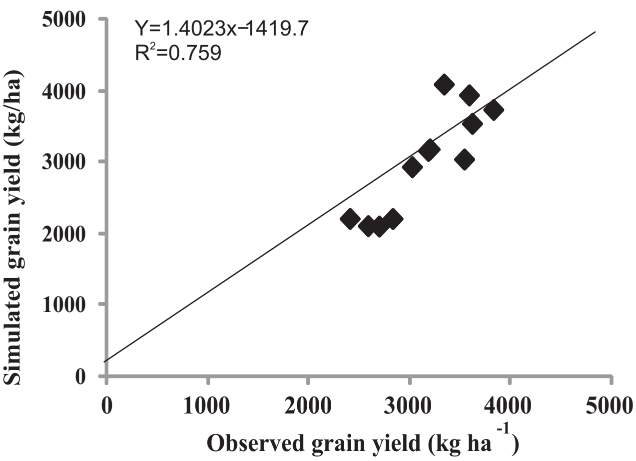

Fig. 1. Observed and simulated grain yield of wheat during validation

model simulation. The Wilmott D-index was 0.98, which indicates good agreement between observed and simulated grain yield of wheat. The CRM was 0.047 and positive value indicates that model under-predicted the grain yield of wheat. However, Singh *et al.* (2008) observed that the measured grain yield of wheat account for 88% variation of simulated grain yield by CERES-Wheat in sandy-loam soil with RMSE of 0.63 t ha^{-1}. Arora *et al.* (2007) reported nRMSD of 25% between observed and DSSAT simulated grain yield of wheat in sandy-loam soil. Timsina *et al.* (2008) reported nRMSE of 15.1% and d-index of 0.92 between observed and DSSAT simulated grain yield of wheat in sandy-loam soil of Punjab, which is in order with the present study. Rezzoug *et al.* (2008) reported RMSE of 0.7 and 0.79 t ha^{-1} during calibration and validation of DSSAT model in sandy clay loam soil under hot summer Mediterranean climate.

Table 8. Validation of the DSSAT model to simulate biomass yield of wheat for the year 2015-16

Treatment	Observed grain yield (kg ha^{-1})	Simulated grain yield (kg ha^{-1})	Prediction error (%)
CTR_0N_{60}	7905	6681	-15.5
CTR_0N_{120}	8556	8811	3.0
CTR_0N_{180}	9479	10478	10.5
CTR_+N_{60}	6801	6675	-1.9
CTR_+N_{120}	8370	8820	5.4
CTR_+N_{180}	9693	10770	11.1
NTR_0N_{60}	7324	6433	-12.2
NTR_0N_{120}	8434	8343	-1.1
NTR_0N_{180}	10422	9622	-7.7
NTR_+N_{60}	7522	6398	-14.9
NTR_+N_{120}	9989	8551	-14.4
NTR_+N_{180}	10259	10059	-1.9
Mean	8730	8470	-3.3

The mean observed biomass yield of wheat was 8730 kg ha^{-1} as against mean simulated biomass yield of 8470 kg ha^{-1}. The prediction error ranged from 11.1 (CT R_+ N_{180}) to -15.5% (CT R_0 N_{60}) with a mean value of -3.3%. The evaluation of the DSSAT model with respect to biomass yield of wheat indicated that the observed above ground biomass yield of wheat accounted for 72.8% variation in the simulated biomass yield of wheat (Fig. 2). The RMSE between the observed and simulated biomass yield of wheat was 854.1 kg ha^{-1}, which accounted for 9.8% of the mean observed biomass yield of wheat. Since nRMSE was less that 10%, it indicates very good agreement between the observed and simulated biomass yield of wheat. RMSEs and RMSEu were 85.6 and 246.6 kg ha^{-1}, respectively. Higher RMSEu indicates higher unsystematic error i.e. error in experimentation than

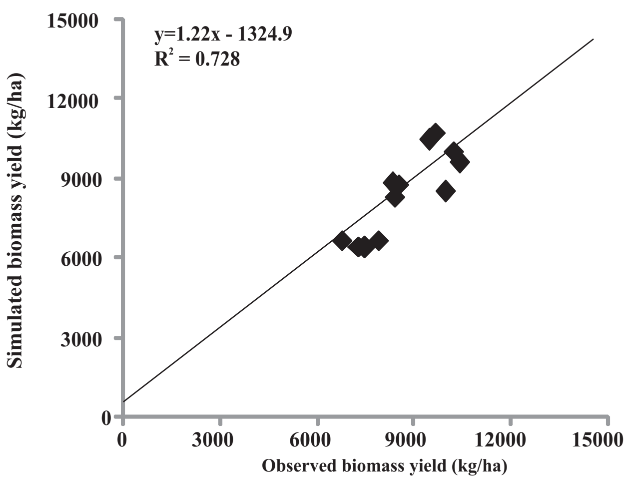

Fig. 2. Observed and simulated biomass yield of wheat during validation

the systematic error i.e. error in the model simulation. The d-index was 0.99 indicating good agreement between the observed and simulated biomass yield of wheat. The CRM was 0.03 and the positive value indicates that model under-predicted the biomass yield of wheat (Table 11). However, Singh *et al.* (2008) reported that the measured biomass yield of wheat account for 93% variation of simulated biomass yield by CERES-Wheat in sandy-loam soil with RMSE of 1.27 t ha^{-1}, whereas, Arora *et al.* (2007) reported nRMSD of 14% between observed and DSSAT simulated biomass yield of wheat in a sandy-loam soil.

Validation of DSSAT model to simulate nitrogen uptake and nitrogen utilization efficiency (NUtE) of wheat: The mean observed N uptake of wheat under different tillage, residue and nitrogen management was 90.5 kg ha^{-1} as against mean simulated value of 80.7 kg ha^{-1} (Table 9 and 10). The prediction error ranged from -25.7 % (NT R_0 N_{180}) to 12.6% (CT R_+ N_{60}) with a mean value of -8.3 %. Evaluation of the model with respect to total N uptake indicated that the observed N uptake of wheat accounted for 88.3% variation in the simulated N uptake. The higher R^2 (0.883) reported in the study indicated that the model could satisfactorily simulate N uptake in wheat (Fig. 3). The RMSE between the observed and simulated N uptake was 15.19 kg ha^{-1} which accounted for 16.8% of the mean observed N uptake. RMSEs and RMSEu were 4.15 and 1.45 kg ha^{-1}, respectively. Higher RMSEs indicates higher systematic error i.e. error in the model simulation than unsystematic error i.e. error in experimentation. The d-index *i.e.* index of agreement was 0.98, which implies good agreement between the observed and simulated N uptake. The CRM was 0.108 and the positive value indicates that model under-predicted the total nitrogen uptake of wheat (Table 11). However, Arora *et al.* (2007) reported RMSD of 13 kg ha^{-1} and nRMSD of 18% while validating DSSAT model with respect to N uptake of wheat under different irrigation and nitrogen management practices in sandy-loam soil of Punjab. These values are in agreement with the present study.

Table 9. Validation of the DSSAT model to simulate total nitrogen uptake of wheat for the year 2015-16

Treatment	Observed N uptake (kg ha^{-1})	Simulated N uptake (kg ha^{-1})	Prediction error (%)
CTR_0N_{60}	60.3	63	4.4
CTR_0N_{120}	90.3	84	-7.0
CTR_0N_{180}	115.2	99.9	-13.3
CTR_+N_{60}	57.1	64.3	12.6
CTR_+N_{120}	85.2	84.9	-0.3
CTR_+N_{180}	116.6	102.9	-11.7
NTR_0N_{60}	62.5	60.3	-3.4
NTR_0N_{120}	84.0	78.4	-6.7
NTR_0N_{180}	122.5	91	-25.7
NTR_+N_{60}	65.7	62.1	-5.4
NTR_+N_{120}	102.4	81.8	-20.1
NTR_+N_{180}	124.1	96.1	-22.6
Mean	90.5	80.7	-8.3

Table 10. Validation of the DSSAT model to simulate nitrogen utilization efficiency of wheat for the year 2015-16

Treatment	Observed N utilization efficiency (kg grain kg^{-1} N uptake)	Simulated N utilization efficiency (kg grain kg^{-1} N uptake)	Prediction error (%)
CTR_0N_{60}	47.3	34.8	-26.5
CTR_0N_{120}	35.7	37.5	4.9
CTR_0N_{180}	31.5	39.3	24.7
CTR_+N_{60}	42.1	34.2	-18.8
CTR_+N_{120}	37.9	37.3	-1.7
CTR_+N_{180}	28.7	39.6	38.0
NTR_0N_{60}	41.7	34.7	-16.8
NTR_0N_{120}	36.0	37.4	3.8
NTR_0N_{180}	29.7	38.8	30.7
NTR_+N_{60}	40.3	33.6	-16.6
NTR_+N_{120}	34.4	37	7.5
NTR_+N_{180}	30.9	38.8	25.4
Mean	36.4	36.9	4.6

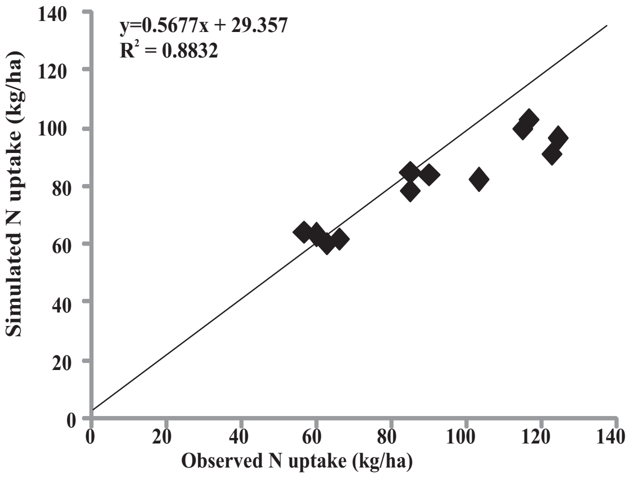

Fig. 3. Observed and simulated total N uptake by wheat during validation

The observed and simulated N utilization efficiency (NUtE) of wheat during validation for the year 2015-16 are presented in Table 10. The mean observed NUtE of wheat was 36.4 kg grain kg^{-1} N uptake as against mean simulated value of 36.9 kg grain kg^{-1} N uptake. The prediction error ranged from -26.3% (CT R_0 N_{60}) to 38.0% (CT R_+ N_{180}) with a

Table 11. Statistical summary comparing observed data with simulated values for wheat crop grown under different tillage, residue and nitrogen management during validation of DSSAT wheat simulation model

Parameter	PE	R^2	RMSE	nRMSE	D	CRM	RMSEs	RMSEu
Grain yield	−5.6	0.759	412.0	13.0	0.98	0.047	66.2	98.8
Biomass yield	−3.3	0.728	854.1	9.8	0.99	0.030	85.6	246.6
N uptake	−8.3	0.883	15.19	16.8	0.98	0.108	4.15	1.45
NUtE	4.6	0.805	7.36	20.2	0.97	−0.015	2.11	0.26

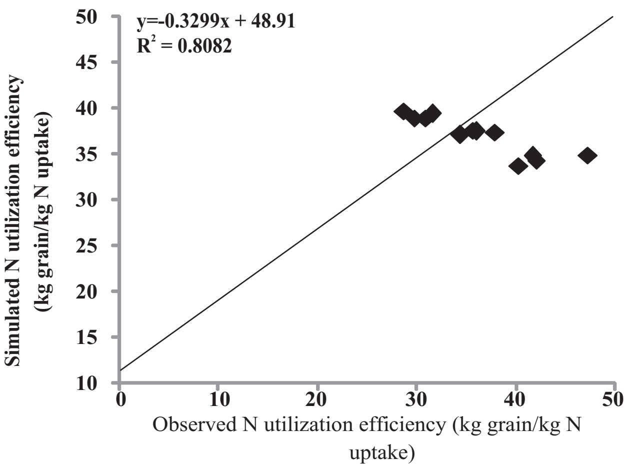

Fig. 4. Observed and simulated nitrogen utilization efficiency by wheat during validation

mean value of 4.6%. The evaluation of the model with respect to NUtE, indicated that the observed NUtE of wheat accounted for 80.5% variation of the simulated NUtE. However, it was observed that there was negative correlation between the observed and simulated NUtE of wheat (Fig. 4). This was due to the fact that NutE decreased with the increase in the N dose but model simulated an increase in the NUtE with the increase in N dose. So it may be inferred that the model could not simulate the NUtE of wheat properly. The RMSE between the observed and simulated NUtE of wheat was 7.36 kg grain kg^{-1} N uptake, which accounted for 20.2% of the mean observed NUtE of wheat (Table 11). The RMSEs and RMSEu were 2.11 and 0.26 kg grain kg^{-1} N uptake, respectively. Higher RMSEs indicates higher systematic error i.e. error in the model simulation than unsystematic error i.e. error in experimentation. The CRM was −0.015 and the negative value indicate that model over-predicted the NUtE of wheat (Table 11). This suggests the need for modification of the parameters responsible for carbon and nitrogen partitioning in plant module of CERES − Wheat model of DSSAT 4.6 to improve its accuracy.

CONCLUSION

From the present study, it was concluded that nitrogen uptake by wheat grain and straw and grain protein content increased significantly with increase in the nitrogen levels. However, there was no significant difference between tillage and residue management with respect to N uptake and grain protein content in wheat crop. Nitrogen Utilization Efficiency (NUtE) by wheat decreased significantly with increase in the nitrogen levels. Farmers could successfully adopt NT system with crop residue mulch to get the economic benefits by saving their labour, fuel and time without significant reduction in grain yield. It is recommended for an upward revision of Nitrogen dose in irrigated wheat crop for attaining better yield if high temperature and rainfall deficit is forecasted. Crop simulation model DSSAT 4.6 could significantly simulate grain yield, biomass yield and N uptake in wheat but could not simulate NUtE of wheat under different tillage, residue and nitrogen management conditions with an acceptable level of accuracy. This validated DSSAT 4.6 crop model for cultivar HD-2967 of wheat can be used to simulate the yield and nitrogen uptake of wheat under different input management scenario, which will help in taking critical decisions with respect to efficient use of inputs and selection of appropriate management practices for sustainable wheat production in the Indo-gangetic plain region.

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Evaluation of Sediment Using GIS Approach in Southern Tamilnadu, India

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Abstract: Most of the reservoir is losing its capacity due to sedimentation. Remote sensing technique was adopted to estimate the water-spread area at different water levels of Vaigai reservoir, India. The ASTER satellite imagery of nine different satellite overpass dates (from year 2000 to 2014) was collected. The water spread area of the reservoir on nine different satellite overpass dates and corresponding elevations were calculated by using Geographical Information system (GIS). Finally, it was inferred that 31.886 Mm^3 of the capacity has been lost due to sedimentation at Vaigai reservoir in a period of 56 years (1958-2014).

Keywords: Reservoir Sedimentation, Soil erosion, Remote sensing, Geographic Information System

Today, nearly all major river systems in the world have dams built across them for the purpose of irrigation, drinking water, and hydroelectric power generation (Jeyakanthan and Sanjeevi, 2013). One of the important factors in reservoir design and operation is the sedimentation problem caused mainly by soil erosion. The problems caused by soil erosion include loss of soil nutrients, declining crop yields, reduction in soil productivity (Renard *et al*., 1997). Worldwide, each year, about 75 billion tons of soil is eroded from the land-a rate that is about 13-40 times as fast as the natural rate of erosion (Zuazo *et al*., 2009). Asia has the highest soil erosion rate of 74 ton/acre/year (El-Swaify, 1997) and Asian rivers contribute about 80 per cent of the total sediments delivered to the world oceans and amongst these Himalayan rivers are the major contributors (up to 50% of the total world river sediment flux). The Indian Reservoirs annually losses water storage capacity from 0.5 to 1.0 percentage (Narasayya *et al*., 2013).

Accelerated soil erosion by water is responsible for about 56 per cent and wind erosion is responsible for about 28 per cent. This means that the area affected by water erosion is roughly around 11 million square km, and the area affected by wind erosion is around 5.5 million square km (Mahabaleshwara and Nagabhushan, 2014). In reality, all the sediment does not settle in the dead storage. Sediment that settles over the dead storage will reduce the effective storage. So the sediment deposition pattern is necessary to know distribution of sediment and fluctuation of the sediment volume that settles in the reservoir, either in dead storage or effective storage (Wulandari *et al*., 2015). Vaigai Reservoir suffers severe sedimentation due to rainfall. The other sources of the sediment into the Vaigai Dam are deforestation, road construction and cultivation on steep slopes (Jain *et al*., 2002). Nevertheless, the sediment deposition in the reservoirs reduces the water storage capacity of the reservoirs and also affects their useful life span. However, quantifying the sediment deposited is a complex problem for water resource planners (Narasayya *et al*., 2013; Jeyakanthan and Sanjeevi, 2013). The most common techniques used to calculate the volume of sediment deposited are direct measurements by hydrographic surveys and indirect measurement using the inflow-outflow records of a reservoir. Nevertheless, these conventional methods are time consuming, expensive and involve more workers (Jeyakanthan & Sanjeevi, 2013). An alternate to conventional methods, remote sensing technique can be used, which is cost and time effective method to estimate the live capacity of a reservoir (Jeyakanthan and Sanjeevi, 2013; Jain *et al*., 2002). Geospatial technique gives us directly the water spread area of the reservoir at a particular elevation on the date of pass of the satellite (Narasayya *et al*., 2013). Any decrease in the water spread area at a specified elevation over a period is indicative of the sediment deposition at that elevation. This when integrated over a range of water levels helps in computing volume of storage lost through sedimentation. Thus, by monitoring the changes of water-spread areas at various operating levels of the reservoir, the quantity of the sediment load that has settled down over a period can be assessed (Mukherjee *et al*., 2007).

The objectives of this research were to calculate the water spread area with elevation and compute the volume of sediment in the reservoir. Integrated use of remote sensing and GIS can be used in soil sedimentation assessment studies. In this research, ASTER imagery from 2000 to 2014 is used to calculate the water spread area and construct a multi-seasonal water spread pattern of the Vaigai Dam. Based on this, the sediment volume can be computed.

MATERIAL AND METHODS

Vaigai Dam located in Periyakulam Taluk of Theni District, Tamil Nadu State of India is selected for assessment of sedimentation using Remote Sensing. It is situated between $10^{0} 00^{'}$ and $10^{0} 10^{'}$ North Latitudes and $77^{0}30^{'}$ and $77^{0} 40^{'}$ East Longitude and it is built across the Vaigai River in Periyar Vaigai Basin during 1955 to 1958 (Fig. 1). The catchment area of the reservoir is 2255.127sq.km and the full reservoir level (FRL) 279.197 m. The live storage of the reservoir lies between 257.556m and 279.197 m above mean sea level. The dead storage capacity lies between 249.936 m and 257.556 m (a.m.s.l). The capacity of the reservoir at maximum water level is 194.785 Mm^3. The average monthly temperature is in the range of 30ºC to 35ºC and an average monthly rainfall of 1017.5mm to 1586.9 mm, respectively. An

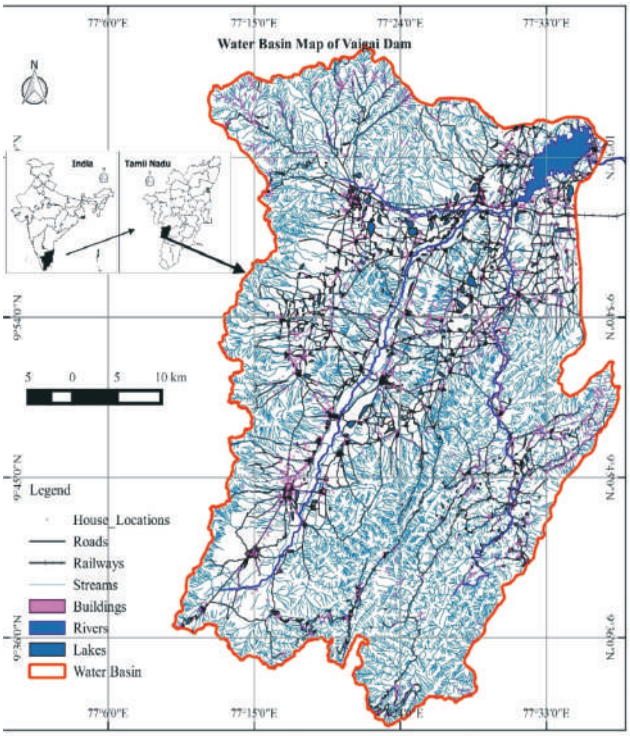

Fig. 1. Location map of Vaigai reservoir and catchment area

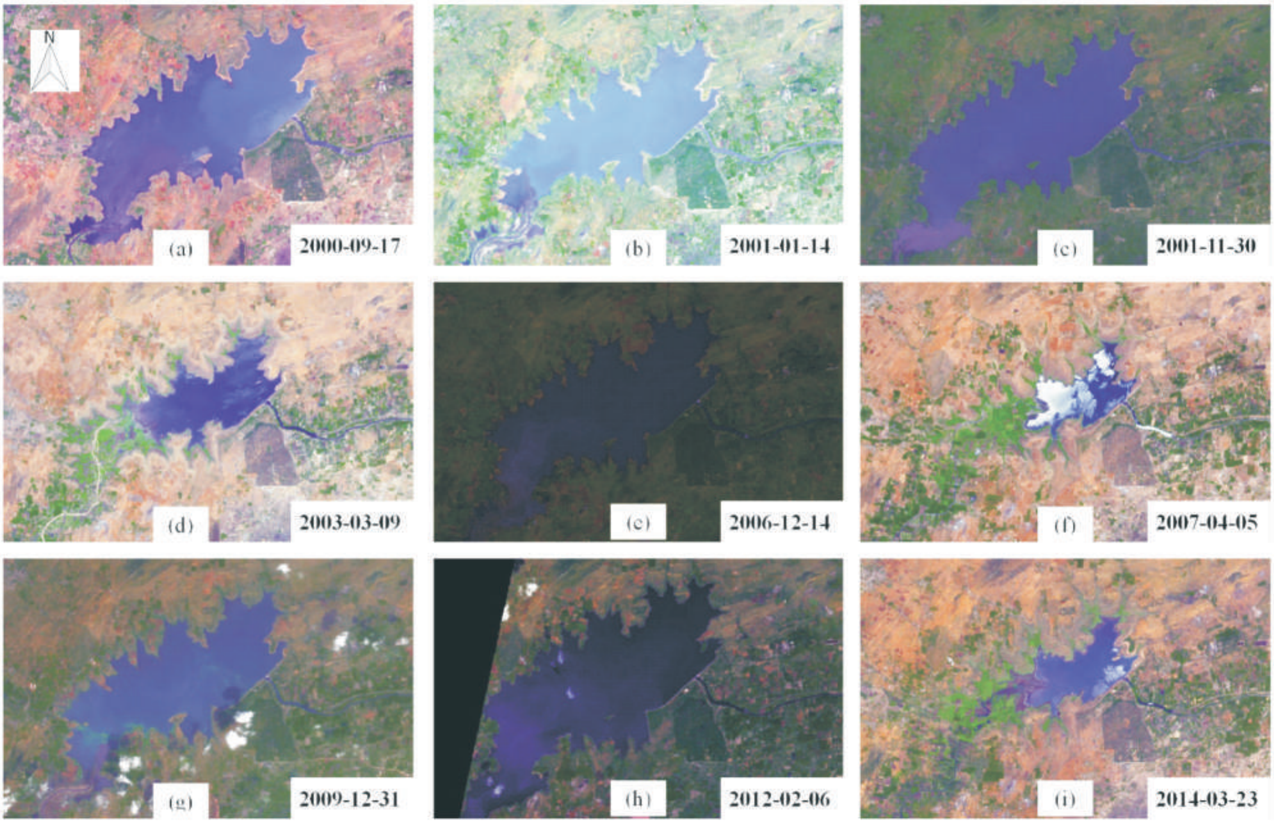

Fig. 2. Temporal data of ASTER satellite imagery; (a). Date of imagery 2000-09-17, (b). Date of imagery 2001- 01-14, (c). Date of imagery 2001-11-30, (d). Date of imagery 2003-03-09, (e). Date of imagery 2006-12-14, (f). Date of imagery 2007-04-05, (g). Date of imagery 2009-12-31, (h). Date of imagery 2012-01-06, and (i). Date of imagery 2014-03-23

important variability is observed between different years. Such variability is eventually related to sediment or soil erosive events. The soils are of deep sandy loam with reddish colour. The area is built with Archean rocks, which composes of gneiss, mica, quartzite, granite gneiss, granites, veins of pegmatites and quartz veins.

Data collection:. The topographical details were purchased from Survey of India (SOI) Toposheet numbers 58F/4, 58F/8 , 58F/12 , 58G/1, 58G/2, 58G/5, 58G/6, 58G/9, and 58G/10 (Scale: 1:50,000) (Table 1). Advanced Space-borne Thermal Emission and Reflection Radiometer (ASTER) Imagery was collected from National Aeronautics and Space Administration (NASA). Spatial resolution of ASTER imagery is 15m. The cloud free data of nine different years (overpass) from the year 2000 to 2014 were used in this study. Based on the status and availability of ASTER imagery and the time spacing between the satellite data, nine scenes were obtained for the following dates of pass: 17 September 2000, 14 January 2001, 30 November 2001, 9 March 2003, 14 December 2006, 5 April 2007, 31 December 2009, 6 January 2012, 23 March 2014. Temporal resolution data of ASTER satellite imagery were used as shorter interval (Fig. 2). The water levels on these days were obtained from the dam authorities (Narasayya *et al*., 2013). Conventional method of surveying may be conducted at longer intervals and the remote sensing based sedimentation surveys may be carried out at shorter intervals, so that both surveys complement one another. Report of Sedimentation studies done during the fourth capacity survey of Vaigai reservoir in the year 2000 was used as long interval data. The Stage-Capacity-Sedimentation data for the years 1958, 1976, 1981,1983 and 2000 are shown in Table 2, water spread area map/ base map of scale 1:3960 and the water elevations of the reservoir at different dates were obtained from the concerned authorities.

Data preparation: The topographic sheets were scanned and geo-referenced with uniform coordinate system i.e. World Geodetic System 84 (WGS 84). Similarly, ASTER imagery was geometrically corrected with the help of image processing software environment. The data were prepared with the help of GIS software using ASTER satellite imagery coupled with Survey of India topographical sheets of 1:50000 scale. The data was collected and stored in vector form (point, Line and Polygon) and also uniform coordinate reference system (WGS 84, UTM Zone 43N) was maintained

Table 1. Data sets used for this study

Name	Type	Source
Topographic sheets (number 58F/4,58F/8, 58F/12, 58G/1, 58G/2, 58G/5, 58G/6, 58G/9, and 58G/10)	Hard copy (1:50000)	Survey of India
Satellite Imagery (different passes 2000, 2001, 2003, 2006, 2007, 2009, 2012 and 2014)	Raster (15m resolution)	NASA
Vaigai Dam capacity-sedimentation survey report (year 1958, 1976, 1981,1983 and 2000)	Report	Public Works Department

Table 2. Capacity -Sedimentation survey report of Vaigai reservoir for the years 1958, 1976, 1981, 1983 and 2000

Elevation in m	Depth from deep bed level	Per cent of depth	Capacity in 1958 in Mm^3	Capacity in 1976 in Mm^3	Capacity in 1981 in Mm^3	Capacity in 1983 in Mm^3	Capacity in 2000 in Mm^3	Sediment deposit of 2000 in Mm^3	Per cent of sediment
249.936	0.000	0.000	–	–	–	–	–	–	–
257.556	7.620	26.041	1.456	0.079	–	–	–	1.456	5.153
258.000	8.064	27.559	1.732	0.125	–	–	0.0036	1.728	6.116
260.000	10.064	34.394	3.583	0.536	0.186	0.194	0.1256	3.457	12.236
262.000	12.064	41.223	7.002	1.845	1.026	1.129	0.5366	6.465	22.883
264.000	14.064	48.064	12.115	4.906	3.295	3.466	1.9258	10.189	36.064
266.000	16.064	64.899	20.338	10.489	8.346	8.118	5.7732	14.565	51.553
268.000	18.064	61.734	31.988	19.634	16.885	16.010	13.8887	18.100	64.066
270.000	20.064	68.569	46.436	33.525	29.294	28.720	26.9800	19.456	68.865
272.000	22.064	75.404	67.867	52.102	47.515	47.249	44.7621	23.104	81.778
274.000	24.064	82.239	93.407	77.006	72.128	72.264	68.1768	25.228	89.296
276.000	26.064	89.074	126.093	109.567	104.494	104.739	99.7704	26.323	93.172
278.000	28.064	95.909	166.649	149.688	144.294	144.399	139.0925	27.557	97.539
279.197	29.261	100.00	194.785	178.191	172.439	172.380	166.5334	28.252	100.000

for vector layers and raster layers. The base map of entire catchment area was created (Fig. 1). The volume of sedimentation depends upon the parameters like the type of catchment, nature of catchment, geology, slope and terrain, rainfall, climate, vegetal cover and human activities (Mahabaleshwara and Nagabhushan, 2014). Normally, no universal solution is available for tracking the sedimentation problem since every reservoir has anomalies in the above said parameters. Hence, it is necessary that every reservoir has to be surveyed periodically. After inception of the reservoir in 1958, the first, second, third and fourth surveys were carried out during 1976, 1981, 1983 and 2000, respectively under the Watershed Management Board Scheme.

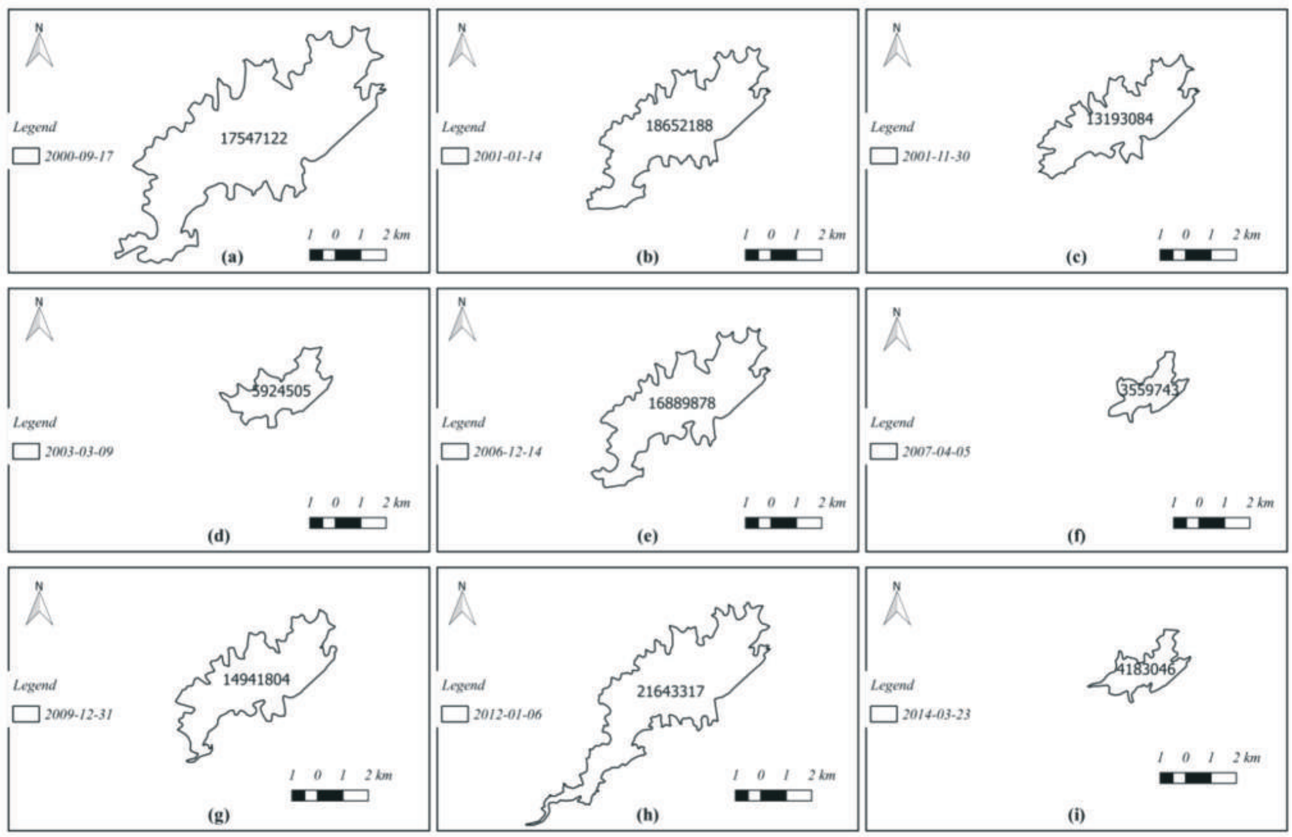

Fig. 3. Water spread area map of Vaigai Dam, computed using temporal data of ASTER satellite imagery; (a). Date of imagery 2000-09-17, (b). Date of imagery 2001-01-14, (c). Date of imagery 2001-11-30, (d). Date of imagery 2003-03-09, (e). Date of imagery 2006-12-14, (f). Date of imagery 2007-04-05, (g). Date of imagery 2009-12-31, (h). Date of imagery 2012-01-06, and (i). Date of imagery 2014-03-23

Table 3. Chart representing the capacity of vaigai reservoir using remote sensing technique

Elevation In (m)	Water spread area using satellite imagery	Date of satellite over passing	Capacity of reservoir using satellite imagery	Cumulative capacity of reservoir
257.556	–	Dead storage	3.753	–
266.71	1.23	5 Apr., 2007	0.690	3.753
266.98	4.18	23 Mar., 2014	9.245	4.443
268.82	5.92	9 Mar., 2003	55.981	13.688
273.79	17.65	14 Jan., 2001	15.462	69.669
274.74	14.94	31Dec., 2009	13.837	85.131
275.61	16.89	14 Dec., 2006	11.020	98.968
276.25	17.55	17 Sep.,2000	8.425	109.988
276.80	13.19	30 Nov., 2001	18.473	118.413
277.95	19.12	6 Jan., 2012	26.013	136.886
279.197	22.652	Full reservoir elevation		162.899

Table 4. Chart representing the capacity loss due to sedimentation in Vaigai reservoir for various dates of satellite over pass

Elevation In (m)	Capacity in 1958 (Mm^3)	Date of satellite over passing	Capacity of reservoir using satellite imagery	Capacity loss in (Mm^3) using satellite imagery
257.556	1.456	Dead storage	–	–
266.71	24.47	5 Apr., 2007	3.753	20.717
266.98	26.05	23 Mar., 2014	4.443	21.607
268.82	37.91	9 Mar., 2003	13.688	24.222
273.79	90.73	14 Jan., 2001	69.669	21.061
274.74	105.50	31 Dec., 2009	85.131	20.369
275.61	119.72	14 Dec., 2006	98.968	20.752
276.25	131.16	17 Sep., 2000	109.988	21.172
276.80	142.32	30 Nov., 2001	118.413	23.907
277.95	165.64	6 Jan., 2012	136.886	28.754
279.197	194.785	Full reservoir elevation	162.899	31.886

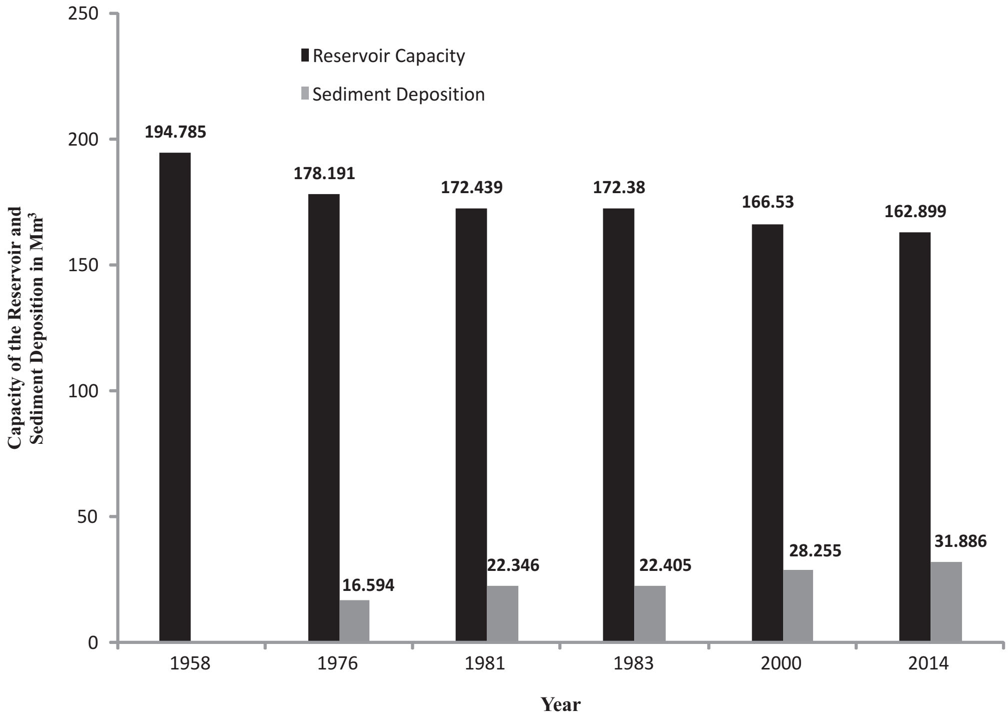

Fig. 4. Figure showing the capacity and sediment deposition of the reservoir for various years from its inception

Computation of water spread area: The water spread area can be calculated by image classification approach. However, in this study the catchment area was digitized by using head-up digitization method for 9 satellite imageries. The area was computed using geometry tool in GIS software. From the original elevation-capacity data, the original capacity at the intermediate elevations corresponding to reservoir elevations on the dates of satellite pass was obtained by linear interpolation. The revised capacity was compared with the original capacity of the reservoir and the difference between these two represents the capacity loss due to sedimentation

Assessment of Vaigai reservoir capacity: The volume of sediment deposit between two reservoir levels is computed from the difference between previous capacity survey and satellite-derived water spread area. The water-spread area of the reservoir was calculated from satellite data and the reservoir elevation corresponding to the date of pass was collected from the dam authority. The reservoir capacity between two consecutive elevations can be assessed using the Cone formula i.e. (Jeyakanthan and Sanjeevi, 2013).

$$V = ₦H \times (A_1+A_2+A_1 \times A_2)) / 3 \quad (1)$$

Where V – Volume/Capacity between two consecutive elevations 1 and 2

A_1 and A_2 – Water spread areas of reservoir at elevations 1 and 2

₦H – difference between elevations 1 and 2

Where V is the volume between two consecutive levels, A_1 is the contour area at elevation 1, A_2 is the contour area at elevation 2 and H is the difference between elevations 1 and 2 .

RESULTS AND DISCUSSION

The revised capacity in the zone between dead storage level and live storage level is 162.899 Mm^3, while the original capacity as calculated and envisaged in the study before the impoundment of the dam was 194.785 Mm^3. Thus, it can be inferred that 31.886Mm^3 of the capacity has been lost due to sedimentation in the zone under study in a period of 56 years (1958–2014). Hence, the rate of sedimentation in the reservoir is 0.569 Mm^3. In India, the sedimentation rate is generally specified as loss per unit catchment area per year; therefore, the loss rate in the zone under study is 252.488 m^3 /km^2 /year. However, in view of excellent results obtained through this approach, the exercise may be replaced with the latest satellite data.

CONCLUSIONS

The application of remote sensing techniques for estimating the sedimentation rate in the Vaigai shows that the average sedimentation rate for 56 years (1958–2014) is 252.488 m^3 /km^2 /year. Suitable conservation measures can be followed to reduce soil erosion and enhance the storage capacity of the reservoir.

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Scientific Methods of Assessing Groundwater for Irrigation Purpose – A Case Study in a Part of Cauvery River Basin, South India

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Abstract: In present study, an attempt is made to evaluate the quality of groundwater for intended usage for irrigation in Cauvery river basin on the basis of various criteria like Salinity Hazard, Sodicity Hazard, Alkalinity Hazard, Permeability Hazard and Specific ion Toxicity. Gibbs plot suggests that rock-water interaction is the main mechanism of geochemistry in the area. The ground water of the study area is generally low alkaline and high saline in nature. A total of 78 samples out of 100 groundwater samples have been found to fall under suitable category for irrigation based on the analysis of the indices. Samples represent high to very high saline and alkaline categories in regions of confluence of Noyyal and Amaravati rivers with Cauvery and also in agricultural belts of Bhavani river basin. Special types of irrigation methods are essential in such stations to control the high salinity consequently improving the yield.

Keywords*:* Groundwater, Cauvery river basin, Irrigation water quality, Gibbs plot, Wilcox plot

Water pollution across river basins varies in severity depending on the degree of urban development, agricultural and industrial practices and systems for collecting and treating wastewater (https://www.idfc.com/pdf/report/2011/Chp-1-A-River-Basin-Perspective-of-Water-Resources-and-C.pdf, 2011). The irrigated areas in the Cauvery basin have increased considerably from about 620, 000 hectares to 850,000 hectares, but proportionately increasing the water demand also. The groundwater levels within the basin range from less than 10 m during the post monsoon period to as deep as 50 m during the hot summer months and the beginning of the Southwest monsoon (François Molle and Philippus Wester, 2009). The competition for water resources in the Cauvery basin and its sub basins has increased pertaining to the rapid changes in water use. The quality of water has become a major threat in most of the river basins in India. Nearly about 70 per cent of the surface water resources and large proportions of groundwater reserves have been contaminated due to indiscriminate discharge of wastewater from the industry, agriculture, and domestic sectors which contain toxic organic and inorganic pollutants. The Indian peninsular rivers are principally fed by rain. During summer, their flow is greatly reduced, and some of them even dry up, until they get recharged in the next monsoon. Nearly all waters contain dissolved salts and trace elements, many of which result from the natural weathering of the earth's surface. In addition, drainage waters from irrigated lands and effluent from city sewage and industrial waste water can impact water quality. The pollution of water resources caused by the discharge of untreated municipal sewage and industrial effluents, and agro-chemical contamination of groundwater has further intensified the claim of good quality water.

The stress on water resources is apparently increasing due to the rising demands and the deteriorating quality of water. In many regions in India, the extraction of groundwater is more than the recharge. The groundwater resource has been exploited to the extent that, many regions in the country are facing severe problems. The overexploitation of groundwater has resulted in a number of problems, such as sea water ingression in coastal areas and pollution in different parts of the country. Groundwater is also polluted due to point and nonpoint source pollution. For example, occurrence of high fluoride content has been reported in 13 States in India. Other pollutants, such as arsenic in West Bengal, and iron in the north-eastern states, Orissa, and other parts of the country have also been reported. In the canal irrigated land of Haryana, Punjab, Delhi, Rajasthan, Gujarat, Uttar Pradesh, Karnataka, and Tamil Nadu, groundwater is affected due to salinization (the affected area comprises over 193,000 km^2 of land) (CWC Report, 2014).

Irrigation is essential for agricultural production in infertile and semiarid regions where rainfall is not sufficient to uphold crop growth. Irrigated agriculture consumes 60–80% of the total water usage and contributes nearly 38 % of the global food production. It has proved to be a principal factor in generating employment opportunities in the rural areas and providing food for affordable prices for downtrodden people in the urban area (Shahinasi and Kashuta, 2008).

In most situations, the primary water quality concern for irrigation is salinity levels, since salts can affect both the soil structure and crop yield. The desirable quality of irrigation water varies to a large extent, depending upon the salinity, soil permeability, toxicity, pH, nitrogen loading etc., some ions in irrigation water may be directly toxic to crops. Establishing toxicity limits in water is rather a complicated phenomenon characterised by the reactions, which take place once the water is applied to the soil and also depends upon the method of irrigation. When an element is added to the soil from irrigation, it may be inactivated by chemical reactions or it may build up in the soil until it reaches a toxic level. An element at a given concentration in water may be immediately toxic to a crop because of foliar effects if sprinkler irrigation is used. If furrow irrigation is used, it may require a number of years for the element to accumulate to toxic levels, or it may be immobilized in the soil and never reach toxic levels (CWC Report, 2014).

In India and various parts of the world, numerous studies have been carried out to assess the geochemical characteristics of groundwater (Sujatha and Reddy, 2003; Subramani *et al.,* 2005). But, the quality of the formation water from the deeper aquifers in part of the river basin is uniformly good and was suitable for all purposes. Cauvery River, being the major source of water for irrigation, less attention is being paid to ascertain the quality of groundwater in this basin amidst the reality of decreasing trend of groundwater potential. Hence, an attempt is made to evaluate the quality of groundwater based on chemical parameters for intended irrigational usage in this basin.

MATERIAL AND METHODS

The Cauvery basin lies in the states of Tamil Nadu, Karnataka and Kerala. Physio-graphically, the basin can be divided into three parts –The Western Ghats, the Plateau of Mysore and the Delta. The delta area is the most fertile tract in the basin. The principal soil types found in the basin are black soils, red soils, laterites, alluvial soils, forest soils and mixed soils. Red soils occupy large areas in the basin. Alluvial soils are found in the delta areas. The cultivable area of the basin is about 5.8 M ha, which is about 3% of the cultivable area of the country. The Cauvery River rises at Talakaveri on the Brahmagiri Range in the Western Ghats in Karnataka at an elevation of about 1,841 m and flows for about 800 kms before it outfalls into the Bay of Bengal. It is joined in its course through Karnataka and Tamil Nadu by a large number of Rivers such as the Harangi, the Hemavathi, the Arkavathi, the Lakshmantirtha, the Kabini and the Bhavani. Near Srirangam, in Tamilnadu, it divides into branches, the northern arm taking the name Coteroon, which remains the main River, and the southern arm which retains the name of Cauvery. The Basin experiences tropical climate and the main climatic feature is the monsoon rain. The north-east monsoon provides the greater portion of the annual precipitation; whereas, the western border of the basin is supported by the southwest monsoon. The eastern side of the basin gets most of the rain during the northeast monsoon. Depressions in the Bay of Bengal affect the basin in the monsoon, causing cyclones and widespread heavy rains (http://www.india-wris.nrsc.gov.in/wrpinfo/index.php? title=Cauvery).

The present study was conducted in a part of Cauvery River Basin covering an arial extent of around 2400 km^2 between the latitudes 10^0 57' 24" N and 11^0 29' 35.1" N and the longitudes 77^0 42' 40.7" E and 78^0 14' 17.9" E. Groundwater samples were collected from 100 open wells in the study area during March 2015 (pre-monsoon season). The sampling sites were chosen to be located at a radial distance of 5, 10 and 15 km intervals adjacent to the river banks across the longitudinal stretch of Cauvery River and its three tributaries namely, Bhavani, Noyyal and Amaravathi in the study area (Fig. 1). After the sampling, the samples were immediately transferred to the laboratory and were stored in refrigerator at 4°C. Electrical Conductivity (EC) and pH were measured electromagnetically in the field using digital meters immediately after sampling. The samples were analyzed for determining the concentration of various chemical constituents (Vega *et al*., 1998) such as, Na^+, K^+, Ca^{2+}, Mg^{2+}, Cl^-, HCO^{3-}, CO^{3-}, SO_4^{2-}, NO_3^-, F^-, and total dissolved solids (TDS) in the laboratory using the standard methods recommended by the American Public Health Association (APHA, 2005). TA, TH, Ca^{2+}, Mg^{2+} and Cl^- were estimated by titration, and Na^+ and K^+ were estimated using Flame photometer (Systronic-128). Estimation of BOD was done by Winkler titration. Fluoride was estimated by SPANDS, while SO_4^{2-}, NO_3^-, NO_2^- and NH_4^+ were determined using UV/VIS spectrophotometer.

It is important to identify and characterize the chemical composition of water being applied for irrigation purposes (Fatemeh *et al.,* 2011). Gibbs plots could be employed to gain better insight into hydro-geochemical processes such as precipitation, rock–water interaction, and evaporation on groundwater chemistry. Gibbs (1970) demonstrated that the mechanism controlling chemistry of waters can be evaluated from a plot of TDS against Na/ (Na + Ca) values, commonly referred as the Gibbs plots. In this present study, the assessment of groundwater for agricultural activities has been evaluated on the basis of various criteria like Salinity Hazard, Sodicity Hazard, Alkalinity Hazard, Permeability Hazard and Specific ion Toxicity following standard

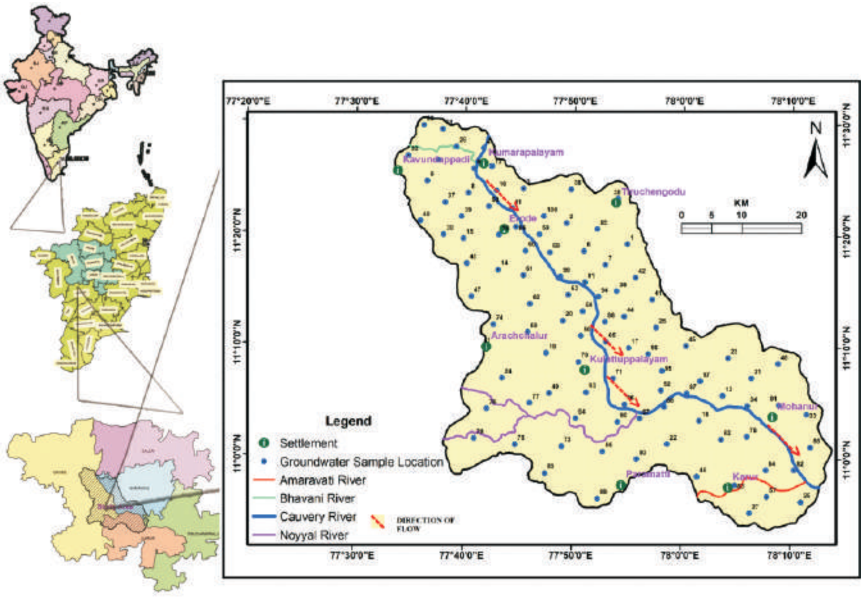

Fig. 1. Map representing the study area

Table 1. Water quality indices for Irrigation water quality

Water quality indices	Units	Sources
Hardness (as $CaCO_3$) = Ca^{2+} ×2.50 + Mg^{2+} ×4.12	mg L^{-1}	Hounslow (1995)
Alkalinity (as $CaCO_3$) = HCO_3^- ×0.82 + CO_3^{2-} ×1.67	mg L^{-1}	Hounslow (1995)
SAR = $Na^+ / \sqrt{((Ca^{2+} + Mg^{2+})/2)}$	meq L^{-1}	Richards (1954)
Na% = $((Na^+ + K^+)\times100)/(Ca^{2+} + Mg^{2+} + Na^+ + K^+)$	meq L^{-1}	Ragunath (1987)
RSC = $(HCO_3^- + CO_3^{2-}) - (Ca^{2+} + Mg^{2+})$	meq L^{-1}	Eaton (1950)
PI = $((Na^+ + \sqrt{HCO_3^-})\times100) / (Ca^{2+} + Mg^{2+} + Na^+)$	meq L^{-1}	Doneen (1964)
Kelly's Ratio = $Na^+ / (Ca^{2+} + Mg^{2+})$	meq L^{-1}	Kelly (1940)
MagnesiumRatio = $(Mg^{2+} \times100) / (Ca^{2+} + Mg^{2+})$	meq L^{-1}	Paliwal (1972)

equations (Table 1). In addition to this, USSL diagram and Wilcox plot have been utilized to ascertain the quality of irrigation water (Bruce Banoeng-Yakubo *et al.,* 2009 b). Salinity was determined by measuring the ability of water to conduct an electrical current. Salinity is usually expressed in terms of Electrical Conductivity (EC) or Total Dissolved Salts (TDS). EC is a comparatively useful measurement than TDS, since it can be directly measured on the field. Moreover, salts present in water are good conductors of electricity, so EC can be directly related to salt content. The sodium or alkali hazard is determined by the absolute and relative concentration of cations and is expressed in terms of sodium adsorption ratio (SAR). SAR is an indicator of sodium hazard of water, wherein the irrigation water quality can be ascertained based on potential water infiltration problems. The waters were classified in relation to irrigation based on the ranges of SAR values.

Alkalinity hazard can be determined through the index called Residual Sodium Carbonate. When total carbonate levels exceed the total amount of calcium and magnesium, the water quality may be diminished. When the excess carbonate (residual) concentration increases, the carbonates combine with calcium and magnesium to form a solid material (scale), which settles out of the water (Subramani *et al.,* 2010). The relative abundance of sodium with respect to alkaline earths and the quantity of bicarbonate and carbonate in excess of alkaline earths also influence the suitability of water for irrigation. This excess is denoted by 'residual sodium carbonate' (RSC) and was determined as suggested by Richards (1954). The water with high RSC has high pH and land irrigated by such waters becomes infertile owing to deposition of sodium carbonate as known from the black colour of the soil. Further, continued usage of high residual sodium carbonate waters affects crop yields. According to the US Salinity Laboratory (1954), an RSC value less than 1.25 meq L^{-1} is safe for irrigation, a value between 1.25 and 2.5 meq L^{-1} is of marginal quality and a value more than 2.5 meq L^{-1} is unsuitable for irrigation.

RESULTS AND DISCUSSION

The groundwater samples were found to be alkaline in nature in the river basin with the pH values falling between 6.8 and 8.7 (Table 2). The pH value exceeds the WHO (1993) standards at only one location (Site 43). The electrical conductivity is a useful parameter of water quality for indicating salinity hazards. Electrical conductivity of groundwater samples in the study area varied from 300 μmhos/cm to 5160 μmhos/cm. It indicates that salinity is more prevalent than sodicity. High values of electrical conductivity indicate the dominancy of sodium and chloride ions. This is evident from the analytical results of the samples at places adjacent to the banks of Noyyal River and near the confluence of Amaravati River with Cauvery. Furthermore, saline water also had relatively more calcium, magnesium and bicarbonate ions. Potassium and carbonate ions were mostly confined up to a range of 5% of the total salt concentration. It is rather complicated to arrive at a general conclusion on the hydro-chemistry water in relation to geographical conditions. In general, water in areas of high rainfall, *i.e.* above 1000 mm per annum and with good drainage was of good quality. This indicates that, in the upstream side, usually subjected to heavy rainfall, the quality of water is good whereas, in the downstream area multiple parameters exceed the acceptable limits. The concentration of chloride increases over bicarbonates towards downstream, indicating salinity problems in irrigated soil. Similarly among cations, sodium, calcium and magnesium were predominant. The TDS values vary in the range of 201 mg/L to 3800 mg/L exceeding the permissible limits at few places adjacent to the banks of Bhavani River, Noyyal River and Amaravati River which are prone to high industrial population. TDS values could be due to the discharge of effluent from dyeing units in those regions. The canal and tank waters were not found in most of the places in the study area or in case if available, they were not able to supply adequate water for irrigating crops even during critical stages of crop growth. Under these circumstances, irrigation only depends on the groundwater (Karunanidhi *et al.,* 2013).

Mechanism of geochemistry: The groundwater samples of the study area mostly occur in the rock–water interaction zone, with only few samples falling in the evaporation zone [(Fig. 2(a) and 2(b)]. This observation suggests that dissolution of carbonate and silicate minerals mostly controlled the groundwater chemistry in the study region (Bruce Banoeng-Yakubo *et al.,* 2009 a). However, few samples coming under the evaporation zone reveal that surface contamination sources, for example irrigation return flow, seem to have affected the groundwater quality in those regions. It is evident that groundwater chemistry is influenced by a number of factors namely, ion exchange reactions, mineral dissolution, intrusion of surface contamination sources, and evaporation (Subramani *et al.,* 2010).

Table 2. Physicochemical parameters of the groundwater samples during March 2015

Parameters	Pre-monsoon (March 2015)		WHO International standard	
	Average values	Range	Most desirable limit	Maximum allowable limit
pH	7.62	6.8 −8.7	7 −8.5	9.2
EC (μmho cm^{-1})	1392.38	300 −5160	–	–
TDS (mg L^{-1})	1000.85	201 −3800	500	1500
Total alkalinity (mg L^{-1})	316	156 −630	120	500
Total hardness (mg L^{-1})	382.5	179 −1291	100	500
Na^+ (mg L^{-1})	148.54	10 −1050.0	–	200
K^+ (mg L^{-1})	25.13	4.69 – 320.6		200
Ca^{2+} (mg L^{-1})	79.22	2.2 −350.0	75	200
Mg^{2+} (mg L^{-1})	50.71	5 −211	50	150
Cl^- (mg L^{-1})	204.73	21.3 −1600	200	600
HCO_3^- (mg L^{-1})	434.51	34.68 −1610	–	–
CO_3^{2-} (mg L^{-1})	0	0	–	–
NO_3^- (mg L^{-1})	38.02	1.0 – 176.08	45	45
SO_4^{2-} (mg L^{-1})	74.19	2.4 – 436.8	200	400
F^- (mg L^{-1})	0.6	0.1 – 2.0		1.5

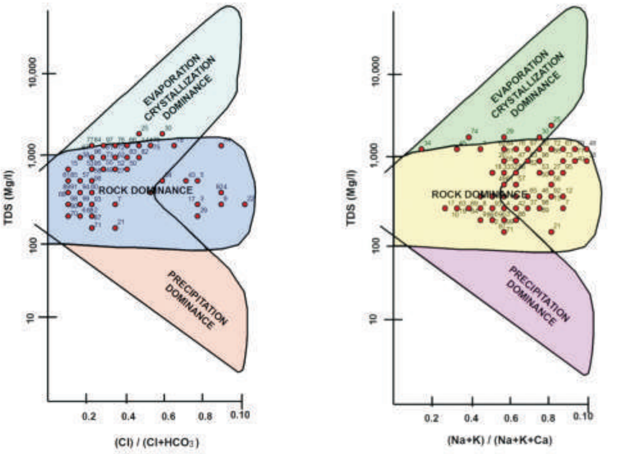

Fig. 2(a) & 2(b). Gibbs plot showing the mechanism controlling groundwater chemistry

Salinity hazard: Based on the classification of irrigation water using ES and TDS according to Richards (1954), about eight samples (well no. 4, 16, 17, 18, 19, 20, 23 and 26) represent high salinity within the study region. All these samples fall under the not desirable zones of the spatial variation maps of sodium, calcium, magnesium and potassium in the study area. The groundwater of the area was found to be fresh water except some samples representing the brackish water category.

Specific ion toxicity hazard: The sodium concentration in the groundwater samples of the study area is found to vary between 10 and 1050 mg L^{-1} during March 2015 (pre-monsoon) with an average value of 148.54 mg L^{-1}. Sodium is a principal chemical in human body, and it is usually not harmful at normal levels of intake from combined food and drinking water. However, a high intake of sodium in drinking water may be problematic for people with heart disease, hypertension or kidney problems that would necessitate them to follow a low sodium diet. Heavy zones of sodium were found in regions of confluence of Noyyal and Amaravati rivers with Cauvery and also in Agricultural belts of Bhavani river Basin.

The percent sodium values in groundwater of the study area ranges from 2.73 to 79.71 percent during Pre-monsoon period. Most of the water samples in downstream are categorized as 'excellent' to 'good' classes with respect to Na% values. As per ISI (1974) guidelines, the maximum tolerance limit of Na% for inland surface water used for irrigation is 60%. Accordingly most of the water samples were identified as suitable for irrigation, where as Na% higher than 60 per cent was noted in twelve well stations (well no 25-27, 31, 35, 38, 40, 66, 67, 77, 78 & 79).

Sodicity hazard by sodium adsorption ratio (SAR): In this study, the SAR value in the groundwater samples ranged from 0.0 to 12.93 during March 2015. Sodium adsorption ratio values (SAR) in Table 3, shows that all samples have been termed low Sodium water and fall under first category (SAR$\leqq$10). Three sites fall under second category (SAR 10-18). Therefore, no sodium hazard has been anticipated to the crops in this region.

Alkalinity hazard: The groundwater samples show RSC values in the study area had a maximum value of 11.63 meqL^{-1}. In general the high concentration of CO_3^{2-} and HCO_3^- represent alkaline nature of groundwater, which may be unfavourable for agriculture uses. The range of residual sodium carbonate in groundwater of the investigated region varies from -26.89 to 11.63 meq L^{-1}. The study indicates that 79 per cent of samples represent 'safe' category for agriculture purposes. The remaining 21 per cent of samples represent 'marginal and unsuitable' categories for agricultural purposes.

Permeability hazard: In the present study, the water samples show potential salinity values ranging from a minimum of (1.44 meq L^{-1}) to a maximum of (48.53 meq L^{-1}) in pre-monsoon period. The huge amount of potential salinity in this basin may be due to the presence of chlorides, which are derived from agricultural sources. The soil permeability is affected by long-term use of irrigation water, which is influenced by Sodium, calcium, magnesium and bicarbonate content of the soil. Doneen (1964) developed a criteria for assessing the suitability of water for irrigation based on a Permeability Index and classified the water quality as Class I, Class II and Class III types. Class I and Class II waters are categorized as good for irrigation with 50-75% or more of

Table 3. SAR classes of groundwater samples

SAR	Category	Representing wells	Precautions and Management Suggestions
0-10	1 (Low Na water)	All samples except three shown below	Little danger
10-18	2 (Medium Na water)	75, 77, 78	Problems on fine texture soils and sodium sensitive plants, especially under low-leaching conditions. Soils should have good permeability.
18-24	3 (High Na water)	Nil	Problems on most soils. Good salt tolerance plants are required along with special management such as use of gypsum.
>24	4 (Very High Na water)	Nil	Unsatisfactory except with high salinity, high Ca levels and use of gypsum.

maximum permeability. Class III type waters are unsuitable with 25 per cent of maximum permeability. From the present investigation, around 77% of the samples belong to Class I category. The permeability index of groundwater samples of the study area (Fig. 3) varied from 7.2 to 93.77 meq/L. The average value was about 57% during March 2012, which is suitable for irrigation under Class I of Doneen's chart (Domenico and Schwartz, 1990).

Wilcox and USSL diagram: In addition, graphical methods like Wilcox diagram and USSL diagram could be employed for the classification of water quality. A Wilcox plot (Wilcox 1955) known as Agriculture diagram can be used to quickly determine the viability of water for irrigation purposes. It employs percent-sodium ratio (vertical axis) and electrical conductance (horizontal axis). Percentage of sodium plotted on Wilcox diagram (Fig. 4) indicates that out of 100 samples, 32 samples fall under excellent to good category, 32 samples belong to good to permissible category, 16 samples belong to permissible to doubtful category, 13 samples belong to doubtful to unsuitable category and 7 samples belong to unsuitable category. The USSL diagram (Fig. 5) is based on taking into account the integration between EC and SAR, in which EC is taken as salinity hazard and SAR is taken as sodium hazard or alkalinity hazard. Most of the samples fall into the C2S1 (medium salinity with low sodium) and C3S1 (high salinity with low sodium) categories during March 2015. From the results, a total of 78 samples out of 100 groundwater samples have been found to fall under suitable category for irrigation based on the analysis of all the above eight indices.

Water salinity is a result of the application of saline

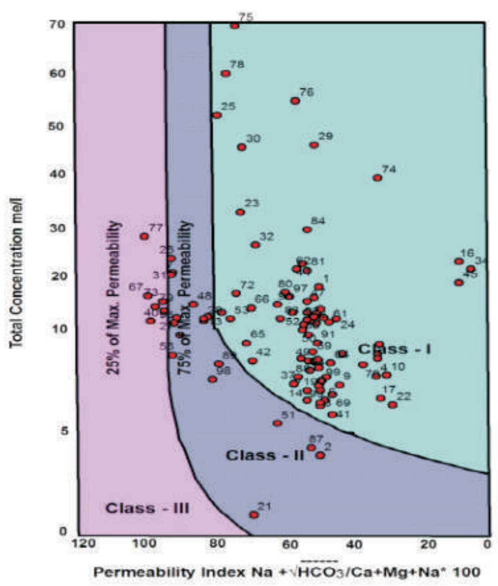

Fig. 3. Doneen's diagram showing irrigation water classes based on Permeability Index and total concentration

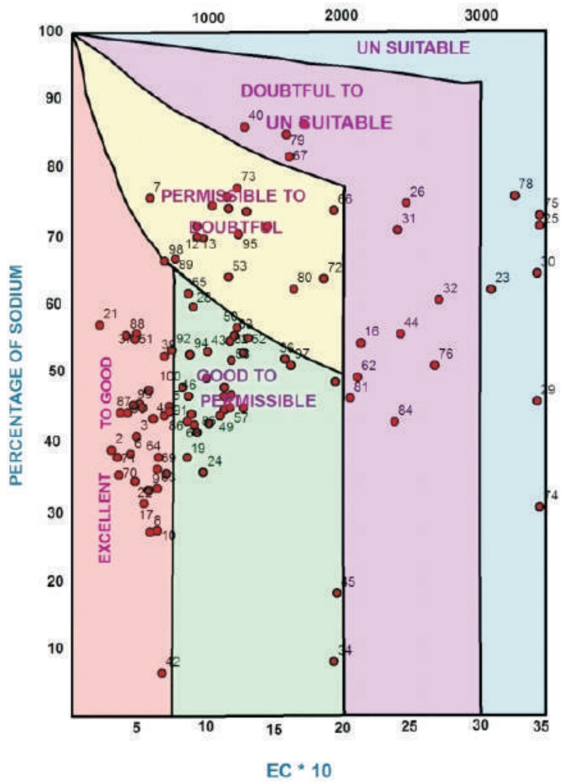

Fig. 4. Wilcox diagram showing the classes of irrigation water based on EC and per cent sodium

irrigation water, insufficient rainfall, leaching of excess salts, poor drainage, and salt water intrusion. Vegetation continually irrigated with high salinity water often becomes weak, ultimately reaching a point of no longer being acceptable (Siamak and Srikantaswamy, 2009; Bruce Banoeng-Yakubo *et al.,* 2009b). Classification of groundwater depending upon their hydrochemical properties based on their TDS values is another way to ascertain the suitability of groundwater for any purposes (Karunanidhi *et al.,* 2013). In addition to salinity, some crops are injured by certain elements and are sensitive to ions, notably Sodium, Chloride, Magnesium etc., Sodium is the dominant cation in the study area. Sodium is a highly soluble chemical element and is often naturally found in groundwater. All groundwater contains some sodium because most rocks and soils contain sodium compounds from where sodium is easily dissolved.

Suitability assessment of groundwater for agricultural purposes in the Cauvery river Basin indicates that groundwater of the study area is generally suitable for irrigation except in few areas. From the classification of irrigation water with respect to the various indices, 78 per cent of the groundwater samples are suitable for irrigation purpose. Wilcox plot indicates that 64 groundwater samples represent

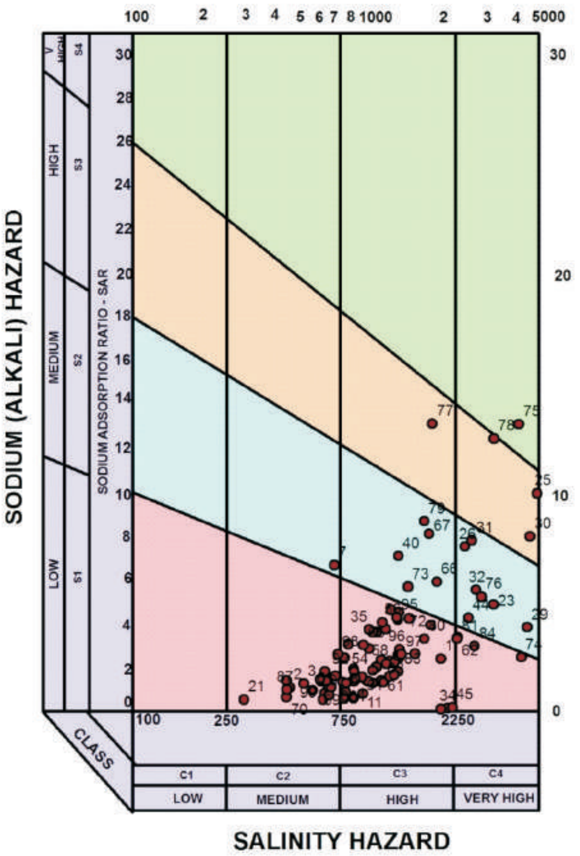

Fig. 5. USSL diagram showing the irrigation water classes based on salinity and alkalinity hazard

excellent to permissible categories while nearly 20 samples are not suitable for irrigation purposes. Doneen's interpretation diagram also indicates that 77 per cent of groundwater samples represent Class-I category, which is suitable for irrigation. The residual sodium carbonate values of groundwater samples indicate that most of the samples come under 'Safe' category (about 79%) for irrigation. Therefore, the groundwater of the study area is low alkaline and high saline in nature. It is clearly indicated in the USSL diagram that 56 samples represent high saline and low sodium (C3S1) category and 22 samples represent moderate saline and low sodium category. Some samples also represent high to very high saline and alkaline categories which cannot be used for agricultural purposes. Special type of irrigation methods could be adopted in such stations to control the high salinity consequently improving the yield of crop.

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Application of Parametric and Nonparametric Regression Models for Area, Production and Productivity Trends of Tea (*Camellia sinensis*) in India

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Abstract: India is the largest tea producing country in the world and tea contributes 1% of the GDP of the country and accounts for 31% of total worlds production. The present study is an attempt to find past trends in tea production in major states and India using various parametric, nonparametric and semi-parametric regression methods. These methods have superiority over the others and hence compared performance of each method using higher values of R^2 and lower values of residual criteria. Comparing parametric regression and nonparametric (Kernel and Loess)/semi-parametric (Spline) regression, it is found that nonparametric/semi-parametric regression performed better than parametric regression for fitting trends in tea production. Even semi-parametric spline regression is selected as best fitted model for trend analysis. It is found that area under tea has increased in all major states and India from 1951 to 2011 except for Kerala and productivity has shown declining trend. Hence the study strongly advocates for researchers towards technological breakthrough in tea production in India.

Keywords: Tea production, Trend analysis, Parametric regression, Semi-parametric regression

Tea (*Camellia sinensis*) has occupied an important place in India's economy for the last several decades. India is the largest tea producing country in the world and contributes 1 per cent of the GDP of the country. India has emerged to be the world leader, mainly because it accounts for 31 per cent of global production (Gupta and Dey, 2010). Major tea producing states in the country are Assam, West Bengal, Tamilnadu and Kerala. Choudhury (2006) reported that the production and export of tea in India has shown a declining trend in the recent years of the current decade. This put forth emphasis to study the trends in area, production and productivity at national and regional level which are very useful for planning and decision making purposes at the national and international levels. Regional analysis of trends will help to formulate and initiate appropriate policy measures if the tea production of particular state is showing increasing or declining trend.

The growth rates of crops are estimated mostly through the parametric models by assuming the linear or exponential functional forms. However, the data may not be following these linear or exponential models or may require fitting of higher degree polynomials or non-linear models. Further, these models lack the econometric consideration, i.e., normality and randomness of residuals. Under these circumstances it becomes imperative to take recourse to nonparametric regression approach, which is based on fewer assumptions. In recent years, non-parametric and semi parametric regression technique has become increasingly popular as a tool for data analysis. These techniques impose only few assumptions about shape of function and therefore are more flexible than usual parametric approaches. The non-parametric technique, which entirely depends on the data, can be used when exact functional relationship is not known. This method is based on the local regression smoother and only assumption about the form of trend. The semi-parametric regression includes regression models that combine parametric and nonparametric models. They are often used in situations where the fully non-parametric model may not perform well or when the researcher wants to use a parametric model but the functional form with respect to a subset of the regressors or the density of the errors is not known. Various scientist viz. Dhekale (2009), Teczan (2010) employed kernel nonparametric regression methodology to find out trends in various crops. Sahu and Pal (2004) used non parametric (kernel, lowess) and semi-parametric (Spline) for modeling of pest incidence. Keeping the above in mind the present study is aimed to develop an appropriate statistical model to fit the trends in area, production and productivity of tea crop based on both parametric (linear, non-linear and time-series) and nonparametric regression models.

MATERIAL AND METHODS

In order to select the major tea growing states in India, percentage share of each and every state to total India's tea production in 2012 are examined and four major states viz. Assam, West Bengal, Tamilnadu, Kerala along with India are selected for present study. To study the trends and growth rates in production long term data on area, production and yield of tea from tea board of India was collected for last 50 year.

Presence of outliers in a time series are tested using Grubb's statistic (www.graphpad.com) and if present in a series, replaced by median. In addition randomness in data is tested using turning point test. The most widely used descriptive measure of central tendency and dispersions like arithmetic mean, range, standard deviation along with simple and compound growth rates per are a used to explain basic features of each series. Simple and compound growth rates are calculated by using formula described by Mishra *et al.* (2012).

Trend Models

Parametric regression (linear and non-linear models): To trace the path of production process different parametric trend models as given in table below are used. Among the competitive trend models, the best models are selected based on their goodness of fit (measured in terms of R^2) value and significance of the coefficients.

where Y is the area/ production/ productivity and X is the time points

Non-parametric regression: In general, nonparametric regression model is of the form

$$Y=m(x) + \varepsilon$$

where Y is the response variable m(x) = E(y/x=x) is the mean response or regression function assumed to be smooth and ε is the independently identically distributed random error with mean zero.

Smoothing techniques are used to estimate the regression function non-parametrically (Hardle, 1990). To obtain an estimate of the mean response value at a point X, most of the smoothers are averaging the Y – values of observations having predictor values closer to the target value X. The averaging is done in neighbourhoods around target value. The main decision to be made in any of the smoothing techniques is to fix the size of neighbourhood which is typically expressed in terms of an adjustable smoothing parameter or bandwidth. Intuitively, large neighbourhoods will provide an estimate with low variance but potentially high bias, and conversely for small neighborhoods.

Non-parametric and semi-parametric regression: Non parametric Kernel and Loess regression and semi-parametric spline regression technique was used in order to obtain a smooth fit of the function m(x). Among these smoothers, kernel weighted local smoother, proposed by Fan (1992), is employed using Epanechnikov kernel with Nadaraya–Watson estimation procedures. Lowess regression, introduced by Cleveland (1979), is obtained on the basis of the data points around it within a band of certain width. The point x_i is the midpoint of the band. The data points within the band are assigned weights in a way so that x_i has the highest weight. The weights for the other data points decline with their distance from x_i according to a weight function. The weighted least squares method is used to find the fitted value corresponding to xi, which is taken as the smoothed value. The procedure is repeated for all the data points. The spline procedure uses the penalized least squares method (Simonoff, 1995), which provides a way to balance the fitting of the data closely and at the same time avoiding excessive roughness or rapid variation. The objective is to estimate *m* by means of a function that (a) fits the data well, and (b) is as smooth as possible. A measure of smoothness of *m* is the integral of the square of its second derivative. The following criterion takes both (a) and (b) into account:

$$\sum_{i=1}^{n}\left(y_i - m\left(x_i\right)\right)^2 + \lambda\int_a^b\left(m''\left(x\right)\right)^2 dx$$

Where λ>0 is a fixed constant and xi ε [a,b], i=1,2.n

The first term is the sum of squares of the residuals; it provides a measure of how well the function *m* fits the data. The integral is a measure for the roughness/smoothness of the function *m*. Functions, which are highly curved will result in a large value of the integral; straight lines result in the integral being zero. The roughness penalty λ, controls how much emphasis one wishes to place on smoothness. By increasing λ, one places more emphasis on smoothness; as λ becomes large the function approaches a straight line. On the other hand, a small value of λ emphasizes the fit of *m* to the data points; as λ approaches zero *m* approaches a function that interpolates the data points.

RESULTS AND DISCUSSION

The maximum growth in area is observed in Tamilnadu, followed by Assam and West Bengal, whereas, minimum growth was exhibited in Kerala. Negative compound growth (0.05 per cent) rate is observed for area under cultivation in Kerala, which revealed that area decrease over the years. Decrease in area under tea cultivation in Kerala may be associated with shifting of tea cultivation by rubber in mid-nineties coupled with decrease in prices of tea in international market which indirectly accounted for profitability of tea in Kerala during late nineties (Kurien, 2001; Vidhya, 2003). Tea production in India has increased from a mere 278.67 million kilogram to 999.18 million kilogram during study period and has registered simple growth rate of 3.85 percent per annum. Assam ranked first in average production (> 50 per cent of production) followed by West Bengal, Tamilnadu and Kerala. Although average production of Assam was highest (313.97 million kilogram) maximum growth in tea production has observed in Tamilnadu. Tea production of Tamilnadu has shown highest growth rate of 8.99 per cent per annum followed by Assam (4.59 per cent per annum) and, West Bengal (3.99 per cent per annum). Tea productivity of India varied from 875 kilogram per hectare to 1876 kilogram per hectare. Tamilnadu has recorded highest productivity (1815.36 kilogram per hectare) and lowest of Kerala (1389.03 kilogram per hectare). Tamilnadu tea industry is endowed with some favourable factors like suitable agro climatic condition (frost free) and proper care of tea bushes (Das and Sharma, 2010). Interesting results of the study that although Assam contributing 50 per cent of total production of India, tea productivity of Assam recorded lowest growth rates (1.39 per cent SAGR, 1.05 per cent CGAR) than any other states. This was mainly due to old age of tea bushes (Arya, 2013). Talukdar and Sahewalla (2005) in their study (1951−2000) also observed similar results of negative compound growth rate in Kerala (−0.10 per cent) and highest growth rate of tea production in Tamilnadu (3.38 per cent).

The test of randomness indicate that under tea cultivation in all states and in whole India followed definite trends (Table 2). Tea production and productivity of Assam, West Bengal and India followed definite trend while Tamilnadu and Kerala have changed randomly. Although the area under tea cultivation of Kerala and Tamilnadu have shown definite trend, production and productivity were random in nature this may be because of variation in area. Changes in cropping pattern of Kerala and Tamilnadu may be one of the reasons for randomness of data and also can't ignore the minor

Table 1. *Per se* performance of tea production in major states of India during 1951−2011

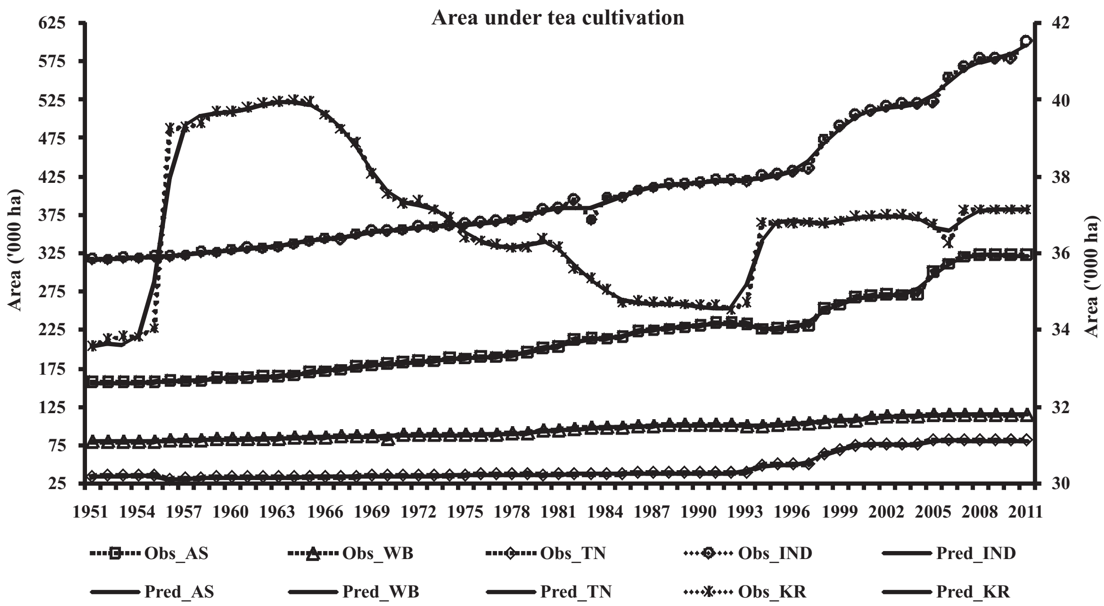
	Assam	West Bengal	Tamilnadu	Kerala	India
		Production (million kg.)			
Maximum	322.21	115.10	81.28	39.96	600.00
Minimum	155.80	79.48	30.34	33.54	316.87
Mean	214.29	95.43	45.69	36.78	406.53
SD	50.59	11.78	17.68	1.83	80.93
CV (%)	23.61	12.34	38.70	4.97	19.91
Skewness	0.80	0.33	1.23	0.18	0.95
Kurtosis	−0.29	−1.17	−0.25	−0.75	−0.21
SGAR (%)	1.72	0.72	2.21	0.17	1.44
CGAR (%)	1.26	0.68	1.66	−0.05	1.04
		Production (million kg.)			
Maximum	589.11	271.60	170.72	74.63	991.18
Minimum	145.90	71.96	24.80	24.52	278.67
Mean	313.97	137.30	85.88	50.72	596.16
SD	122.08	50.92	45.95	13.11	228.11
CV (%)	38.88	37.09	53.50	25.85	38.26
Skewness	0.21	0.63	0.49	−0.21	0.21
Kurtosis	−1.21	−0.35	−1.04	−0.85	−1.30
SGAR (%)	4.59	3.99	8.99	2.69	3.85
CGAR (%)	2.32	2.10	3.24	1.41	2.30
		Productivity (kg ha^{-1})			
Maximum	1857.83	2426.59	3104.44	2065.62	1876.00
Minimum	933.79	904.27	721.72	726.92	875.00
Mean	1422.93	1414.95	1815.36	1389.03	1424.73
SD	284.04	372.28	563.2	371.98	317.41
CV (%)	19.96	26.31	31.02	26.78	22.28
Skewness	−0.24	0.59	−0.02	−0.17	−0.35
Kurtosis	−1.29	−0.02	−0.41	−1.23	−1.38
SGAR (%)	1.39	2.37	2.99	1.95	1.75
CGAR (%)	1.05	1.41	1.55	1.46	1.24

SD=Standard deviation, CV= coefficient of variation, SGAR = Simple growth rate per annum, CGAR=Compound growth rate per annum fluctuation in production between the consecutive years due to the factors beyond the control of the farmers. By and large tea industry in India is developed through some policy implications and implementation before and after WTO, which may attribute to noticeable changes in tea acreage and production.

Trend Analysis of Area, Production and Productivity

Parametric techniques: Area and production of Assam and India have followed cubic trend while productivity has followed quadratic trend (Table 3). Assam contributes 50 per cent of area and production of tea in India, which could lead to follow same trend. Area under tea of Assam, Kerala and India followed cubic trend model with three points of inflection. As b_1 and b_3 are found to be positive, there by indicate that area has increased during initial and recent period while negative value of b_2 indicates decline area in middle part of study. Exponential trend in tea production in Tamilnadu mainly associated with increased area under tea cultivation, suitable agro-climatic conditions and young tea bushes. Production behaviour of tea, as visualized through area, production and productivity follow mostly the polynomial trend, thereby indicating more than one point of inflections.

Non-parametric and semi-parametric regression: Results of trend analysis of tea area, production and productivity using kernel & loess regression (nonparametric) and spline regression (semi-parametric) are presented in Table 4, 5 and 6. In case of area, R^2 values were ranges from 0.981 to 0.999 for kernel, loess and spline regression. Comparing values of AICc, RMSE, MAPE, MAE, MaxAPE and MaxAE, spline regression has recorded lowest values in all states and whole India. Same trend is observed in production and productivity of tea in India and major states. Spline regression has provided lowest bandwidth for tea production in all states and India. Comparing values of AIC_c, RMSE, MAPE, MAE, MaxAPE and MaxAE spline regression recorded lowest value. Except for Kerala, area under tea cultivation in all states and in India has increased continuously throughout the study period (Fig. 1). Area under tea cultivation in Tamilnadu has increased due to shifting cultivation of food crops and forest by tea (Venugopal, 2012). Official registration of small-growers of tea started functioning from late 1980s and continued flourishing all through 1990s, which could associate with increase in area under tea cultivation in Assam (Sarkar, 2009). In Kerala, tea cultivation reached maximum in 1966 and then started declining upto 1993 and thereafter showing stagnant growth. The area under tea cultivation in Kerala recorded negative compound growth rate (Table 1 and Fig. 1). The production has increased in all states and in whole India (Fig. 2). Effect of area expansion can clearly be visualized in the increasing production scenario of tea in all states and India except Kerala. Although in Kerala area has shown declining trend, production has increased over the years. Increased in tea production in Kerala was attributed to



Note: Obs= Observed data series, Pred=Predicted trend using spline function, AS= Assam, WB=West Bengal, TN=Tamilnadu, KR=Kerala and IND=India

Fig. 1. Observed and expected trends of area under tea cultivation using spline in major states of India

Table 2. Test of outliers and randomness for area, production and productivity of tea in India

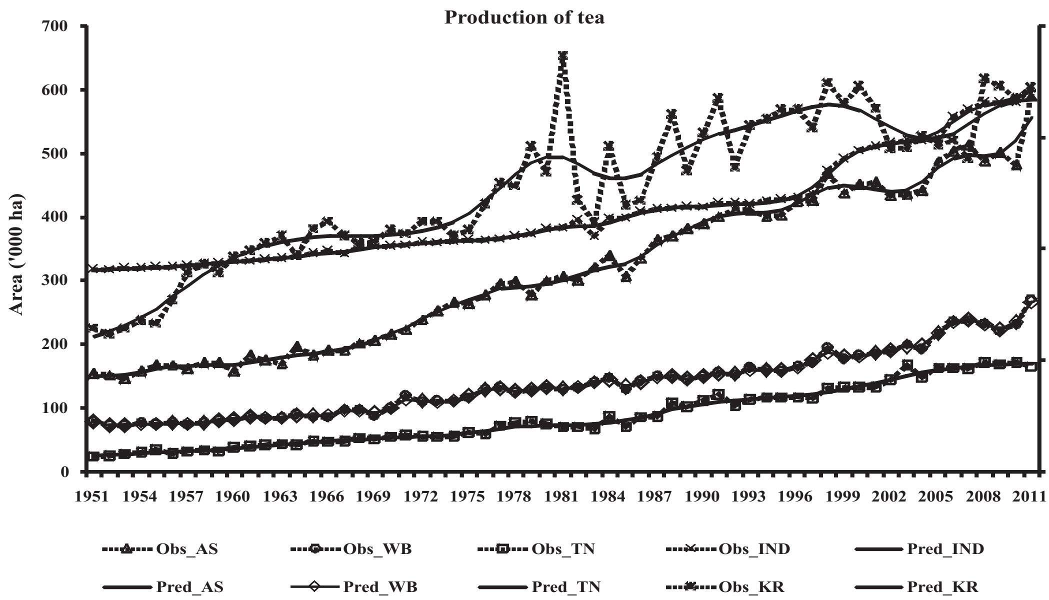
Particulars	P	τ_{cal}	Inference	Outlier
Assam				
Area	8	9.78	Trend	No
Production	27	3.97	Trend	No
Productivity	31	2.75	Trend	No
West Bengal				
Area	14	7.95	Trend	No
Production	31	2.75	Trend	No
Productivity	33	2.14	Trend	No
Tamilnadu				
Area	12	8.56	Trend	No
Production	38	0.61	Random	No
Productivity	39	0.31	Random	No
Kerala				
Area	17	7.03	Trend	No
Production	37	0.92	Random	No
Productivity	40	0.00	Random	No
India				
Area	6	10.39	Trend	No
Production	31	2.75	Trend	No
Productivity	33	2.14	Trend	No

Note: *=5 per cent level of significance, **=1 per cent level of significance, Area in '000 hectare, Production inmillion kg., Productivity in kg/ha, No of Observations= 62, P=No. of turning points in a series, E(P)=40 and V(P)= 10.70.

Table 3. List of linear and non-linear models

Model No.	Model	Name of the model
I.	$Y_t = A + b_0 t$	Linear equation
II.	$Y_t = A + b_0 t + b_1 t^2$	Second degree polynomial
III.	$Y_t = A + b_0 t + b_1 t^2 + b_2 t^3$	Third degree polynomial
IV.	$Y_t = AB^t$	Exponential model
V.	$ln(Y_t) = ln(b_0) + t\, ln(b_1)$	Compound model
VI.	$Y_t = b_0 + b_1 ln(t)$	Logarithmic model

increased productivity (Joseph, 2002). In India, tea productivity has increased to 1865 kilogram per hectare in 1997 and thereafter showing declining trend (Fig. 3). Sarkar (2009) observed similar declining trend of tea productivity in India. Comparing R^2 value with parametric regression and nonparametric/semi-parametric regression, nonparametric/semi-parametric regression perform better than parametric regression for fitting trends in area production and productivity of tea in India (Table 3, 4). In production of Tamilnadu state, value R^2 of non-parametric regression has recorded more than 0.960 but in case of parametric trend model value was listed as 0.82 (Table 3). Same in case of tea productivity of Kerala state, R^2 value of spline and kernel regression has observed more than parametric model (Table 3). Even values of RMSE, MAE, MAPE, MaxAE and MaxAPE for area production and productivity of major states an India for non parametric regression has observed lower than



Note: Obs= Observed data series, Pred=Predicted trend using spline function, AS= Assam, WB=West Bengal, TN=Tamilnadu, KR=Kerala and IND=India

Fig. 2. Observed and expected trends of production of tea using spline in major states of India

Table 3. Trends in area, production and productivity of tea in major states of India

	Model	R^2	Sig.	Constant	b_1	b_2	b_3	RMSE	MAPE	MAE	MaxAPE	MaxAE
						Assam						
Area	Cubic	0.98	0.01	147.42*	2.080**	−0.039**	0.001**	7.34	2.21	5.08	9.35	21.49
Production	Cubic	0.98	0.04	149.10**	0.290**	0.211**	−0.001*	17.35	4.23	13.06	9.95	58.63
Productivity	Quadratic	0.87	0.02	799.10*	31.22**	−0.28*		79.75	4.57	65.42	13.07	238.92
						West Bengal						
Area	Quadratic	0.98	0.01	78.52**	0.336**	0.005*		1.60	1.29	1.26	5.65	4.68
Production	Cubic	0.98	0.05	62.74**	2.600**	−0.042**	0.001*	8.45	5.13	6.80	18.03	18.39
Productivity	Exponential	0.94	0.03	884.46**	0.01*			88.70	4.70	68.00	13.53	290.50
						Tamilnadu						
Area	Quadratic	0.92	0.02	39.41**	−1.024**	0.029*		4.99	8.66	3.98	30.23	11.89
Production	Exponential	0.98	0.01	27.23**	0.03*			7.19	6.06	5.03	17.61	25.28
Productivity	Cubic	0.82	0.05	714.13**	32.45**	1.05*	−0.02**	236.72	8.20	162.32	30.95	772.66
						Kerala						
Area	Cubic	0.46	0.03	34.32**	0.585**	−0.024*	0.003**	1.33	3.28	1.21	7.75	2.64
Production	Quadratic	0.85	0.02	24.34**	1.205*	−0.009**		5.05	7.62	3.91	28.26	21.09
Productivity	Cubic	0.87	0.01	716.93*	16.88**	0.51*	−0.01**	135.02	6.67	97.57	28.69	592.64
						India						
Area	Cubic	0.99	0.01	307.53**	3.189*	−0.086**	0.002**	9.06	1.53	6.56	6.27	27.23
Production	Cubic	0.99	0.04	27.86**	2.27**	0.320**	−0.003*	19.12	2.49	14.77	7.11	51.19
Productivity	Quadratic	0.93	0.05	720.23**	34.11**	−0.28*		80.41	5.08	69.41	15.69	163.88

Note: *=5 per cent level of significance, **=1 per cent level of significance, Area in '000 hectare, Production in million kg., Productivity in kg ha^{-1}

Table 4. Trends in area of tea in India using non−parametric and semi−parametric regression

Model	Bandwidth	R^2	AIC_c	RMSE	MAPE	MAE	MaxAPE	MaxAE
Assam								
Kernel	0.05	0.997	4.76	2.61	0.62	1.47	4.83	13.05
Loess	0.12	0.997	3.48	2.37	0.55	1.30	4.49	12.14
Spline	0.003	0.999	2.46	1.64	0.34	0.81	3.10	8.38
West Bengal								
Kernel	0.05	0.996	2.64	0.78	0.53	0.50	5.01	4.15
Loess	0.151	0.995	1.14	0.78	0.53	0.50	5.01	4.15
Spline	0.06	0.996	0.79	0.73	0.48	0.45	4.83	4.00
Tamilnadu								
Kernel	0.05	0.990	3.45	1.31	1.50	0.71	11.45	5.69
Loess	0.124	0.996	2.29	1.20	1.35	0.63	10.58	5.25
Spline	0.002	0.999	1.45	0.58	0.61	0.28	4.89	2.23
Kerala								
Kernel	0.05	0.950	0.17	0.41	0.52	0.19	5.41	1.92
Loess	0.12	0.960	0.14	0.38	0.48	0.18	5.19	1.84
Spline	0.003	0.981	0.12	0.25	0.29	0.11	3.51	1.25
India								
Kernel	0.05	0.997	5.12	4.65	0.61	2.69	5.10	18.81
Loess	0.123	0.998	4.91	4.44	0.56	2.48	4.99	18.42
Spline	0.011	0.998	3.29	3.79	0.48	2.07	4.33	15.99

Note: Area in '000 ha

Table 5. Trends in tea production in India using non-parametric and semi-parametric regression

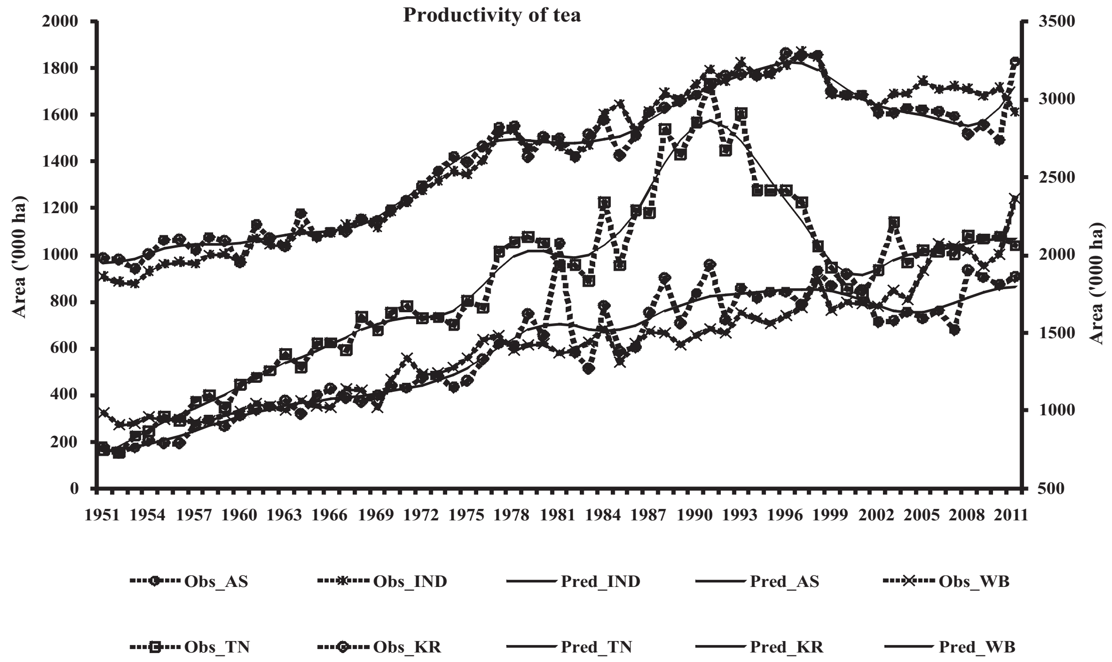
Model	Bandwidth	R^2	AIC_c	RMSE	MAPE	MAE	MaxAPE	MaxAE
Assam								
Kernel	0.06	0.991	18.47	12.77	2.78	9.13	10.88	52.26
Loess	0.27	0.992	20.58	15.18	3.29	10.88	11.59	55.66
Spline	0.02	0.993	11.27	10.22	2.26	7.11	8.06	38.70
West Bengal								
Kernel	0.08	0.984	17.94	6.92	3.28	4.79	12.19	20.58
Loess	0.31	0.984	19.1	7.39	3.56	5.29	12.96	21.20
Spline	0.003	0.998	−5.75	2.45	1.28	1.82	4.28	6.75
Tamilnadu								
Kernel	0.06	0.993	15.38	4.54	4.12	3.34	13.63	16.05
Loess	0.6	0.984	18.59	6.08	5.38	4.33	22.86	19.30
Spline	0.04	0.991	8.49	4.54	4.17	3.33	13.54	15.55
Kerala								
Kernel	0.08	0.991	15.58	4.09	5.22	2.75	25.93	19.35
Loess	0.25	0.892	18.12	4.36	5.74	3.01	27.14	20.25
Spline	0.14	0.993	8.39	3.93	4.95	2.61	24.46	18.26
India								
Kernel	0.23	0.991	21.54	21.89	2.58	15.80	7.73	81.59
Loess	0.33	0.994	21.2	21.32	2.32	14.67	7.79	88.41
Spline	0.002	0.998	3.57	3.79	0.48	2.07	4.33	15.99

Note: Production in million kg.

Table 6. Trends in tea productivity in India using non-parametric and semi-parametric regression

Model	Bandwidth	R^2	AIC_c	RMSE	MAPE	MAE	MaxAPE	MaxAE
Assam								
Kernel	0.063	0.970	9.47	46.50	2.55	35.46	10.87	162.03
Loess	0.145	0.970	9.35	46.60	2.55	35.13	11.19	166.87
Spline	0.051	0.976	5.06	42.88	2.35	32.41	9.10	135.69
West Bengal								
Kernel	0.081	0.970	7.49	65.27	3.18	46.41	13.29	179.89
Loess	0.306	0.960	9.82	71.28	3.51	51.92	14.06	186.62
Spline	0.003	0.999	−1.39	0.73	0.04	0.53	0.16	2.09
Tamilnadu								
Kernel	0.052	0.970	8.34	96.77	3.76	70.70	11.66	271.71
Loess	0.156	0.970	10.92	103.02	4.04	76.17	11.64	281.53
Spline	0.061	0.968	5.65	100.18	3.93	74.02	11.75	273.87
Kerala								
Kernel	0.081	0.910	10.24	111.47	5.04	74.28	25.34	523.61
Loess	0.570	0.870	10.94	131.97	6.47	95.43	28.96	598.29
Spline	0.211	0.911	5.13	110.45	5.01	73.66	24.63	508.78
India								
Kernel	0.081	0.980	9.49	42.51	2.16	31.74	8.02	129.25
Loess	0.170	0.980	9.01	42.52	2.15	31.41	7.74	126.67
Spline	0.002	0.998	−1.77	0.46	0.02	0.35	0.08	1.25

Note: Productivity in kg/ha.



Note: Obs= Observed data series, Pred=Predicted trend using spline function, AS= Assam, WB=West Bengal, TN=Tamilnadu, KR=Kerala and IND=India

Fig. 3. Observed and expected trends of productivity of tea using spline in major states of India

parametric regression (Table 5 & 6). This clearly indicated superiority of these techniques over parametric models. These models perform well where parametric model fail to visualize the past scenario. From nonparametric and semi–parametric regression, spline regression has shown lowest values of AIC_c, RMSE, MAPE, MAE, MaxAPE and MaxAE for area, production and productivity of tea in major states and India hence spline regression was best fitted among the non–parametric and semi–parametric model for tea production in India. Various scientist *viz*. Aydin (2007) and Pal (2011) observed similar results of advantage of spline over kernel and loess smoothing.

From above study, it is concluded that Kerala and Tamilnadu are productive states. However, endeavors should be made to increase the area under tea cultivation especially in Kerala, whereas, efforts needs to take for boost up production in Tamilnadu. Comparing productivity, West Bengal is one of the dominant state. Very old bushes may lead to low productivity in Assam and hence replenishment of bushes is very important to sustain the production in Assam. As such the study strongly advocates for researchers towards technological breakthrough in tea production in India. From the methodologies for trend analysis, non–parametric regression analysis is performed well than parametric regression. Moreover the semi–parametric spline regression model was selected as the best fitted trend function. This technique may be further utilized for detecting trends in various crops efficiently.

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An Ecological Study for Diatomic Epiphytic Algae Population on *Phragmits australis* and *Ceratophyllum demersum* Plants in Bani-Hassan River in Holy Kerbala Province-Iraq

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Abstract: The present study was carried out at four stations along Bani-Hassan River at Kerbala holy city. Some physio chemical parameters, qualitative and quantitative of epiphytic algae attached with *Phragmits australis* and *Ceratophyllum demersum* were measured. The results showed a clear association between air and water temperature, which ranged from 15-40 °C and 11-34 °C, respectively. The electric conductivity and salinity were 1050-1980 µs cm^{-1} and 1.23-0.10 per cent, respectively. A narrow range of pH was noticed in the stream 6.4-8.0 during the study period and total dissolved solids were 510-990mg l^{-1}. Dissolved oxygen content showed that the river had good aeration, the lowest value was 1.3 mg l^{-1} and the highest 8.2 mg l^{-1}. The recorded values of BOD_5 did not exceed the permitted values, and it ranged from 0.1 – 4.7 mg l^{-1}. The results revealed that the river was light alkaline and alkalinity values was 32-84 mg l^{-1}. Total hardness values was 360-1250 mg l^{-1}, and Calcium and Magnesium values were 81-713.4 mg l^{-1} and 9.2-379.3 mg l^{-1}, respectively. Sulphate values was 2.5-18.3mg l^{-1}, while the silicate values was ND-30 mg l^{-1}. Water nutrient values were ND-59.1µg l^{-1}, ND-13.6µg l^{-1} and 1-30 µg l^{-1} for phosphate, nitrate and nitrite, respectively. The Chla and Phya values were ND-19.2 and ND-8.5µg cm^{-1}, respectively. Total numbers of diatomic algae 130 species diagnosed belonged to two orders, Centrales recorded 5 genus and 14 species, Pennales had recorded 27 genus and 116 species.

Keywords: Epiphytic diatom, Macrophytes, Lotic system, Water quality, Ntrients

Diatoms are a lineage of unicellular photoautotrophs within the heterokont algae (Goertzen and Theriot, 2003), which emerged on our planet ~150 million years ago (Anderson and Cummins, 1979; Müller-Navarra *et al*., 2000) and they were considered one of the major sources of crude oil (Sims *et al*., 2006). Diatoms are responsible for nearly one-quarter of the annual global photosynthetic production of organic matter, which was nearly equal to the proportion attributed to tropical rain forests (Kooistra *et al*., 2007), while their silica cell wall makes up 40-78 per cent of their weight (Aoyagi and Omokawa, 1992). Currently, among the 20,000–200,000 species of diatoms only a few had been studied as potential biofuel producers (Field *et al*., 1998). Diatom storage products is included Chrysolaminaran and a suite of highly unsaturated (Sicko-Goad *et al*., 1984; Mann and Droop ,1996).

Much of the epiphytic flora growing on marine macrophytes is diatoms (Jacobs and Noten, 1980). These may contribute significantly to the primary production of mangrove systems where diatoms from different substrata are the main microalgae forms(Siqueiros Beltrones, 2002). The growth of epiphytic algae influenced by nutrient availability in aquatic ecosystem specially nitrogen and phosphorous compounds that reduced the photosynthetic capacity (Limpens, 2003). Some of the factors most often found to be important in determining the distribution patterns of benthic diatoms in lotic systems were water chemistry (particularly pH, ionic strength and nutrient concentrations), substrate, current velocity, light (degree of shading) grazing and temperature (Potapova *et al*., 2002). The relation between diatoms and environmental variables arestrong and quantifiable making diatoms appropriate quantitative indicators of ecological conditions in lotic systems (Oliveira *et al*., 2001). These types of algae act as indicators of the extent of water pollution (Dere *et al*., 2002). In the polar marine environment, resting spores allow the diatom population to survive the polar winter and were important inoculums for spring and summer blooms (Horner, 1985). Epiphytic algae has mechanisms for attachment e.g. diatoms have tubes, stalks and pads which are helping diatoms to attach on substrata (Stenvenson *et al*., 1996).The aim of present work is to measure some physiochemical parameters as well as qualitative and quantitative of epiphytic algae that attached with *Phragmits australis* and *Ceratophyllum demersum*at, four stations were selected along with Bani-Hassan River at Kerbala holy city.

MATERIAL AND METHODS

Four stations were selected along Bani-Hassan River with length 65 Km and 32-42 m³ discharge (Kerbala environment department). The samples were collected monthly and started from November 2015 to October 2016.

Water samples collected in polyethylene bottle while algae samples were collected in plastic bags with little water from same site and five drops of formalin were added for samples preservation until reach to laboratory.

Air and water temperature was measured by mercurial thermometer (0–100) m˚, while pH values was measured by pH meter which manufactured by HANNA company. The electrical conductivity measured EC device which manufactured by HANNA and results expressed by µs/cm, while the values of total dissolved solids were measured by TDS meter made of HANNA company. Dissolved Oxygen was estimated by Winkler`s method. Total hardness evaluated titration with EDTA–2Na (0.01N) and Eriochrome Black T (EBT)as indicator and results expressed by mg/l (Lind , 1979), while the values of calcium and magnesium were estimated according to method described by (APHA,2003). Sulphate was estimated by turbidomeric method and reactive phosphate by method described by Vollenweider (1974). The nitrate was measured byHI96708 portable HANNA and nitrite measured by HI96728 portable HANNA. Chla and Phya were estimated according to method (Tebbutt , 1977).

RESULTS AND DISCUSSION

Air temperature ranged between 15 and 40˚c while water temperature ranged between 11and 32˚c (Fig. 1, 2). The temperature is considered most important environmental factor that affects physical, chemical and life properties of water body, as well as effect of solubility of gases and salts, which is changing taste and water smell (AL– Mousawi, 1994). The electrical conductivity values ranged between 1060 and 1980µs cm^{-1}. The results of current study showed significant ifference in EC values with higher values in winter and autumn (Fig. 3) and this due to laundering of soil and cliff the salts to water body during rainy seasons (Salman, 2006). Low EC values during the summer were due to dilution because high water level (Al– Saraaf, 2006). Salinity is considered as an indicator for dissolved salts in water body, and it's closely linked to total dissolved solid and increased in area which is under agriculture and industrial effect (Yousry, 2009). The values of salinity ranged between 0.1 and 1.23 at stations 1, 2 (Fig. 4).

The pH is representing level of hydrogen ions which is affected by dissolved gases such as carbon dioxide and hydrogen sulfide, as well as carbonate and bicarbonate in the water (WHO1996). Increasing of pH values in rivers is related to photosynthesis processes and growth of aquatic plants which consume carbon dioxide that's leading to increase pH (Davis and Cornwell, 2008). Total dissolved solid (TDS) is a

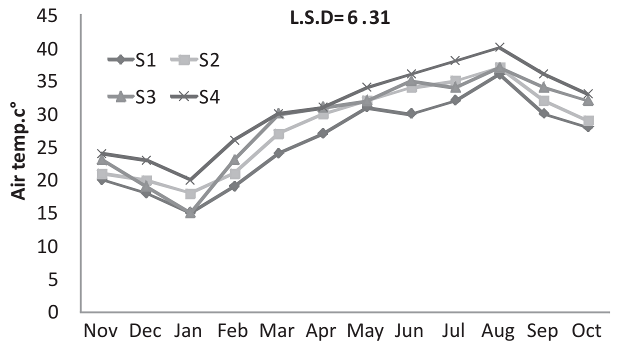

Fig 1. Variation in air temperature values during study period

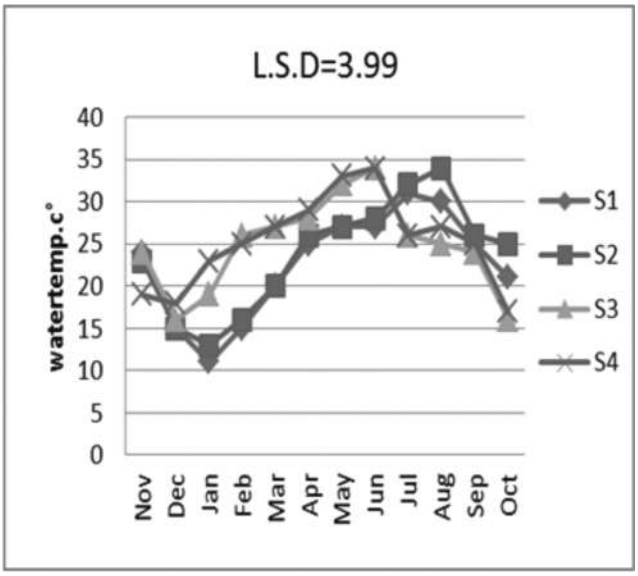

Fig. 2. Variation in water temperature during study period

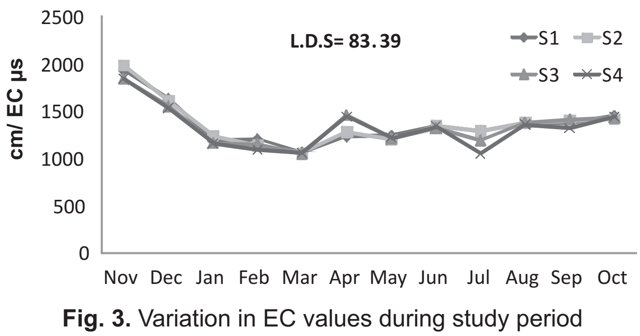

Fig. 3. Variation in EC values during study period

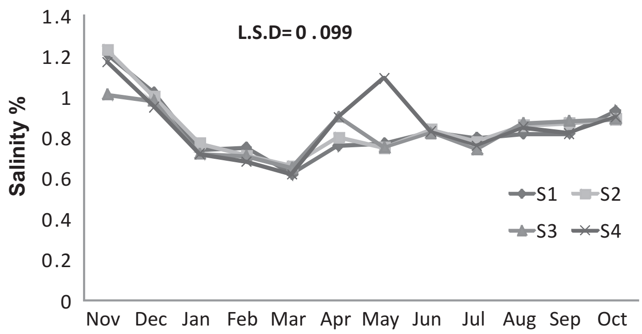

Fig. 4. Variation in salinity values during study period

term used to describe inorganic salts and little amount of organic materials in the water, and basic components of TDS are Calcium, Magnesium, Chloride and Hydrogen Chloride (Wurts and Michal, 2004). The results showed increased values of TDS in summer and autumn and values ranged between 510 and 990 mg l^{-1} (Fig. 6) and also noticed negative correlation between TDS and water temperature (r=-0.18).

Dissolved oxygen is one of most important factor in aquatic environment, which has vital role for organismsand deficiency of dissolved oxygen leads to great damage to organisms and it`s also sign of organic pollution (APHA, 2003). Values of DO ranged between 1.3 and 8.2mg l^{-1} (Fig. 7). Biological oxygen demand is amount of oxygen required for oxidation organic material to carbon dioxide and water if oxidation occurred by microorganism and used organic matter as source of food the consumed oxygen is known as biological oxygen demand (Wilson, 2009). The values of BOD ranged between 0.1 and 4.7 mg l^{-1} (Fig. 8). Total alkalinity is considered as content of water from carbonate, bicarbonate and hydroxides to know water quality and suitability of water for different uses (APHA, 2003). The values of total alkalinity ranged between 32 and 84 mg l^{-1} (Fig. 9). The results of statistical analysis appeared significant difference between months and sites and positive correlation between air and water temperature, (r=0.65); the electrical conductivity and salinity, (r=0.04); pH and sulphate, (r=0.27); dissolved oxygen and salinity, (r=0.30); BOD and calcium and sulphate, (r=0.30 ;r=0.16); total alkalinity and hardness and silicate, (r=0.38 ; r=0.47); hardness and calcium and sulphate, (r=0.60; r=0.15); calcium and air and water temperature, (r=0.014; r=0.29) at $p<0.05$.

The hardness is representing total concentration of cations and it doesn`t consist by one ion but by polyvalent ions and ions of calcium and magnesium are prevalent as well as other cations (Muylaert *et al.*, 2009). The values of hardness ranged between 360 and 1250 mg l^{-1} (Fig. 10). Calcium and magnesium are the main reason for water hardness and calcium works to reduce buffering capacity of water as a results of its ability to reduction of carbon dioxide (Hassan *et al.*, 2014). Results of study showed risen of calcium values during the winter due to laundering of soil in rainy seasons specially limestone soil and enter the water to rivers as well as industrial and agriculture that increase calcium values (Al-Saraaf, 2006). The values of calcium and magnesium fluctuated as between 81-71.4and 9.2-379.3 mg l^{-1}, respectively (Fig. 11, 12).

Sulphate values were 2.5-18.7 mg l^{-1} and the results of study showed the highest value in summer at station 1 (Fig. 13). Dissolved silicate is important food component for diatom algae due to interference in diatomic cell wall

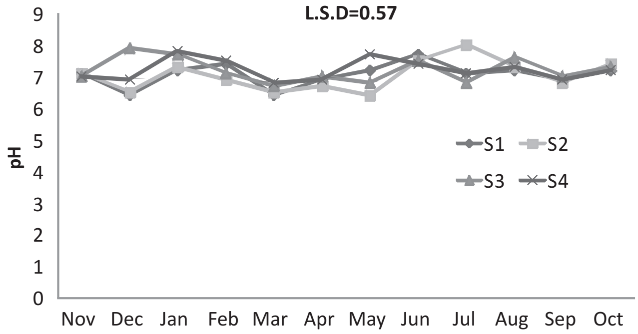

Fig. 5. Variation in pH values during study period

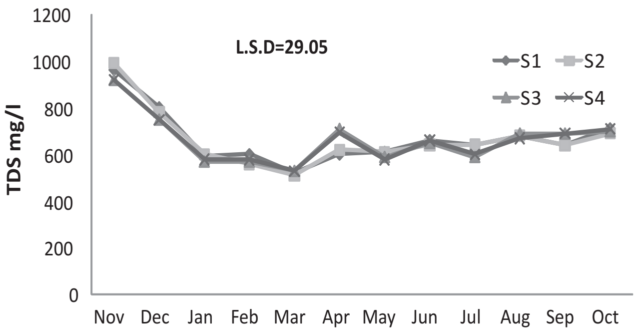

Fig. 6. Variation in TDS values during study period

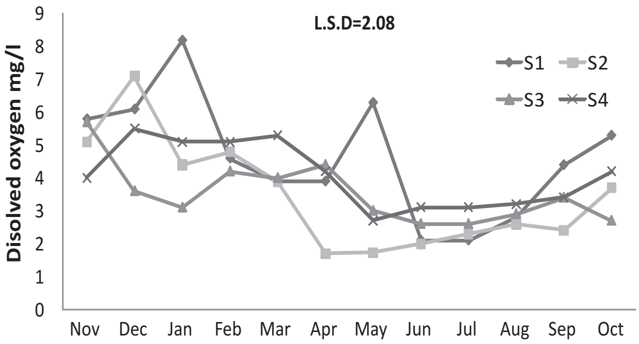

Fig. 7. Variation in disolved oxygen during study period

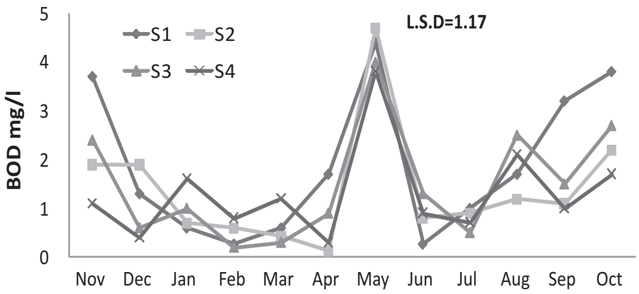

Fig. 8. Variation in BOD values during study period

Table 1. Diatomic algae numbers at four stations

Bacillariophyceae??	S4	S3	S2	S1
Order Centrales				
Conscinodiscus lacustris Grun	_	_	+	+
Cyclotella comate (Ehr.) Kutz	+	_	+	+
C. glomerata Bachmann	+	_	+	_
C. meneghiniana Kutzing	+	+	+	+
C. ocellata Pantocksek	_	+	_	+
C. stelliger Cleveet Grunow	+	_	+	+
Melosira ambigua O. Muller	+	+	+	+
M. granulata (Her.) Ralfs	+	_	_	+
M .italica (Her.) Ralfs	+	_	+	+
M. meneghiana Kutzing	+	+	+	+
Stephanodiscusastrea (Ehr.) Gunow	+	+	_	+
S .dubius (Fricke) Hustedt	+	_	_	+
S. species	_	+	+	+
Thalassiora weissflogii Grun	+	_	+	+
Order Pennales				
Chnanthesclevie Grum *A*	_	_	+	+
A. delicatula Kutz	+	_	+	+
*A. lanceolata*de Brebission	_	+	+	+
A. exgua Grun	_	+	+	+
A. microcephala Kutz	+	+		_
A. plonensis Hustedt	+	_	+	+
A. saxonica Krasske	+	+	+	+
Amphipora alata Kutz	+	_	_	+
Amphora veneta Kutz	_	+	_	+
Asterionella formosa	_	_	_	+
Bacillaria paxillifer (Muller). Hendey	+	_	+	+
Camplydiscusnoricus Ehe.	_	_	_	+
Caloneis bacillum	+	_	+	+
Cocconeis placentula	+	+	+	+
Cocconeis pediculus	+	+	+	+
Diploneis ovalis (Hilse) Cleve	_	+	_	+
D. smith de Brebission	_	+	+	_
Cymbella affinis (AgradhKutz.) VarHerck	+	+	+	+
C. caespitosa Kutz	+	_	+	+
C. cistula (Hemprich)	_	+	+	_
C. cymbiformis	_	+	+	+
C. gracilis (Rahb.) Cleve	_	+	+	_
C. heteroplura Ehr.	+	_	+	+
C. Helvetica Kutz	_	_	_	+
C. leptroceros	+	+	+	+
C. parva	_	_	+	+
C. pusilla Grum	_	+	_	+
C. tumida Grum	+	_	+	+
Cymatopleura solea	+	+	_	_
C. elliptica	_	+	_	_
Diatomaelengatumm	+	+	+	+
D. vulgure	+	+	+	+
D. hiemale	_	_	_	+
Eunotiaexgua	+	_	+	_
E. pediculus	+	+	+	+
E. paerupta	+	_	_	+
Fragilaria breristriata	+	+	_	+
F. canpucina	+	_	+	+
F. construens	_	+	_	+
F. intermedia	+	+	+	+
F. producta	+	+	+	+
F. virescens	+	+	+	_
Gomphonema angustrum (Kutz) Rabh	_	+	+	+
G. capitatum	+	_	+	+
G. constricum Ehr.	+	_	+	+
G. intricatum Kutz	_	+	+	+
G. fanensis Maillard	_	+	_	+
G. gracile Ehe.	+	_	_	+
G. lanceolatum Ehr.	_	+	+	+
G. parvulum (Kutz.) Grum	_	+	+	_
G.oliveace(Lyngbe)Dawson	+	+	_	+
G. subtile Ere.				
Gyrosigmaacuminatum	_	+	+	_
G. personis	_	_	+	+
Neidium affine (Ere) Cleve	+	+	+	+
N. productum (W.Sm.) Cleve	_	+	_	+
Naviculacincta Ehe .Kutz	+	+	+	+
N. cryptocephala Kutz.	+	_	+	+
N. enigmatica Germain	_	_	+	+
N. graciloides A. Mayer	+	+	+	+
N. grecilis Ehe.	+	_	_	+
N. gremmie Krasske	_	+	+	+
N. halophila (Grum.) Cleve	+	+	_	+
N. mensiculus Schumann	+	_	+	_
N. microcephala	+	_	+	+
N. phyllepta Kutz.	_	+	_	+
N. pupula Kutzing	_	+	_	+
N. soehrensis	_	_	+	+
N. subtilissima	_	+	+	+
N. trivialis Lange-Bertalot	+	+	_	+
N. vulpina	_	_	_	+
Nitizschia apiculata Gregory	+	_	+	+
N. acicularis	_	+	+	+
N. clausii	_	+	_	+
N. dessipata	+	_	+	+
N. linearis	+	_	+	+
N. longossima	_	_	+	+

N. minutula	_	+	_	+
N. microcephala	_	+	_	+
N. palea	+	+	+	+
N. paleacea	+	_	_	+
N. pussila	_	+	+	_
N. romana	+	+	+	+
N. tryblioenlla	+	_	+	+
N. segmoidea	_	_	+	+
N. stagnorum Rabh	+	_	+	_
Mastogloiamura diivoigt	_	+	+	+
M. smithii	_	+	_	+
Peronia fibula	_	+	+	+
Pinnularia appendicula	_	_	+	+
P. intermedia Lagerstedt	+	+	_	+
P. gentilis	_	+	+	_
P. gibba	+	+	_	_
P. globiceps	_	_	+	+
P. nodosaEhr.	_	+	_	_
P. viridis	_	+	+	_
Rhoicosphenia marina	+	+	_	+
Rhopalodia gibba	_	_	+	_
Rhopalodia gibberula	_	+	_	+
Surirella linearis	_	+	+	+
S. delicatissma Lewis	_	_	_	+
*S. ovalis*de Brebisson	+	+	+	+
S. ovate Kutz	+	+	+	+
S. robusta	_	_	+	_
S. tenera Gregory	+	+	_	_
Stauroneis anceps	_	+	+	+
S. parvula	+	+	+	+
S. salina	+	+	_	_
Synedraacus	+	_	+	+
Synedra miniscula	_	_	_	+
S. pulchella	+	_	+	+
S. capitata	_	_	_	+
S. tabulata	+	+	+	+
S. ulna	+	+	+	+
S. vaucheria	+	_	+	+
Tabellaria fenestrata	+	_	+	+

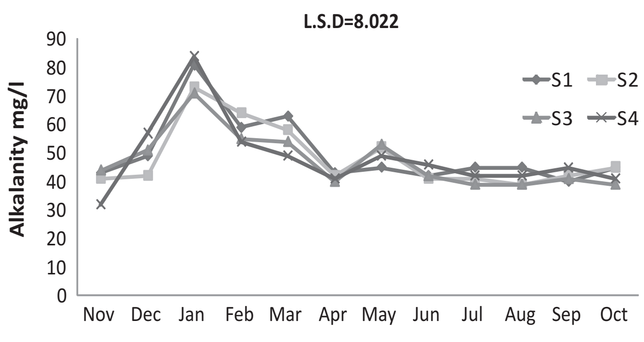

Fig. 9. Variation in alkalanity values during study period

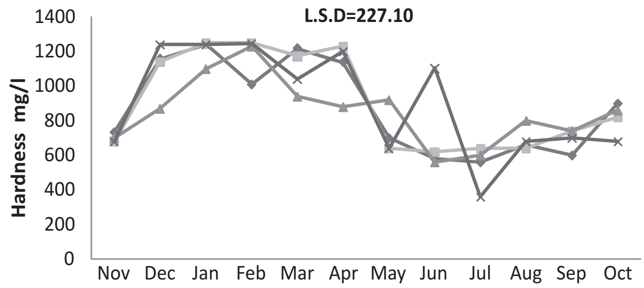

Fig. 10. Variation in hardness values during study period

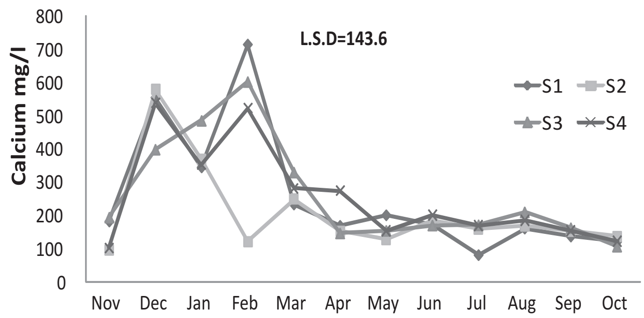

Fig. 11. Variation in calcium values during study period

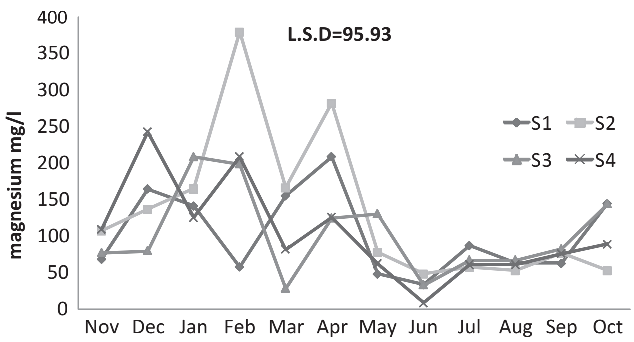

Fig. 12. Variation in magnesium values during study period

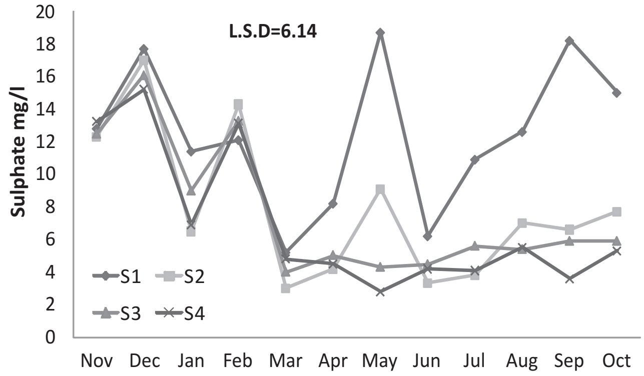

Fig. 13. Variation in sulphate values during study period

instruction (Al−Lami, 1986). Silicate values wereND−28 mg l^{-1} and study results has shown high values during summer and autumn (Fig. 14) and results of study is compatible with (Turner *et al*., 2005; Horne and Goldman, 1994). Phosphorus is one of important nutrients, which is affecting onthe growth and cellular activities for phytoplankton but it`s concentrations in aquatic environment is low (Smith, 2004). The results of study has revealed high values for phosphorus during the summer due to decomposition of aquatic plants and organic material as well as dust , soil minutes and fertilizer from agriculture fields (Appelo and Postma, 1999). Phosphorus values was ND−59.1 µg l^{-1} (Fig. 15). Statistical analysis revealed significant difference between months of studyand negative correlation with algal biomass attached with *P*. *australis* and *C*. *demersum* (r=−0.14 ;r=−0.19); nitrate and dissolved oxygen, (r=−0.31); and positive correlation between silicate and *p.australis*, (r=0.28) ;nitrite and silicate and algal biomass attached with *P. australis* , (r=0.99 ; r=0.29); sulphate and TDS and magnesium(r=0.27; r=0.64); Chl A and Phy A and algal biomass attached with *C. demersum* , (r=0.83; r=0.66) at P<0.05.

Nitrate is considered a common form of inorganic nitrogen in aquatic environment (Hassan *et al*., 2014). The results of statistical analysis has revealed significant differences in nitrate values between months and sites during study period and value was ND−13.6 µg l^{-1} (Fig. 16), higher value was during the summer due to increase in salts concentrations and decomposition operations (Antoine, 1977). Nitrite is unstable ion and usually present in a few amounts in well aerated water and easily oxidize to nitrate and reduced to ammonia when oxygen concentration is low (Goldman and Horne, 1983). Nitrite values were 1−30 µg l^{-1} (Fig. 17) and the results of study gave high values during the winter due to rains and high discharge of rivers which added nitrite from neighboring fields (Maulood *et al* .,1979; Lau and Lane, 2002). Chlorophyll a is considered as an indicator of algal biomass (Felip and Catalan, 2000) and it`s common pigment in all organisms which are performed photosynthesis operations so it`s concentration used to determine algae biomass (AL−Fatlawi, 2011). The results of study revealed high values during summer and was ND−19.2 µg cm^{-1} (Fig. 19).

A diatomic alga showed abundance during the study period and it is well−known phenomenon in Iraqi water inland and the result is compatible with (Mohammed, 2015; Hassan *et al*., 2007; Leghari *et al*., 2002). The diatomic algae have been diagnosed attached with *P. australis* recorded 89 species (Fig. 20) belongs to 25 genus, where Centrales recorded 7 species while pennales recorded 82 species. The diatomic algae have been diagnosed attached with *C. demersum* recorded 100 species (Fig. 21), which belongs to 31 genus where Centrales recorded 12 species while

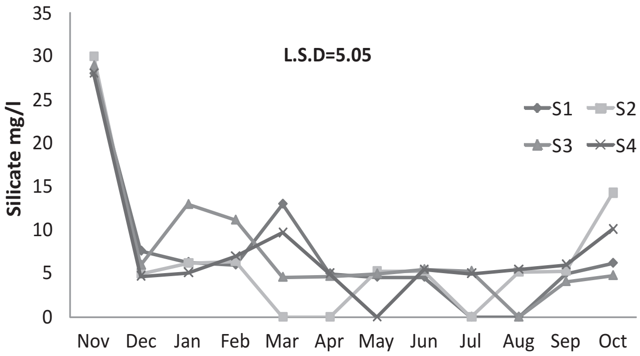

Fig. 14. Variation in silicate values during study period

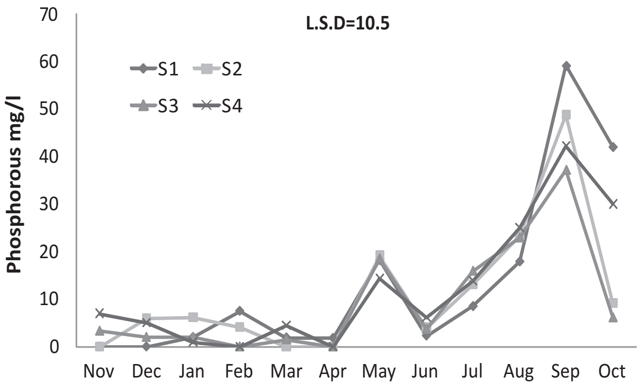

Fig. 15. Variation in phosphorous values during study period

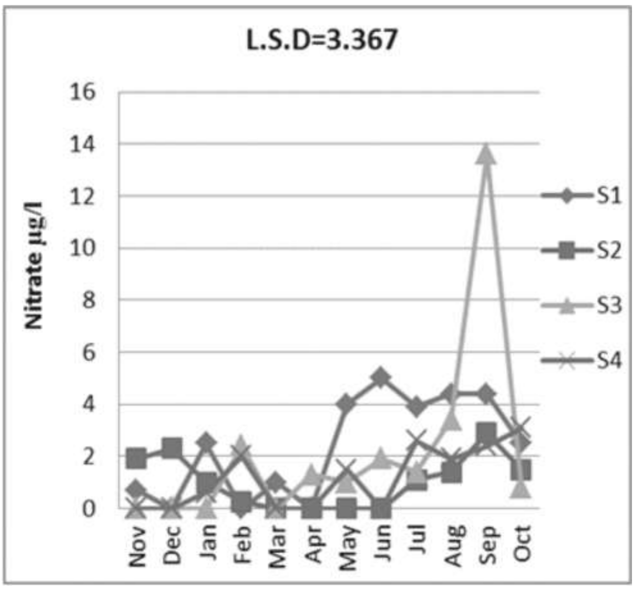

Fig. 16. Variation in nitrate values during study period

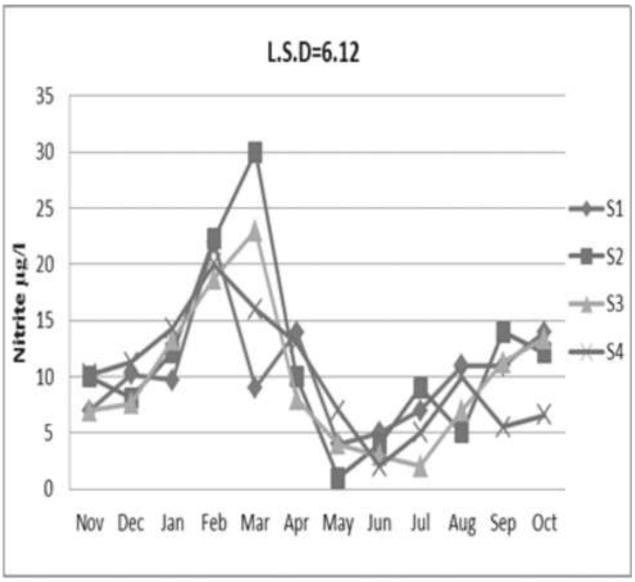

Fig. 17. Variation in nitrate values during study period

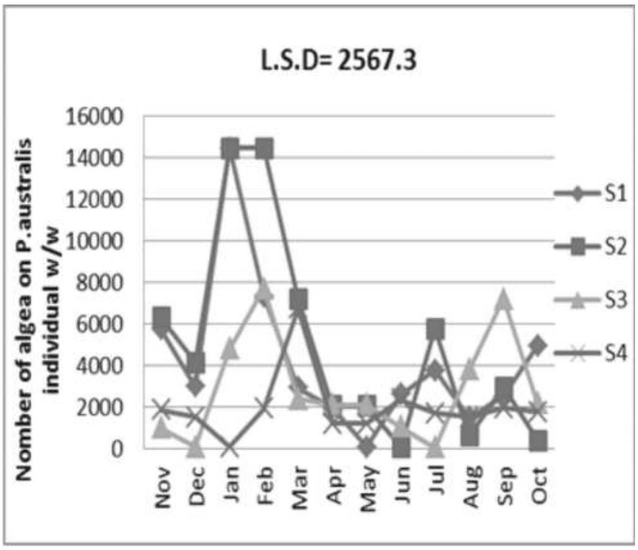

Fig. 20. Variation in number of algae attached to *P. australis* values during study period

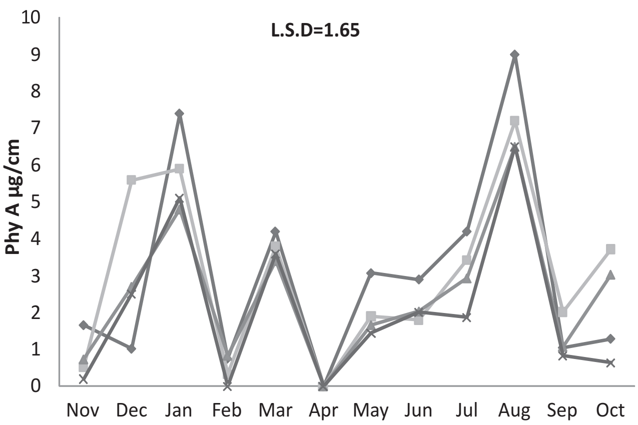

Fig. 18. Variation in Phy a values during study period

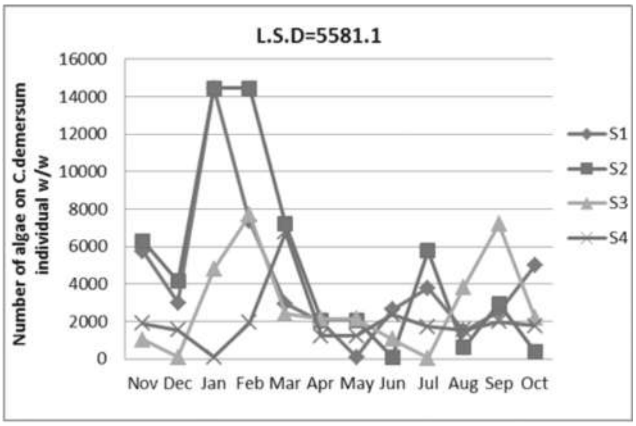

Fig. 21. Variation in algae attached to *C. demersum* values during study period

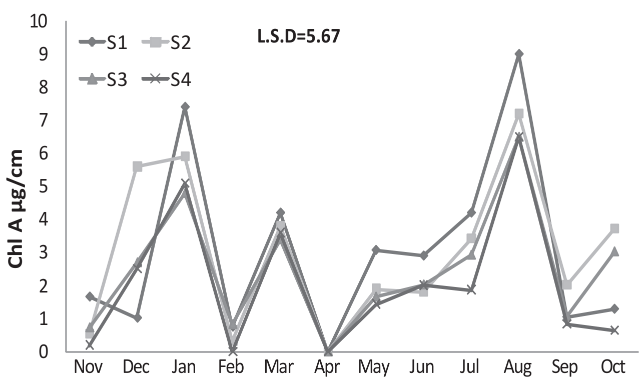

Fig. 19. Variation in Chl A values during study period

pennales recorded 88 species. The abundance of diatomic algae is due to ability to grow in different environment and has siliceous cell wall (Sabanci, 2010). During the study period the abundance of some species like *Navicula, Nitischia, cembella, pinnularia*, *synedra*, with the highest number as 15,15,11,7,7, was observed.

Existence of *Nitischia sp*. is evidence on organic pollution and high endurance for pollutants (Round, 1960), while existence of *Navicula* and *Cymbella* is evidence of brackish water (Kassim *et al*., 1997). Some species has observed on both *P*. *ausralis* and *C*. *demercem* like *Cocconeis Placentula Cocconie spediculus, Cyclotella meneghiniana, Eunotia pediculus, Fragilaria intermedia, Diatoma vulgure, Navicula graciloides, Cymbellaaffinis, Nitischiapalea, Synedra ulna*. Number of epiphytic algae species varied according to the host macrophyte. Higher numbers of algae species were attached on *C. demersum* followed by *P. australis*. The biomass of epiphyte algae also varied according to stations and seasons, this variation in biomass may be due to nutrients concentration, released substances from macrophyte and pollution (Wetzel, 2001).

CONCLUSIONS

Quantitative differences were observed in algae distribution according to type of vegetative plant, where *C. demersum* more than *P. australis* in numbers. Some species preferred specific host plant e.g. *Campylodiscus noricus, Nitischia sigmoidea, Surirularobusta, synedra miniscula, Pinularianodosa, Navicula* were found attached to *C. demersum* while *Achnanthes Clevie, Diatoma hiemale, Gomphonema subtle, Nitischia longosima, Tetraedron minimum* were attached with *P. australis*. phosphorus and nitrate are most important factors in affecting algal growth.

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Effect of Land Use on Fertility Status of Some Old Alluvial Soils of Eastern India

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Abstract: Triplicate soil samples were collected from six locations across four land use systems viz. forest, grazing, cultivated and orchards lands at two soil depths (0–15 cm and 15–30 cm) in Banka district located in old alluvial plain zone of Eastern India. Data revealed that bulk density of cultivated land was found significantly higher than the forest land in surface soil. Aggregate stability and soil organic carbon were recorded significantly higher in forest land followed by orchards, grazing and cultivated land in surface soil. In surface soil, CEC was in increasing order as forest < grazing < orchard < cultivated land. Available N, P and K were found higher in forest land in surface soil, whereas, similar trend was observed in sub-surface soil. DTPA extractable micronutrient (Mn, Fe, and Cu) was found highest in forest land and lowest in cultivated land. In surface soil, Zn was found inverse i.e. highest in cultivated land and lowest in grazing and orchards land.

Keywords: Land use, Forest, Soil characteristics, Hot subhumid climate, Soil sustainability

Increasing population pressure has historically resulted in land use change from natural forest to cultivated and grazing lands with subsequent changes. Land use changes such as deforestation, conversion of rangeland to cropland and cultivation are known to result in changes in soil physico–chemical properties. Land use pattern also plays a vital role in governing the nutrient dynamics and fertility of soils (Venkatesh *et al*., 2003). Thus, every effort should be directed to maintain the soil fertility through sustainable use of the ecosystem. The effects of different land use systems and their associated management practices on soil properties are documented (Mulugeta, 2004; Wakene and Heluf, 2004; Ashagrie *et al*., 2005). The present investigation involved survey and sampling in Banka district located in South Bihar old Alluvial Plain Zone (Agro climatic Zone IIIA) of Bihar to investigate the influence of different land use system on soil fertility status. Banka is a district encompassing an area of about 301900 ha. The major land use types in Banka are forests (43310 ha), cultivated land (160040 ha), grazing lands (1700 ha) and orchards (7300 ha) by I.W.M.P. – I – Banka (2010–11). The agricultural productivity of Banka is low due to undulating terrain and lack of irrigation facilities. However, there is no published literature regarding the comparative nutrient status across various land use systems in Banka. This information is important to address the issue of agro-ecosystem transformation and sustainable land productivity. Agricultural sustainability requires periodic evaluation of soil fertility status which is important in understanding the factors that impose serious constraints to crop production under different land use types and for adoption of suitable land management practices (Chimdi *et al*., 2012). This study will enable development and recommendation of sustainable land use systems.

MATERIAL AND METHODS

The study was conducted across various land use types having the same original land use in adjacent locations in Banka. Geographic coordinates of district is Latitude, Longitude and Altitude 24° 30' to 25° 08' N, 86° 30' to 87° 12' E and 50 to 240 m, respectively and average annual rainfall is 1200 mm. Agricultural fields sampled from predominantly included fields under rice– wheat, maize–wheat or maize–mustard system, whereas mango, guava and jack fruit orchards represented the horticultural system in this study area. Agriculture in these areas is being carried out for well over 100–130 years, and the cultivable land has been passed on from generations to generations. The orchards are only 50-60 years old. The land for human use has been claimed from forests. Forests were mixed and changed with altitude in Banka district. During collection of samples; dead plants, furrow, old manures, wet spots, areas near trees and compost pits were excluded. This was done to minimize differences, which may arise because of the dilution of soil organic matter due to mixing through cultivation and other factors. Samples were air-dried, mixed well and ground to pass through a 2 mm sieve for the analysis of selected soil physical and chemical properties. Separate soil core samples from the 0–15 cm and 15–30 cm depths were taken with a sharp-edged steel cylinder forced manually into the soil for bulk density determination.

Soil sampling: A general visual field survey of the area was carried out to have a general view of the variation in topography and land use in the study area. Based on this survey, six different sites were selected that had four adjacent fields representing various land use types namely cultivated, forest, grazing and orchard lands. The sampled areas are presented in Fig. 1. Triplicate soil sample were collected from each site from the depths of 0–15 cm and 15–30 cm separately each in a radial sampling scheme using an auger (Wilding, 1985). Over this concern, elevation map was demonstrated for the reflection of soil properties corresponding to variation in elevation (Fig. 2). Elevation map represented that there was the gentle slope in Amarpur comparison to Banka and Baunsi blocks.

Physical properties: Soil mechanical analysis was done by hydrometer method as described by Bouyoucos (1962). The soil textural class was determined by using USDA textural triangle. The soils under study showed percent variation in texture composition and textural class of the soils ranging. Maximum water holding capacity of soil was estimated by Keen and Rockzowski's method (Baruah and Barthakur, 1997). Water soluble aggregates size distribution of soil was carried out by wet sieving method (Yoder, 1936).Bulk density of soil was determined by core method (Uhland, 1949).

Chemical properties: pH of the soil samples was determined in water using a soil-water suspension ratio of 1:2 with a glass electrode pH meter (Jackson,1973). EC of the soil sample was determined in soil-water suspension (1:2) at room temperature by conductivity meter (Jackson, 1973).

Fig. 1. Position of soil sampling based on geographical co-ordinates

Soil organic carbon was estimated by wet digestion method (Walkley and Black, 1934) and cation Exchange Capacity by sodium acetate saturation method (Black, 1965). Determination of soil available nitrogen by alkaline potassium permanganate method (Subbiah and Asija, 1956) and available phosphorous was extracted with Bray's P-1

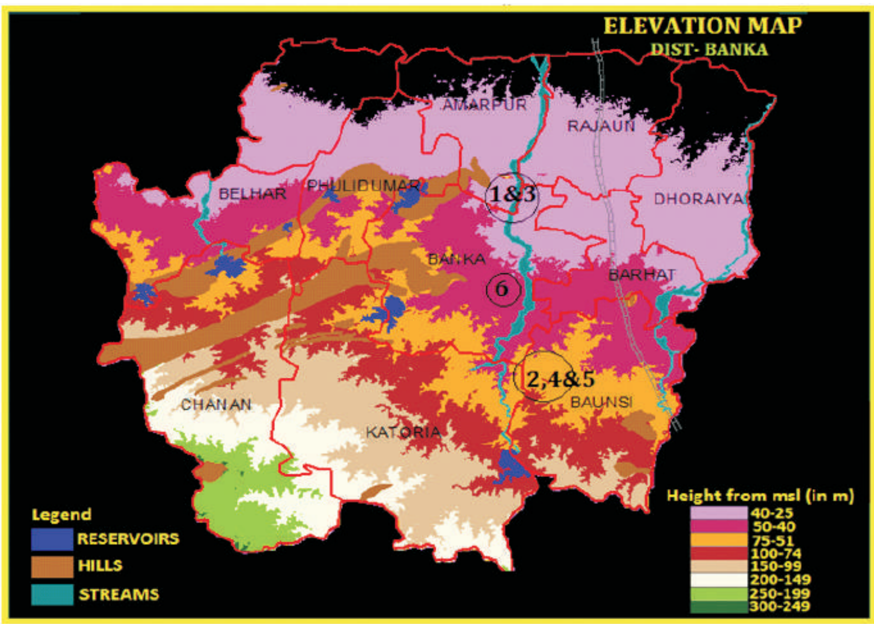

Fig. 2. Elevations map of Banka district

[0.03N NH4F and 0.025N HCl (pH-2.5)] where soil pH <6.0 and Olsen's reagent (0.5M $NaHCO_3$; pH-8.5) where soil >6.0. Phosphorus in the aliquot was by ammonium–molybdate–ascorbic acid method using spectrophotometer (Model No.: Elico SL 177) at a wave length 720 nm (Page et al. 1982). Available K was determined by flame photometer after extracting the soil with neutral normal ammonium acetate (Schollenberger and Simon, 1945). Available micro-nutrients and heavy metal were extracted with the help of mixed solution of 0.005 M DTPA, 0.01 M calcium chloride and 0.1 M Triethanolamine (TEA) at pH 7.3 (Lindsay and Norvell, 1978). Micronutrients were estimated with the help of Atomic Absorption Spectrophotometer (Model AAS-4141M).

Statistical analysis: The soil physico-chemical properties were subjected to analysis of variance. The least significance difference (LSD) test was used to separate significantly differing treatment means after main effects were found significant at $P < 0.05$. Simple correlation analysis was executed with the help Pearson's Correlation Coefficient to reveal the between selected soil parameters.

RESULTS AND DISCUSSION

Physical properties: The highest bulk density (BD) in surface soil was recorded in cultivated land use followed by grazing land, orchard land and the lowest in forest land whereas in subsurface soil (15-30 cm), the highest BD was in cultivated land followed by grazing land), orchard land and in forest land. Trend of BD was similar both in surface and subsurface soil irrespective of land use system (Table 1). Cultivated soil was found to have higher BD than rest land uses due to the higher sand content, low organic matter and destruction of soil aggregates by intensive tillage operation. In surface soil, increasing trend of MWD was cultivated soil < grazing < Orchard < Forest land (Table 1). Similar trend of MWD was recorded in subsurface soil. Similar result was reported by Abad *et al*. (2014) that the cultivated soils were considerably lower in MWD in comparison to forest and pasture land use types. The aggregate stability depends on interaction between primary particles and organic constituents to form stable aggregates, which are influenced by various factors related to soil environmental conditions and management practices. Intensive cultivation and lower organic matter content in cultivated land decrease the aggregate stability. The same finding was supported by Caravaca *et al*. (2004) indicated that aggregate stability of cultivated soil was significantly lower than that of forest soil.

In surface soil, increasing trend of MWHC was grazing < forest < orchard < cultivated soil, whereas, in subsurface soil trend was grazing < orchard< cultivated < forest land. In surface soil the highest MWHC was obtained for cultivated soil (41.50 %) while in subsurface soil the highest MWHC was for forest land (41.87 %) (Table 1). This may due to deposition of root residue by the forest. FAO, (1981) gives a range of values for WHC, which are not associated with particular vegetation types but based upon the soil depth and texture, the influence of parent material, seasonal flooding conditions, top soil texture and other minor correcting factors.

Chemical parameters: Most of the soil was slightly acidic to normal in nature (Table 2). In surface soil, the highest pH was recorded in cultivated land use followed by orchard, forest

Table 1. Effect of land use on soil physical parameters in Eastern India old alluvial plain zone

Parameters	Bulk density ($Mg\ m^{-3}$)		MWD of water stable aggregate(mm)		Max. water holding capacity (%)	
Soil depth (cm)/ Land use	0-15	15-30	0-15	15-30	0-15	15-30
Forest	1.52	1.59	1.98	0.81	37.65	41.87
Grazing	1.56	1.61	1.42	0.76	37.12	37.10
Cultivated	1.59	1.65	1.00	0.65	41.50	40.49
Orchards	1.55	1.60	1.81	0.77	38.42	37.64
CD (p=0.05)	0.05	NS	0.16	0.10	3.01	3.33

Table 2. Effect of land use on soil chemical parameters in Eastern India old alluvial plain zone

Parameters	pH		EC ($dS\ m^{-1}$)		SOC (%)		CEC [cmol (p+) kg^{-1}]	
Soil depth (cm)/Land use	0-15	15-30	0-15	15-30	0-15	15-30	0-15	15-30
Forest	5.87	5.81	0.08	0.07	0.73	0.46	14.07	15.79
Grazing	5.86	5.86	0.07	0.06	0.45	0.33	14.01	14.43
Cultivated	6.20	6.35	0.12	0.10	0.39	0.29	14.89	17.86
Orchards	6.13	6.02	0.16	0.11	0.51	0.33	14.74	17.62
CD (p=0.05)	0.23	0.20	0.04	0.03	0.09	0.07	NS	NS

and the lowest in grazing land whereas in subsurface soil the highest pH was observed in cultivated land followed by orchard, grazing and the lowest in forest land. Light textured soil and heavy rainfall during rainy season results in leaching of bases and consequently lowering the pH of forest soil. Continued application of fertilizer, irrigation and other agronomic practices in cultivated soil resulted in higher soil pH in comparison to other land uses. Similar results were reported by Sharma *et al*. (2014) in Himalaya's foothill. In surface soil, the highest EC was in orchard land use followed by cultivated forest and grazing land whereas in subsurface soil similar trends were observed (Table 2). Light textured soil and heavy rainfall during rainy season results in leaching loss of soluble salts. In surface soil, the highest SOC was recorded in forest land use (0.75 %) followed by orchard), grazing and cultivated land (0.39 %), whereas, in subsurface soil the highest SOC was and in forest (0.46 %) followed by orchard and grazing and cultivated land (0.29 %) (Table 2). Highest organic carbon content was observed forest soil that may be due to continuous leaf fall and growing of grasses on the surface layer of soil. The continued tillage operation year after year, less use of organic matter and turning over of soil has resulted in decrease of organic carbon content in cultivated soil. Similar results were reported by Ahukaemere *et al*. (2015) in forest, fallow and cultivated land. In surface soil, the highest CEC was in cultivated land use followed by orchard, forest and grazing land without much variation whereas in subsurface soil similar result was found (Table 2). Highest cation exchange capacity was observed cultivated soil that may be due to presence of exchangeable cation and clay content.

Available macronutrient: In surface soil, the highest available nitrogen was recorded in forest land use followed by orchard land, grazing land and lowest in cultivated land whereas in subsurface soil the similar trend was observed (Table 3). Highest available nitrogen content was observed in forest soil that may be due to organic matter while lower in cultivated soil due to leaching losses and less organic matter content. Figure 3 represents the losses of available nitrogen in different land uses with reference to forest land in both soil depths. The maximum loss of nitrogen was observed in cultivated soil. This might be due to the intensive crop cultivation followed in the region and also low input addition in the soil.

In surface soil, the highest available phosphorus was recorded in forest land use followed by grazing land, cultivated land and the lowest in orchards land whereas in subsurface soil the highest available phosphorus was observed in forest land followed by orchard land, cultivated land and the lowest grazing land was observed (Table 3).

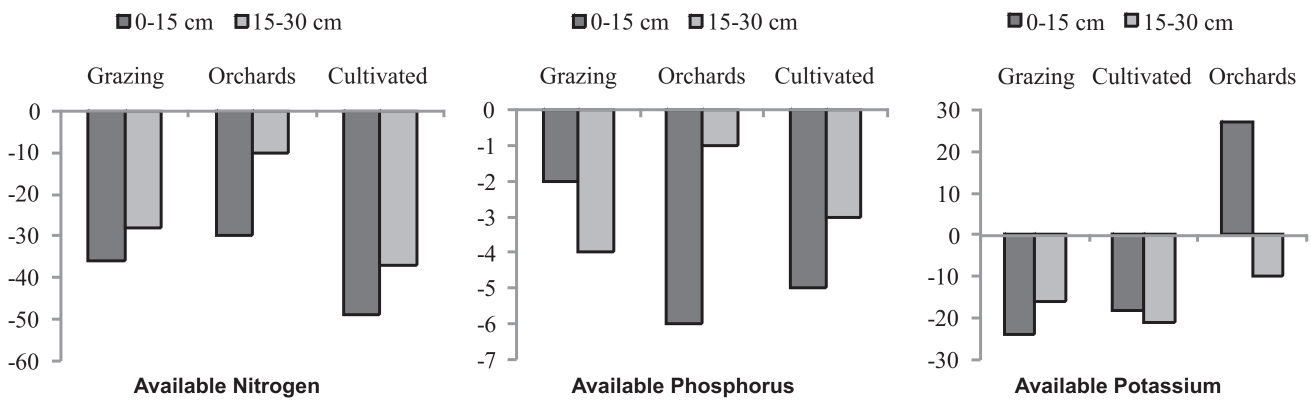

Fig. 3. Losses (or gain) in available nitrogen, available phosphorus and available potassium in different land use with reference to forest land in Eastern India old alluvial plain soils

Table 3. Effect of land use on available macronutrients in Eastern India old alluvial plain zone

Parameters	Available nitrogen (kg ha^{-1})		Available phosphorus (kg ha^{-1})		Available potassium	
Soil depth (cm)/Land use	0–15	15–30	0–15	15–30	0–15	15–30
Forest	313	270	21	12	262	212
Grazing	277	242	19	8	238	196
Cultivated	264	233	16	9	244	191
Orchards	283	260	15	11	289	202
CD (p=0.05)	23	16	3	2	26	26

Highest available phosphorus content was observed in forest soil that may be due to organic matter while lower in cultivated soil due to less organic matter content and low use phosphatic fertilizers. The loss of available phosphorus was 2, 5 and 6 kg ha^{-1} in grazing, cultivated and orchard land, respectively in surface soil, whereas in subsurface soil the loss was 4, 3 and 1 kg ha^{-1} followed in the same order (Fig. 3). In surface soil, the highest available potassium was recorded in orchard land followed by forest land use, cultivated land and the lowest in grazing land whereas in subsurface soil the highest available phosphorus was observed in forest land followed by orchard land, grazing land and the lowest cultivated land was observed (Table 3). Most of the Indian soils are rich in potassium, due to presence of potassium containing minerals like illite, muscovite, gluconite, biotite, phlogopite, sanidine and orthoclase in Indian soil (Naidu *et al.*, 2011). Orchard land had highest available potassium in surface soil. This was due to management practice followed like addition of potassium rich fertilizers in orchard land results increase in soil available potassium. Similar result reported by Gandhe (2015) in garden soils of around Indore (M.P). The gain or loss of available potassium in surface soil was (–) 24, 27 and (–) 18 kg ha^{-1} in grazing, orchard and cultivated land, respectively whereas in subsurface soil was (–) 16, (–) 10 and (–) 21 kg ha^{-1} followed in same order (Fig. 3).

Available micronutrients: In surface soil, the highest available manganese was recorded in forest land followed by grazing and cultivated land and the lowest in orchard land whereas in subsurface soil the highest available manganese was observed in forest land followed by cultivated land, grazing land and the lowest in orchard land was observed (Table 4). The Highest manganese were found in forest land due to organic matter and presence of parent material while lower in cultivated soil due to presence of less organic matter. The loss of available manganese was 8, 13 and 8 mg kg^{-1} in grazing, orchard and cultivated soil, respectively in surface soil whereas in subsurface soil the loss was 8, 11 and 7 mg kg^{-1}, respectively followed in the same order (Fig. 4). In surface soil, the highest available iron was in forest land followed by grazing land, orchard land and the lowest in

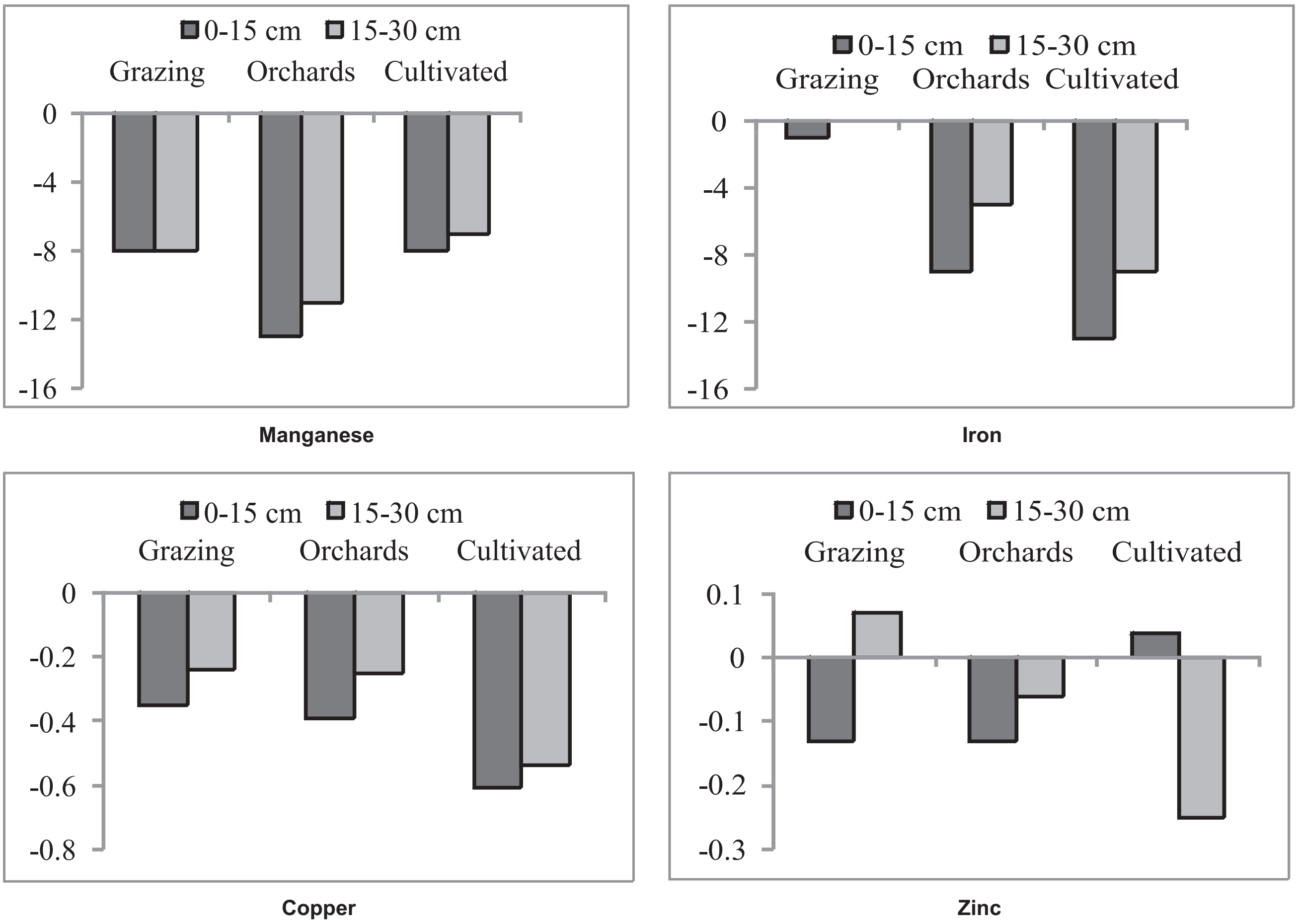

Fig. 4. Losses (or gain) in DTPA extractable Manganese, Iron, Copper and Zinc in different land use with reference to forest land in Eastern India old alluvial plain zone

Table 4. Effect of land use on DTPA extractable micronutrients in Eastern India old alluvial plain zone (mg kg^{-1})

Parameters	Manganese		Iron		Copper		Zinc	
Soil depth (cm)/ Land use	0-15	15-30	0-15	15-30	0-15	15-30	0-15	15-30
Forest	49	45	42	32	2.87	2.21	1.72	1.80
Grazing	41	37	41	32	2.52	1.97	1.59	1.87
Cultivated	41	38	29	23	2.26	1.67	1.76	1.55
Orchards	36	34	33	27	2.48	1.96	1.59	1.74
CD (p=0.05)	2	3	2	3	NS	0.32	0.13	0.11

Table 5. Pearson's correlation matrix for various soil physicochemical parameters in Eastern India old alluvial plain zone

	pH	EC	SOC	N	P	K	Fe	Mn	Cu	Zn	CEC	MWHC	MWD	BD	Clay
pH	1.00														
EC	0.71**	1.00													
SOC	-0.20	0.01	1.00												
N	-0.24*	-0.03	0.62**	1.00											
P	-0.02	0.01	0.36**	-0.04	1.00										
K	0.23	0.31*	0.36**	0.13	0.40**	1.00									
Fe	-0.15	0.02	0.59**	0.38**	0.31*	0.23	1.00								
Mn	-0.46**	-0.30*	0.19	0.15	-0.05	0.09	0.19	1.00							
Cu	-0.06	0.21	0.67**	0.65**	0.18	0.22	0.63**	0.09	1.00						
Zn	-0.18	-0.09	0.07	0.15	0.12	0.16	0.09	0.01	0.18	1.00					
CEC	0.13	0.14	0.36**	0.27*	0.06	0.07	0.20	-0.08	0.38**	0.42**	1.00				
MWHC	0.18	0.28*	0.35**	0.18	0.11	0.25*	0.36**	-0.02	0.36**	0.20	0.53**	1.00			
MWD	-0.04	0.14	0.66**	0.60**	0.02	0.18	0.54**	0.01	0.67**	-0.13	0.14	0.26*	1.00		
BD	0.15	-0.11	-0.66**	-0.33*	-0.40**	-0.48**	-0.56**	-0.19	-0.62**	-0.35**	-0.40**	-0.40**	-0.37**	1.00	
Clay	0.30*	0.22	-0.36**	-0.38**	-0.03	-0.10	-0.20	-0.15	-0.23	-0.05	-0.48**	-0.19	-0.23	0.33*	1.00

** Significant at P = 0.01 level; * Significant at P = 0.05 level

cultivated land whereas in subsurface soil the highest available iron was observed in forest and grazing land followed by orchard land, and the lowest in cultivated land was observed. The loss of available iron was 1, 9 and 13 mg kg^{-1} in grazing, orchard and cultivated soil, respectively in surface soil whereas in subsurface soil the loss was 0, 5 and 9 mg kg^{-1}, respectively followed in the same order (Fig. 4).

The effect of land use on available zinc has been presented in Table 4. In surface soil, the highest available zinc was recorded in cultivated land followed by forest land and the lowest in grazing and orchard land whereas in sub-surface soil the highest available zinc was observed in grazing land followed by forest land, orchard land and the lowest in cultivated land was observed. The gain (or loss) of available zinc was (-) 0.13, 0.04 and (-) 0.13 mg kg^{-1} in grazing, orchard and cultivated soil, respectively in surface soil whereas in subsurface soil the loss was 0.07, (-) 0.25 and (-) 0.06 mg kg^{-1}, respectively followed in the same order (Fig. 4). In surface soil, the highest available copper was recorded in forest land followed by grazing land, orchard land and the lowest in cultivated land whereas in sub-surface soil the highest available copper was observed in forest land followed by grazing land, orchard land and the lowest in cultivated land was observed. The loss of available copper was 0.35, 0.61 and 0.39 mg kg^{-1} in grazing, cultivated and orchard soil, respectively in surface soil, whereas, in subsurface soil the loss was 0.24, 0.54 and 0.25 mg kg^{-1}, respectively followed in the same order (Fig. 3). The maximum loss of copper was recorded in the intensive cultivated soil.

Relations between various soil physicochemical parameters : Soil organic carbon was positively and significantly correlated with available N, P, K, CEC, micronutrient Fe, Cu, MWD, MWHC while inversely and significantly correlated with clay and BD. Phosphorus was positively and significantly correlated with K and inversely and significantly correlated with BD. Cation exchange capacity was positively and significantly correlated with MWHC while inversely and significantly correlated with BD and clay. Maximum water holding capacity (MWHC) was positively and significantly (correlated with BD while inversely and significantly correlated with BD. Mean Weight diameter (MWD) was inversely and significantly correlated while Bulk density was positively and significantly correlated with clay (Table 5).

The present study has quantitatively expressed the turn down of the fertility status of cultivated land over existing land use in the old alluvial plain zone. Thus, the management practices such as grazing, deforestation, and continuous cultivation turn down the soil fertility as compared to existing natural land use system like forest land. Conversion in land use from forest land to cultivated land can have detrimental effect on soil fertility. Agricultural disturbances, like tillage, removal of crop residue and enhanced soil erosion could be the major cause of carbon losses from the soil.

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Iron Content in Soil, Water, Fodder, Grain, Organs and Muscular Tissues in Cattle of Western Siberia (Russia)

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***Abstract*:** The iron content in the soils, water, fodder and grain were determined in two ecological zones of Novosibirsk area, which are differing in the level of environmental pollutions. The concentrations of iron in soils, water, fodder and grain did not exceed the maximum contaminant levels and did not differ between the ecological zones. The maximal content of iron in both animal breeds was observed in the spleen and lungs. The interbreed differences have been revealed in the content of iron in lungs, spleen and muscular tissue indicating a role of genetic background in accumulation of iron by the organs of cattle.

***Keywords*:** Iron, Soil, Fodder, Black-and-White and Hereford breeds, Western Siberia

Iron is a widespread element in nature contained in rocks and soils in quantities of more than 0.01 per cent and in vegetable and animal organisms in their dry matter it is present less than 0.01 per cent (Kabata-Pendias, 2011). A lack of iron in an organism results in iron deficiency (anemia). Even a slight deficiency of iron leads to exhaustion, decrease in body temperature, a greying of hair, embrittlement of skin derivates, loss of physical force and endurance, and also decrease of production of thyroid hormone. Deficiency of iron affects the immune status of calves, and also an erythropoiesis and a thrombopoiesis (Lukovic *et al*., 2013). Excess iron intake in an organism can lead to damage of organs and gradual dysfunction of organs with chronic toxicity. The strongest toxic effect of overdose is shown by iron in the liver, heart, and pancreas beta cells, and in all tissues with high activity of mitochondrions. The generating activated oxygen is capable to cause synergetic toxic effect with intracellular iron (Eaton andQian, 2002).

In Western Siberia biomonitoring of content of iron and other heavy metals in water, the soil, sterns and food is regularly conducted (Patrashkov *et al*., 2003; Chysyma *et al*., 2003 a, b; Marmuleva *et al*., 2003; Korotkevich *et al*., 2014; Petukhov *et al*., 2016a). Environmental pollution by heavy metals can affect the quantity and quality of the products of farm animals resistant to diseases and the genetic structure of populations (Miller *et al*., 2013; Petukhova, 2013; Narozhnyh *et al*., 2013; Korotkevich *et al*., 2014a). Therefore, a necessary and promising direction for monitoring the environmental parameters in farmland is to assess the level of heavy metals in the soil, plant food, organs and tissues of animals, as important indicators of environmental safety (Afonina *et al*., 2003a, b; Narozhnykh *et al*., 2016;Petukhov *et al*., 2016). The purpose of this work was to study the content of iron in soils, water, fodder, grain, organs and muscular tissue of the Black-and -White and Hereford cattle of Western Siberia.

MATERIAL AND METHODS

In total 20 soil samples, 17 water samples and 18 grain and 24 samples of rough forages in two ecological zones of the Novosibirsk region differing on the level of ananthropogenic impactwere taken.From the zone 1 (Maslyaninsky 54°20'04"N 84°12'59"E, Krasnoozersky 53°59'N 79°15'E and Novosibirsk districts 55°01'N 82°56'E) with a high level of agro-and technogenic environmental impact located in east part of the area on the raised geomorphological structures with a dominance of humus and gray forest soils, 15 soil, 12 water, 13 grain and 17 samples of rough forages were selected. From the zone 2 (Ubinsky district 55°18'N 79°41'E) with low level of environmental impact, which is in the central part of the area where in the under geomorphological structure soils with the increased salting and humidification, 5 samples of soil, waters, grains and 7 samples of fodder are taken.

The iron content in the soil, fodder and grain was determined after decomposition of sample with a mixture of mineral acids in a microwave sample preparation system. Measurement of iron was performed using atomic absorption spectrometry with a photometer "Quantum-2A".Approximately 300 samples of various organs and muscle tissues (a weight of each sample was 100 g) were taken from 62 bulls of Black-and-White and Hereford breeds aged 18 months. The meat cattle was grown up in a zone 1 and dairy cattle of Black-and-White was reared in a zone 2. Concentration of iron in organs and muscular tissue was defined on the atomic absorption spectrophotometer (Shimadzu AA-7000, Japan).

Statistical analysis: The data are presented as mean standard deviation. They were tested for normality before statistical analysis by Shapiro-Wilk test. As in certain cases, distribution of data did not correspond to normal, therefore we used an approach offered for small samples without a normal distribution determination (Hozo *et al*., 2005):

$$\bar{x} \approx \frac{a + 2m + b}{4} + \frac{a - 2n + b}{4n}$$

$$S^2 \approx \frac{1}{n-1}\left(a^2 + m^2 + b^2 + \left(\frac{n-3}{2}\right)\frac{(a+m)^2 + (m+b)^2}{4} - n\left(\frac{a + 2m + b}{4} + \frac{a - 2m + b}{4n}\right)^2\right)$$

where n - sample size; a - the minimum value of the characteristic; b -the maximum value of the characteristic; m – median, S^2 – variance.

Statistical analysis of the data was performed using STATISTICA 8.0 and Microsoft Exel 2007. Differences were considered statistically different when $p < 0.05$.

RESULTS AND DISCUSSION

The content of iron in the soil, water, fodder and grain is shown in Table 1. Between the two zones, there was no significant difference in iron content in the samples studied.

Content of iron in water was 30% less than the established maximum contaminant level (MCL) in Russia and USA (EPA, 1992). Water with high concentration of iron can promote manifesting of a bacterium that sometimes leads to a discoloration of water and formation of mucous. The iron content strongly varies in farm animal fodder. In plants, iron content depends on a type and kind of the soil in which they grow. Therefore, the value of iron content reached 70-80 mg kg^{-1} in a lucerne on uncontaminated soils and low content of iron, which are grown up on sandy soils (40 mg kg^{-1}), as well as for some herbs, were recorded (Underwood, 1977). The majority grains of cereals have small trans-species distinctions in iron content from 30 to 60 mg kg^{-1}. Bean and seed oils may contain from 100 to 200 mg kg^{-1} of iron. In various regions of Western Siberia, an excess of MCL in iron content was not revealed in fodder though significant differences between territories were recorded (Korotkevich *et al*., 2014b).There is a considerable variability of iron in the spleen, lungs and hair in dairy and beef cattle (Table 2). The data on the content of iron in the organs and tissues of cattle of different productivity can be regarded as physiological and ecological reference values for Western Siberia conditions.

Distribution of iron in the organs and muscle tissue of Black-and-White breed can be represented as a ranked series: muscle <hair <kidney <heart <liver <lungs <spleen in a ratio of 1: 1.1: 1.4: 1.5: 4.5: 11.2 and in Hereford as follows: muscle <kidneys <heart <liver <hair <lungs<spleen in a ratio of 1: 1.9: 2.0: 2.6: 3.3: 4.1: 11.3. This data show that two animal breeds have the greatest iron accumulation in spleen and lungs, and a minimum iron accumulation was recorded in skeletal muscle. Ranked range for iron differed between dairy and beef cattle. The iron content in muscle tissue, hair and kidney differed little in Black-and White breed but in Hereford cattle, the Fe concentration in the hair was in 3 and 1.9 times higher than in muscle and kidney.

The interbreed differences in the accumulation of iron were established in tissues and organs of cattle (Table 2). The iron concentration in spleen, lungs, skeletal muscle was greater in animals of Black-and-White breed then in Hereford breed. Interbreed differences in iron content have been found

Table 1. Iron content in the soil, fodder, grain (mg g^{-1} of dry matter) and water (mg l^{-1}) in the two ecological zones of Novosibirsk region

Sample	Zone 1	Zone 2	MLC
Soil	2.98±0.20	3.45±0.18	–
Water	0.20±0.04	0.21±0.08	0.3
Fodder	77.3±11.5	102.0±17.0	100-200
Grain	54.5±7.5	52.0±5.0	100

Table 2. The content of iron in the organs and muscle tissue of cattle (mg kg^{-1} of natural humidity) in two ecological zones of the Novosibirsk region

Breed		Black-and-White	Hereford
Organ or tissue	n	Mean±SD	Mean±SD
Muscles	29	52.3±13.5	24.4±9.1
Hair	31	54.5±38.6	81.5±60.1
Kidneys	31	57.6±16.4	47.2±16.1
Liver	29	73.5±24.0	64.3±17.4
Heart	31	80.6±32.7	48.3±16.0
Lungs	28	233.8±104.9	99.8±50.5
Spleen	30	585.8±307.5	276.6±122.4

in cattle breeds with the same productive direction in other studies. For example,the meat from animals of Bruford breed was less rich of iron that meat of Hereford breed (Ramos *et al*., 2012). However, the difference is only 15–20 per cent. In present study, the difference was more significant, which could be due to different directions of productivity and different environmental conditions. The iron concentration in the meat of Hereford breed was below 40 per cent and in the meat of Black–and–White breed was higher by 30% than in the cattle (Ramos *et al*., 2012). Another article presents the data on iron accumulation in two muscles *Longissimus lumborum* and *Semitendinosus muscles* in five cattle breeds Polish Red, White–Backed, Polish Black–and–White, Simmental and Polish Holstein–Friesian. The iron accumulation in the *Longissimus lumborum muscles* did not differ much between these breeds. The iron accumulation in the *Semitendinosus muscles* differed between Simmental and Polish Holstein–Friesian breeds, but not between Polish Red, White-Backed, Polish Black-and-White (Litwińczuk *et al*., 2015). In present study, the iron content in Black–and–White cattlewas more than 2 times higher than in the earlier report (Litwińczuk *et al*., 2015). In general, the iron content in the muscle tissue of cattle did not vary significantly depending on the breeding region, age or breed, changing in the range of 20–60 mg kg^{-1}.

The accumulation of iron in the tissues depends on the amount taken into the body, administration method, and duration of exposure, the composition of the diet and physiological features of the animal. When animals receive an excessive amount of iron it is accumulated mainly in the liver, spleen and bone marrow, and at very high doses, iron can be deposited in the heart and kidneys (Underwood, 1977). Thus, an iron increase was observed in chicken`s liver, kidney, spleen and bone at a content of 400–800 mg kg^{-1} feed (Cao *et al*., 1996). A slight increase in iron (25%) occurred in the muscle tissue of bulls when they feed by element concentration was 1000 mg kg^{-1} compared with the animals treated with 100 mg kg^{-1} (Standish *et al*., 1969). An iron increased concentration was recorded in sheep`s liver, kidney, spleen, muscle, and with the additional administration in the diet of 760 mg kg^{-1} of iron as a ferric citrate (Rosa *et al*., 1982). Similar effects were observed in the following experiment. The iron levels in skeletal muscle didn't differ in sheep treated with 40 or 80 mg kg^{-1} of iron (Rallis *et al*., 1989). The maximum permissible level is determined as a dietary iron level, which, when it enters the body for a certain period will not degrade performance or health of animals. So for cattle, sheep and poultry, it is 500 mg kg^{-1}, and for pigs – 3000 mg kg^{-1} (NRC, 2005). In the calves` experiment, it is shown that even a high iron concentration entering the organism, does not cause a significant increase in its content in skeletal muscle. Therefore, for 6 week calves were given 100, 500, 1000, 2000 and 5000 mg kg^{-1} of iron, then the concentration of this element in the muscles was determined and the result was –33.3, 35.8, 35.9, 41.0, 47.3. However, iron levels increased up 3, 5 and 40 times, respectively in the kidney, spleen and liver (Jenkins and Hidiroglou, 1987).

The iron accumulation level in liver and kidneys in cattle from Poland varied in the narrow range of 43–53 mg kg^{-1} and 67–72 mg kg^{-1}, respectively (Falandysz and Lorenc–Biala, 1989, Zmudzki, 1978). These values were higher in Finland, and represent 72 and 120 mg kg^{-1} in liver and kidneys respectively, (Nuurtamo *et al*., 1980). The findings of our study were similar to values of iron accumulation in cattle from Poland.

CONCLUSIONS

The iron content in soils, water, fodder and grain from different ecological zones of Western Siberia does not exceed the maximum contaminant level. Differences between zones on the concentration of iron in the soil, water, fodder and grain have not been identified. In contrast to iron contents in soils, water, fodder and grain, there were significant differences in the iron contents in spleen, lung and skeletal muscle of two breeds of cattle. It is suggest that genetic background and direction of productivity have a significant impact on the accumulation and distribution of iron in different organs and tissues. The data obtained could be used for subsequent environmental monitoring of this element in soils, water, fodder and grain in other ecological zones; and as physiological standards of iron contents in the organs and muscle tissue in cattle reared in Western Siberia.

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Effect of Long-term Fertilization and Algalization on Active Soil Organic Pools, Crop Yield and Dehydrogenase Activity under Rice- Wheat Cropping Sequences

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Abstract: The present investigation aimed at understanding the influence of fertilization and algalization on active pools of Soil organic matter (SOM) under continuous rice wheat cropping system. The experiment was carried out with three treatments viz. control (unfertilized), 50% NPK and 50% NPK + BGA in 2014 inVertisol at Indira Gandhi Krishi Vishwavidyalaya, Raipur, India. The greater accumulation of soil organic carbon (SOC) in surface soil (0–15 cm depth) than the subsurface soil (15–30 cm) in all three treatments, maximum being in surface soil with treatment 50% NPK + BGA (6.38 g kg^{-1}) followed by 50% NPK (6.13g kg^{-1}) and control (4.42g kg^{-1}). The present investigation suggested that long term nutrient management and continuous cropping of two cereals i.e. rice and wheat, caused depletion of soil organic pools including hot water soluble carbon, acid hydrolysable carbohydrate, soil microbial biomass carbon and nitrogen and DHA under no fertilization, whereas; the addition of suboptimal dose of primary nutrients with or without BGA facilitated improvement in soil organic fractions as well as dehydrogenase activity in upper and lower soil profile depth over unfertilized control. The study unveiled that combined application of BGA with fertilizers may be a better option for crop nourishment and soil health maintenance under rice based cropping system.

Keywords: Fertilization, Algalization, Active Pool, Crop Yield

During 60's, green revolution greatly boosted the food grain production in India where the vital role for increasing food grain productivity was played by fertilizers. However, long term cultivation of crop with excess amount of fertilizers led to loss in soil fertility, declined yield and disturbed soil biota under various cropping systems. Rice−wheat system is one of the most dominant cropping systems in India contributing major share in national economy. Stagnation or declining yield of rice and wheat in such long term cultivation has been witnessed (Ladha *et al.*, 2003) and the reason might be declined fertility status of soil. The rice and wheat requires contrasting edaphic conditions i.e. alternate flooding (reducing) and drying (oxidizing) which influence transformation and availability of nutrients in soil to a great extent. Soil fertility declination in many rice growing states like Chhattisgarh influenced the total food grain production. The nutrient supplying capacity of a soil is directly or indirectly related to the SOM and its fractions or pools in soil. Active pool is generally used as indicator of soil functions because of its quick response to the nutrient management practices.

Soil organic carbon (SOC) content is positively related with the crop yield and microbial biomass and influenced by several factors such as tillage, cropping systems, management practices, manuring, fertilization and depth of soil profile. The dehydrogenase activity (DHA) reflects microbial activity in soil and influenced by manuring and fertilizer application (Luo *et al.*, 2015). Not only excess fertilization, but imbalance application of fertilizers also resulted in declined yield under continuous cropping (Fan *et al.*, 2007) as unremitting removal of nutrients by crop causes declined soil fertility. Similarly, the yield reduction and declined soil organic carbon and its fractions in soil has occurred due to continuous nutrient mining without addition (Ortas and Lal, 2014), climatic fluctuations (Manna *et al.*, 2013), conventional farming systems etc. Hence, sustaining crop yield through integrated nutrient management for long run can be achieved by managing soil carbon and its fractions in soil (Nayak *et al.*, 2012). Like manuring and fertilization, term 'algalization' is popularly used for application of blue green algae in paddy soil. Blue green algaeis known because of its nitrogen fixation capacity especially in rice field, but they can also contribute towards some other soil functions (Gupta *et al.*, 2015) and may influence soil activities if apply in combination with fertilizers. There has rarely been focused on effect of blue green algae on soil organic pools under a decade of continuous cropping of rice and wheat. The present work was carried out to assess the impact of fertilization alone and in combination with algalization under rice wheat continuous cropping system.

MATERIAL AND METHODS

The long term fertilizer experiment (LTFE) was started during 1999 under the All India Coordinate Research Project (AICRP) at Indira Gandhi Krishi Vishwavidyalaya, Raipur (21°4´N, 81°4´E), Chhattisgarh, with the mean sea level of 293 m. The climate is sub-humid type with the average annual rainfall of 1317.77 mm and most of the rainfall occurs during monsoon season (June to September). The soil order is vertisol, fine montmorillonite, hyperthermic, udicchromustert, locally called as *Kanhar* and is recognized as *Arang* II series. Rice was transplanted at beginning of June in puddled soil with following nutrient management treatments: control, 50% NPK and 50% NPK + BGA (Table 1). It was hypothesized that the BGA can contribute towards some soil quality parameters to some extent when apply as supplement with suboptimal dose of primary nutrients. After harvesting of rice, wheat was transplanted under same treatments and grain yield of both crops were recorded.

Soil samples were collected randomly from same replicated field in June 2014 after harvesting of wheat and before transplanting of rice crop with auger from each treatment at two depths i.e. 0-15 and 15-30 cm. The samples were dried in air, ground properly and sieved to obtain desirable sized particles. The fresh soil samples were taken for DHA estimation. The soil samples were analyzed at laboratory of Indian Institute of Soil Science, Bhopal.

Soil organic carbon was estimated from dry sample by adopting the standard method of Walkley and Black (1934). 1 g of 0.2 mm air dried soil sample was digested with 1 N $K_2Cr_2O_7$ and titrated back with 0.5 N ferrous ammonium sulphate. The hot extraction method as described by McGill *et al.*(1986) was adopted for estimation of hot water soluble carbon. 10 g air dried soil water suspension (1:2) was shaken in a horizontal shaker for an hour followed by centrifugation. The supernatant was filtered and washed, volume made up to 50 ml. 10 ml of filtrate was digested with 0.4 N $K_2Cr_2O_7$ and Sulphuric acid followed by water bath and titrated with 0.035 N FAS. Brink *et al.* (1960) described the method for determination of acid hydrolysable carbohydrate (AHC) in soil. 5 g dry soil with Sulphuric acid was allowed for steam-bath and 5 ml of filtrate aliquot was taken and added 0.2 per cent anthrone into it. A fumigation - extraction method as described by Vance *et al.* (1987), was adopted for determining the soil microbial biomass carbon (SMBC). 10 g fresh soil sample was incubated with an identical non fumigated sample and then shaken with 0.5 M K_2SO_4. The 10 ml of filtered aliquot was digested with 0.4 N $K_2Cr_2O_7$ and titrated back by 0.035 N FAS. Standard procedure described by Brookes *et al.* (1985) were used for estimation of SMBN. Two subsamples (fumigated and non-fumigated) for each sample, were extracted with 2 M KCl and 10 ml of aliquot was taken after shaking and filtering. The aliquots were distillated with MgO and devarda alloy followed by titration with H_2SO_4 and readings were interpreted to obtain SMBN values. Soil dehydrogenase activity was estimated by method as described by Cassida *et al.* (1964). 4 g of fresh moist soil plus $CaCO_3$, distilled water and 3% Triphenyltetrazolium chloride (TTC) was taken in a centrifugal tube followed by thoroughly mixing and put in incubator for 24 hrs. Thereafter, centrifuged and washed with methanol and the reading was recorded in spectrophotometer at 485 nm. The present experiment was laid out in randomized block design with three replications with the plot size of 20x10 m.

RESULTS AND DISCUSSION

Soil organic carbon: The greater accumulation of SOC in surface soil in treatment 50% NPK + BGA (6.38 g kg^{-1}) followed by 50% NPK (6.13g kg^{-1}) and the lowest concentrations were observed in control (4.42g kg^{-1}). However; 50% NPK + BGA and 50% NPK amended treatments were statistically at par with each other. The SOC trend in subsurface soil was quite similar to that of surface soil (Table 2). The improved SOC status of soil due to algalization and fertilization revealed that the active carbon pool reacts quickly towards the addition of any nutrient sources, whereas continuous cropping without nutrient addition cannot even maintain SOC level in soil. Addition of considerable amount of organic matter by blue green algae has been observed (Gupta *et al.*, 2015) and it might be related to the greater accumulation of SOC in soil. I norganic fertilizers increased the biological yield and hence returned crop residue to soil as a result SOC stock increased (Purakayastha *et al.,* 2008; Gong *et al.,* 2009). Impact of fertilizers and residual effect of BGA on wheat biomass, stubbles and rhizodeposition could also be associated with SOC accumulation in soil. The least SOC content in unfertilized control were also chronicled by

Table 1. Treatment details for fertilizers and blue green applied during 1999-2014

Treatment	Quantity of manure/ fertilizer added	Fertilizer used		
Control (unfertilized)	—	N	P	K
50 % NPK	50:30:20 kg ha^{-1} N:P_2O_5:K_2O respectively	Urea	Single super phosphate	Muriate of potash
50 % NPK + BGA	50:30:20 kg ha^{-1}N:P_2O_5:K_2O respectively + 10 kg ha^{-1} dry BGA culture in kharif (rice) crop only.			

Table 2. Long term effect of fertilization and algalization on active C pools and dehydrogenase activity under rice−wheat cropping sequences

Treatment	SOC ($g\ kg^{-1}$)	WSC ($mg\ kg^{-1}$)	AHC ($mg\ kg^{-1}$)	SMBC ($\mu g\ g^{-1}$)	SMBN ($mg\ kg^{-1}$)	DHA (μg TPF g^{-1} soil 24^{-1} hour)
Soil depth 0–15 cm						
Control	4.42 b	35.32 c	480.51 c	315.15 c	15.63 c	46.365 c
50% NPK	6.13 a	40.55 b	669.44 b	352.66 b	18.50 b	48.918 b
50% NPK +BGA	6. 38 a	53.61 a	688.93 a	397.77 a	21.53 a	63.224 a
Soil depth 15–30 cm						
Control	3.81 b	22.98 c	312.55 c	259.66 c	9.33 c	36.490 c
50% NPK	4.60 a	31.11 b	570.74 b	267.63 b	10.58 b	39.261 b
50% NPK +BGA	4.75 a	43.12 a	612.43 a	275.29 a	12.70 a	54.024 a

many researchers (Srinivasarao *et al.*, 2012; Basak *et al.*, 2012)

Accumulation of greater SOC in surface soil than subsurface soil has been perceived (Liang *et al.*, 2012; Venkatesh *et al.*, 2013), which indicates that surface soil is more sensitive to nutrient management practices than subsurface soil because of greater microbiological and enzymatic activity in rhizosphere, accelerated decomposition rate by temperature, tillage practices etc.

Hot water soluble carbon: The HWSC content varied from 35.32 to 53.61mg kg^{-1} and 22.98 to 43.12mg kg^{-1} in surface and subsurface soil, respectively (Table 2). Trend is similar in both the profile depths indicating that carbon fraction dissoluble in water is influenced; however extent is low in treatments under puddled rice field in subsurface soil as well. Water soluble carbon, the most active fraction of SOC (Campbell *et al.,* 1999) depleted under unfertilized control. However, concentrations were greater in 50% NPK + BGA receiving treatment in both surface and subsurface soils and it could be related to the above ground biomass returned and nutrient addition to the soil. Other reasons for more accumulation of HWSC in upper soil may be less leaching of soluble C fraction and adsorption on oxide and clay minerals at lower soil depth (Sekhon *et al.*, 2009). The fertilizers increased plant biomass and indirectly promoted C sequestration, which specifies that plant biomass returned contributed to water soluble C fraction and thus; improved HWSC content under 50% NPK treatment over control might be due to such biomass addition. BGA increased biological yield of crop by fixing substantial amount of N in soil (Paudel *et al.*, 2012) and the stubble and root biomass may also increase the HWSC in soil.

Acid hydrolysable carbohydrate: Rice–wheat rotation as a result of 15 years of continuous cropping resulted improved status of AHC content in both surface and subsurface soil when BGA combined with fertilizers. The AHC content in surface soil varied between 480.51mg kg^{-1} in control to 688.93 in 50% NPK+BGA treatment, whereas the concentrations were 312.55mg kg^{-1} to 612.43mg kg^{-1} in control and 50% NPK+BGA treatment respectively in subsurface soil; however the trend was similar (Table 2). Like WSC, acid hydrolysable carbohydrate is also considered as most active fraction of SOC. Hence it is evident that BGA promote biomass addition in soil, the AHC buildup may be linked with such addition. The AHC is mainly associated with polysaccharides and plant roots exudates could encourage polysaccharide accumulation in soil (Kuzyakov and Domanski, 2000). Thus, the accelerated root growth due to fertilization and algalization led to improvement of AHC content in soil. Further, the concentration of AHC decreased with increasing soil depth, because of lack of or less addition of biomass and reduced microbial activity.

Soil microbial biomass carbon: Microbial biomass carbon, the sensitive fraction to management practices, under the contrasting edaphic requirements of both (rice and wheat) crops, improved with algalization and fertilization. In surface soil, the SMBC content varied from 315.15 $\mu g\ g^{-1}$ to 397.77 $\mu g\ g^{-1}$ with largest occurred in 50% NPK + BGA treatment and lowest in control. In subsurface soil, the greater value of SMBC (275.29 $\mu g\ g^{-1}$) was in treatment amended with 50% NPK + BGA and lowest value (259.66$\mu g\ g^{-1}$) was in control. However, the differences in all treatments were significant in both surface and subsurface soils (Table 2). Increase in microbial biomass C under BGA receiving (50% NPK + BGA) treatment can be attributed to increased carbon supply for microorganisms. Application of mineral fertilizers in long run promoted plant growth and subsequently formation of more mucigel and sloughed off cells (Sekhon *et al.*, 2009) which might related with greater accumulation of SMBC. Improvement in SMBC content due to application of inorganic fertilizers over no fertilization has also been observed by many workers (Gong *et al.*, 2009; Banger *et al.*, 2010). This suggested that SMBC content increased in treatment receiving suboptimal dose of NPK in order to control > 50% NPK > 50% NPK+BGA.

The SMBC content in surface soil was greater than in subsurface soil and the reason ascribed was addition of plant residue and root biomass in surface soil. Microbial activity decreased with increase in soil depth and therefore, the C contributed by microorganisms reduced in deeper profile. Liu *et al.* (2013) also reported that the root biomass was the main source of SMBC accumulation in deep soil profile, though both rice and wheat are shallow rooted crops and hence their contribution to deeper soil layers were reduced and it may be interconnected with the lower microbial biomass C in deeper soil layers.

Microbial biomass nitrogen: Influence of long term fertilization and algalization was significant on SMBN in surface and subsurface soils. Like SMBC, the microbial biomass nitrogen accumulated more on top soil than sub−soil. The concentration of SMBN was greater in treatment amended with 50% NPK + BGA (21.53mg kg^{-1}in surface and 12.70 mg kg^{-1}in subsurface soil) followed by 50% NPK (18.50mg kg^{-1}in surface and 10.58mg kg^{-1}in subsurface soil) and lowest in control (15.63 mg kg^{-1}in surface and 9.33 mg kg^{-1}in subsurface soil) in both upper and below soil depths (Table 2). Decreasing SMBN content with fertilizer especially nitrogenous fertilizer has been observed (Lovell and Jarvis,1998) Microbial growth and activity could stimulate by organic carbon as a result of organic matter incorporation into soil (Sastre *et al.*, 1996), which showed that treatments receiving suboptimal dose of NPK with or without BGA increased SMBN content over control because of more residue biomass returned. Manna *et al.* (2007) also recorded lowest SMBN content in unfertilized control as compared to the fertilized treatments and it may be due to lower microbial activity, less plant biomass return and depleted SOC content.

Dehydrogenase activity: Long term practice of algalization and fertilization resulted buildup of DHA in both surface and subsurface soils over control. The greater activity in surface soil recorded were 63.224µg TPF g^{-1} soil 24^{-1}hour and 46.365µg TPF g^{-1} soil 24^{-1} hour in 50% NPK + BGA and 50% NPK amended treatments respectively. Similarly in subsurface soil; the trend was however similar to that of surface soil, DHA varied from54.024µg TPF g^{-1} soil 24^{-1} hour in treatment receiving 50% NPK + BGA to36.490 µg TPF g^{-1} soil 24^{-1} hour in unfertilized control (Table 2). The quantity of organic matter added into soil influenced DHA more than that of its quality, which suggested that fertilizer application resulted improvement in enzymatic activity through addition of root biomass and rhizodeposition each year which acted as substrate for enzymes (Singh and Wanjari, 2013). BGA application resulted organic matter addition in soil. Consequently, the dehydrogenase activity was greater in treatment receiving 50% NPK + BGA followed by 50% NPK. Likewise; the lowest activity was recorded in control as compared to fertilized treatments (Liu *et al.*, 2010; Mandal *et al.*, 2007).The similar trend of DHA in subsurface soil indicates fertilizers and blue green algae encouraged microbial activity in deeper soil layer as well through supplying food substrate, however; the magnitude was low and thus lower SMBC concentration.

Crop yield: The rice yield recorded under long term continuous nutrient management was highest in 50% NPK amended treatment (52.85 q ha^{-1}) followed by 50% NPK + BGA treatment (50.30q ha^{-1}) while least being recorded in control (25q ha^{-1}). Contrast to this, highest wheat yield was recorded in 50% NPK + BGA treatment (22.65q ha^{-1}) followed by 50% NPK treatment (21.70 q ha^{-1}) and least concentration in control (9.110q ha^{-1}). As a result of better nutrient availability due to algalization and fertilization, rice yield increased over control. Similar results were reported by Shah Alam *et al.* (2014). Likewise; the residual effect of BGA led to increase grain yield of wheat crop (Singh *et al.*, 2002).

CONCLUSION

Continuous cropping of rice−wheat for one and half decade with combination of various nutrient management practices significantly influenced active fractions and enzymatic activity in soil. Application of NPK at suboptimal rate resulted greater crop yield, buildup of SOC pools as well as dehydrogenase activity in top soil and sub−soil as compared to unfertilized control. However; the upsurge was enhanced on combined administration of NPK with blue green algae. Thus, it can be concluded from above experiment that BGA combined with fertilizers may be a better and cheaper choice for crop nourishment and soil health maintenance under rice based cropping system.

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Assessment of Soil Fertility Status of Mid Himalayan Region, Himachal Pradesh

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Abstract: A study was conducted to assess the soil fertility status of mid Himalayan region based on two hundred and fifty surface soil samples collected at a depth of 0-15 cm by using systematic sampling methodology using GPS points. The soils of this region were predominantly neutral in soil reaction with low soluble salts and high in organic carbon content. Soil fertility assessment of crop fields showed the soils of mid-Himalayan region are high in available K and P contents and relatively medium to low in available N content. Among the micronutrients tested, widespread deficiencies were recorded for available Cu (69.23ha), B(50.26ha), Zn (43.84ha) and Fe (42.01ha). The correlation studies between the soil properties and available nutrients showed that OC has significant and positive correlation with the availability of N, P, S, B and Mn indicating the compelling role of OC in the maintenance of balanced soil health.

Keywords: Fertility status, Mid-Himalayan Soils, Micronutrients, Nutrient Index

The mid-hills zone of Himachal Pradesh extends from 651 to 1800 m above mean sea level with mild temperate climate and it occupies 32 per cent of the total geographical area and about 37 % of the cultivated area of the state (Parmar, 2014). With its bestowed climatic conditions, farmers in mountainous areas can produce a variety of off season vegetables and other cash crops, but cultivating the land without best management practices leads to environmental degradation through loss of soil fertility. Limited area under the fertile soils in the mountain landscapes is assuming extra significance because of the decreasing land availability for agriculture caused by the demand for alternate uses. Under these conditions, the high cropping intensity and unscrupulous use of chemical fertilizers adopted by the farmers to reach the higher productivity levels have ultimately rendered the soils in this region with depleted nutritional status (Sharma *et al.,* 2001).

A farmer must take into account the requirement of crops and the characteristics of the soil while making decisions on the timing and quantity of fertilizer application. Lack of understanding about soil health is leading to indiscriminate or imbalanced use of chemical fertilizers and exposing farm based livelihoods to soil health related risks. The assay of soil fertility status is essential for judicious use of fertilizers and assurance of better crop yields. Among the diagnostic techniques for fertility evaluation such as fertilizer trails, soil test and plant analysis; the soil test provides the most accurate information on the availability of various plant nutrients. Soil-test based fertility management is an effective tool for increasing productivity of agricultural soils that have high degree of spatial variability resulting from the combined effects of physical, chemical or biological processes. Long-term sustainability of hill agriculture system must rely, as much as possible on balanced use of fertilizers and effective management of resource inputs. The crop lands in the mountain province of Himachal Pradesh in the western Himalayas have witnessed depleting N from the soil system at an alarming rate. The situation of P and K seems to be slightly satisfactory with positive balance. However, information available on those aspects in the mid-hill conditions of Himachal Pradesh is highly sporadic and inconclusive. In such situations, assessment of site specific soil fertility status and study of their relation with other physicochemical properties would be of high significance. Hence, it was hypothesized that soil fertility related risks can be managed through soil test based balanced nutrition to bring in sustained intensification and resilience building. Therefore, the present study was envisaged to understand the current soil fertility status of mid Himalayan region. This would help the farmers to make more informed decisions to increase the productivity of their lands and to improve their livelihood.

MATERIAL AND METHODS

The study was conducted at Solan district, which is located between 30° 50` to 31° 15` N latitude and 76° 42` and 77° 22` E longitude with an altitude ranging from 1200-1550 m above mean sea level. This area comes under the mid Himalayan region of Himachal Pradesh, which includes more than 100 villages. It shares common boundaries with Shimla district in the north; Ropar district of Punjab and Ambala district of Haryana in the south and Bilaspur and Sirmour districts of Himachal Pradesh in the east and west, respectively.

Collection of soil samples: A systematic survey has been conducted in the grid areas and composite surface soil samples from 0–15 cm depth were collected from randomly selected villages of Anji, Dharot, Chibar Pattar, Dadhog, Ber, etc. by using GPS. Eight to ten cores of surface soil samples were collected and mixed together to make a composite sample. The sampling points were taken from the cadastral map of each village by locating in such a way, that each 10 hectares area may represent one grid based sample. The total area covered under this study was 192.31 ha. Samples were collected during the autumn season of 2015 when there was no standing crop. Out of the total samples collected, 32 per cent samples collected from the irrigated area and rest of the samples from the fields depending on the seasonal rains. The cropping pattern is mainly marked by the cultivation of vegetables.

Soil analysis: Collected soil samples were air dried under shade, crushed gently with a wooden roller and passed through 2.0 mm sieve to obtain a uniform representative sample. These samples were analyzed for different physicochemical properties such as soil color, texture, pH, EC, OC and available macro and micro-nutrients. Colour of the soil was judged by visually comparing a soil sample with the chips of standard Munsell Soil Colour Charts (*hue*, *value* and *chroma* indices) to describe colours. The soil texture was judged by feel method as suggested by Thien (1979). Soil pH was measured by glass electrode pH meter using soil to water ratio of 1:2 and EC of supernatant liquid was determined by using microprocessor based EC meter. OC was estimated by Walkley and Black's rapid titration method as described by Jackson (1973). Available N was determined by alkaline $KMnO_4$ method (Subbiah and Asija, 1956), available P was determined using colorimetric method, while K by flame photometric method and S by $CaCl_2$ extraction method as out lined by Tabatabai (1996). The available Fe, Cu, Mn and Zn in soil samples were extracted with DTPA (0.005 M DTPA + 0.01 M $CaCl_2$ + 0.1 M triethanolamine, pH 7.3) as per method described by Lindsay and Norvell (1978). Concentration of Zn, Fe, Cu and Mn in the DTPA extracts was determined using Atomic Absorption Spectrophotometer (AAS). The concentration of available B was estimated by hot water procedure as laid out by Keren (1996).

The nutrient index was arrived based on the formula suggested by Parker *et al.* (1951) as given below

$$\text{Nutrient index} = \frac{(N1 \times 1) + (Nm \times 2) + (Nh \times 3)}{Nt}$$

N_l = Number of samples falling in low category of nutrient status.

N_m = Number of samples falling in medium category of nutrient status

N_h = Number of samples falling in high category of nutrient status

N_t = Total number of samples analysed for a nutrient in any given area

Separate indices were calculated for different nutrients like N, P, K and S. The soils were rated as per the nutrient index values as low (<1.5), medium (1.5 to 2.5) and high (>2.5).

RESULTS AND DISCUSSION

Physico chemical properties: The soil varies from dark grey to dark greyish brown in color, loamy to sandy loamy in texture and neutral to slightly acidic in reaction. It has been assumed that the organic matter or humus content, which is mainly responsible for the color of soils, has a fertility value. The pH values ranges from 6.59 to 7.81with mean pH value of 7.36 (Table 1). Higher rainfall and lower temperatures associated with increasing altitude results in lower pH (Katherine *et al.,* 1985). EC of soil varies from 0.049 dS m^{-1} to 0.793 dS m^{-1} with a mean value of 0.426 dS m^{-1} (Table 2). The EC values under normal range (< 1.0 dS m^{-1}) may be ascribed to leaching of salts to lower horizons of soil due its light texture. The soils of the study area are predominantly high in organic carbon (OC) which ranges from 0.15 to 1.98 per cent (Table 2). Among the soil samples studied, only 11.6%of soils exhibited the lower levels of OC whereas, 31.6 and 56.8 per cent of samples showed medium and high OC contents, respectively. The prevailing low temperature results in suppression of microbial and enzymatic activities, which results least soil organic matter decomposition and its accumulation in surface soils (Bhattacharyya *et al.,* 2008). Parallel to the present findings, Khera *et al.* (2001) also reported the higher levels of OC ranged between 0.80–2.30 percent in the Central Himalayan region

The higher OC in soils of this region further supported by the findings of Pathak *et al.* (2010) who reported *in situ* burning of 38.66 per cent of agro residues in the states of Punjab and Haryana, whereas it was confined to 14.38 per cent in Himachal Pradesh, which indicates the proper recycling of agro wastes in this region. Maintenance of high cattle population per unit cultivable land in mid hills zone also upkeeps much organic matter in the surface soils (Bala *et al.,* 2004).

Status of macro-nutrients: The available N content in soils varied from 201.21 to 603.37 kg ha^{-1}, with an average of 312.91 kg ha^{-1} (Table 2). Considering the available nitrogen rating values as prescribed by Arora (2002), 42% of the soils (80.77 ha) appeared to be in low status and the soils in

109.61 ha and 1.92 ha were found medium and low in available N status, respectively. Since organic carbon content is an indicator of available N status, the soils of the area should also be sufficient in N content. This trend was reported earlier reported by many workers (Mondal *et al.,* 2015; Singh and Rathore, 2013). The present study also confirms the positive correlation between N and OC (Table 3) but the lower N status in 42 per cent of soils indicates its expeditious depletion from the surface soils. The available P content of mid Himalayan soils varied from 7 to 9 kg ha^{-1} in soils with low P content and 10.06 to 25kg ha^{-1} in soils with medium P content and 26 to 45 kg ha^{-1} in soils with high available P content (Table 2). Very less per cent of soils (2.8%) exhibited the deficiency of P (Fig. 1). Out of the total area under study, 138.46 ha showed medium in available P content and 48.08 ha and 5.77 ha of area showed high and less in available P content. The research findings of Singh and Rathore (2013) also indicate the higher levels of available P in soils located in greater topographic position of Aravali mountain ranges. Relatively higher phosphorus content in soils could be due to lesser availability of free oxides of Ca, Mg and Na at higher altitude which induce the fixation and subsequent precipitation of phosphorus. The available K in the soils of the study area ranged from 70.56 to 448 kg ha^{-1}, with an average of 193.83 kg ha^{-1} (Table 2). In the total study area 165.38 ha was classified under medium category with respect to availability of K (Fig. 1) and only 6.8 per cent (13.08 ha) of soils were under low range. Prevalence of clay minerals like illite and kaolinite in hills soils attributed to the sufficient levels of K. These results confirms the findings of Sharma *et al.,* (2001) who reported medium to high fertility status of available P and K in the soils of Lohnakhad in sub–humid mid–hill zones of Himachal Pradesh. Available 'S' content varied from 14.0–32.0 kg ha^{-1} with an average of 23.77 kg ha^{-1}. On the basis of the rating suggested for available S content by Hariram and Dwivedi (1994), 20 per cent of soils exhibit the deficiency symptoms (Fig. 1).

Table 2. Salient soil properties of study area

Soil Characteristics	Range	Mean
pH	6.59 –7.81	7.36
EC (dS m^{-1})	0.049–0.793	0.426
Organic carbon (%)	0.15–1.98	1.09
Available N (Kg ha^{-1})	201.21–603.37	312.91
Available P (Kg ha^{-1})	7.0–45.0	21.41
Available K (Kg ha^{-1})	70.56–448.0	193.83
Available S (Kg ha^{-1})	14–32	23.77
Available Zn (ppm)	0.29–5.07	1.25
Available B (ppm)	0.21–0.98	0.546
Available Fe (ppm)	2.14–15.69	7.298
Available Mn (ppm)	0.45–8.87	2.363
Available Cu (ppm)	0.10–5.91	0.9

The soil nutrient index in the reference area was in

Table 1. Limits for the test values for rating the soils

Classification for pH values						
Strongly acid	Moderately acid	Slightly acid	Neutral	Moderately alkaline	Strongly alkaline	Reference
< 5.5	5.5–6.0	6.0–6.5	6.5–7.5	7.5–8.5	> 8.5	Muhr *et al.* (1965)
Classification for total soluble salts (EC as dS m^{-1})						
No deleterious effect on crop		Critical for germination	Critical for salt sensitive crop		Injurious to most crops	Reference
< 1.0		1.0–2.0	2.0–3.0		>3.0	Muhr *et al.* (1965)
Macro–nutrients parameters		Low	Medium		High	Reference
Organic Carbon (%)		< 0.50	0.50–1.0		> 1.0	Muhr*et al.* (1965)
Available N (Kg ha^{-1})		< 280	280–560		> 560	Arora (2002)
Available P (Kg ha^{-1})		< 10	10–25		> 25	Arora (2002)
Available K (Kg ha^{-1})		< 118	118–280		>280	Arora (2002)
Available S (Kg ha^{-1})		< 20	20–40		> 40	Hariram and Dwivedi
Micro–nutrient		Critical level (Deficient)	Critical level (Sufficient)			
Available Zn (ppm)		< 0.6	> 0.6			Bansal and Takkar (1986)
Available B (ppm)		< 0.5	> 0.5			Katyal and Rattan (2003)
Available Fe (ppm)		< 4.5	> 4.5			Lindsay and Norvell (1978)
Available Mn (ppm)		< 1.0	> 1.0			Lindsay and Norvell (1978)
Available Cu(ppm)		< 0.5	> 0.5			Lindsay and Norvell (1978)

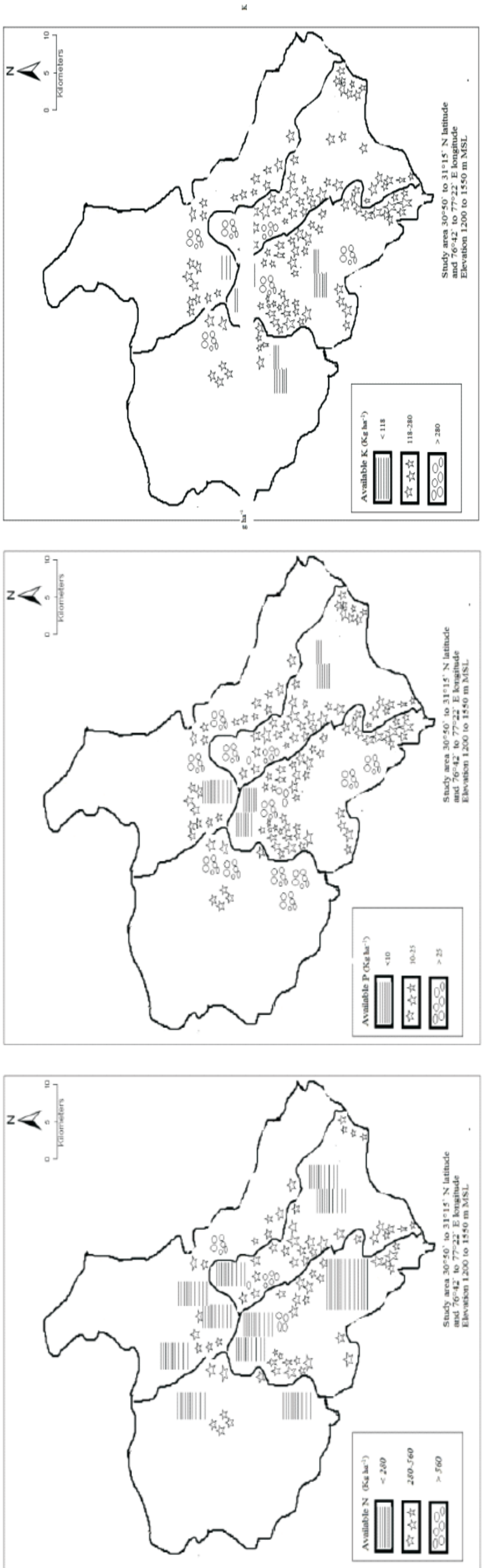

Fig. 1. Status of available macronutrients in the study area as per the nutrient index (a) available N (b) Available P (c) Available K

medium category for the all available macronutrients. The values for available N, P, K and S worked out from nutrient index were 1.59, 2.22, 2.00 and 1.80, respectively

Micronutrient status: The Zn content ranged between 0.29 – 5.07 ppm with a mean of 1.25 ppm. Available Fe content ranged between 2.14–15.69 ppm with a mean of 7.298 ppm. A mean of 2.363 ppm and 0.9 ppm was observed with respect to available Mn and Cu, respectively. The B content in soils ranged between 0.21 to 0.98 ppm with mean of 0.546 ppm. Considering the critical limits as suggested by Lindsay and Norvell (1978), the deficiency of micronutrients in the soils of the study area were in the order of Cu (36%) > B (26%) > Fe (22.8%) > Zn (22%) >Mn (9.6%) (Fig. 2). The critical observation of data indicated that soils rich in organic carbon are less prone to Mn deficiency. These results find support from the research findings of Chinchmalatpure *et al.* (2000). Such observations were further substantiated by generation of electrons during decomposition of organic matter in turn reducing the oxides of Mn and changing them to more soluble forms that are easily available to plants Availability of high concentrations of Mn in soils rich with OC content was earlier reported by Chander*et al.* (2012) in Madhya Pradesh and Jharkhand soils and Prabhavathi *et al.* (2013) in soils of South Indian regions.

Correlation among soil parameters: Correlation among soil parameters showed a significant and positive effect of soil OC on the availability of N, P, S, B and Mn contents and positive effect on other available nutrients. These results clearly suggest the need to manage optimum amounts of soil OC to regulate adequate supplies of essential plant nutrients. Strong and positive correlation exists between available N (r=0.351**) and OC (Table 3). There is a definite relation of organic carbon with available N as organic matter releases most of the mineralizable N in a proportionate amount present in the soil (Mondal *et al.,* 2015; Singh and Rathore,

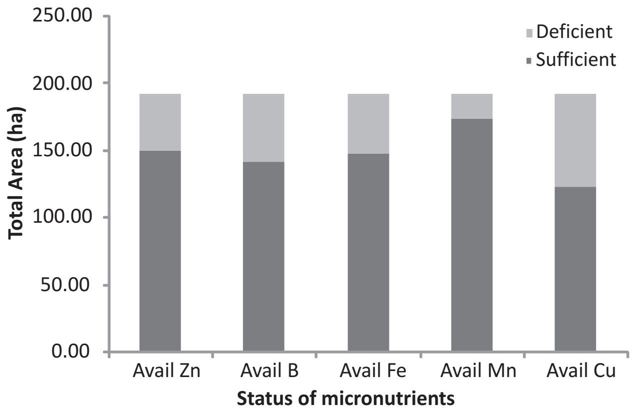

Fig. 2. Status of available micro-nutrients in soils of mid Himalayan region

Table 3. Correlation coefficient (r) between physico-chemical properties and available macro and micro nutrients

	pH	EC	OC	N	P	K	S	Zn	B	Fe	Mn
pH											
EC	0.261^{**}										
OC	0.115^{NS}	0.069^{NS}									
N	0.180^{**}	-0.113^{NS}	0.351^{**}								
P	0.005^{NS}	-0.008^{NS}	0.341^{**}	0.263^{**}							
K	-0.024^{NS}	-0.046^{NS}	0.009^{NS}	0.036^{NS}	-0.022^{NS}						
S	0.036^{NS}	0.028^{NS}	0.133^{*}	0.122^{NS}	0.520^{**}	0.066^{NS}					
Zn	-0.484^{**}	-0.135^{*}	0.009^{NS}	0.152^{*}	-0.021^{NS}	-0.012^{NS}	-0.089^{NS}				
B	0.074^{NS}	-0.000^{NS}	0.359^{**}	0.250^{**}	0.116^{NS}	-0.047^{NS}	0.060^{NS}	0.100^{NS}			
Fe	-0.300^{**}	-0.047^{NS}	0.074^{NS}	0.036^{NS}	0.079^{NS}	0.060^{NS}	0.005^{NS}	0.144^{*}	-0.083^{NS}		
Mn	0.075^{NS}	-0.014^{NS}	0.184^{**}	-0.051^{NS}	-0.016^{NS}	0.043^{NS}	-0.106^{NS}	-0.158^{*}	0.008^{NS}	0.110^{NS}	
Cu	-0.345^{**}	-0.180^{**}	-0.076^{NS}	0.037^{NS}	-0.058^{NS}	-0.118^{NS}	-0.073^{NS}	0.096^{NS}	-0.048^{NS}	0.036^{NS}	0.006^{NS}

* and ** indicate significance of value at P=0.01 and 0.05, respectively

2013). Available N showed a positive significant correlation with available P (r=0.263**) and positive relation with available K (Table 3). The positive relation among the major nutrients indicates the synergistic effects. Similar findings reported by Meena *et al.* (2006) in soils of Rajasthan and Kumar *et al.* (2009) in soils of Jharkhand region. Contrary to the reports many workers (Ghosh *et al.,* 2015; Singh *et al.,*2014; Jatav and Mishra, 2012) observed non-significant correlation of potassium with all other parameters studied.

The available Zn in the soil has significant and negative relationship with pH (r = -0.484**) thereby indicating that availability of Zn increases at lower pH levels. To some extent, organic matter reduces the pH of the soil locally, which helps in increasing solubility of zinc through its effect on weathering of minerals containing zinc. Products of organic matter decay may also have chelating effect on zinc and helps to increase its availability to plant

The findings of Yadav and Meena (2009) in Degana soil series of Rajasthan state also confirm the relation between Zn with pH. Similarly, Fe and Cu were negatively and significantly correlated with soil pH (r= −300** & r=-0.345**) indicating their higher availability at acidic pH. The studies on soil properties in hilly regions of Jammu district (Mondal *et al.,* 2015), Bhimber district (Nazif *et al.,* 2006) and Assam region (Talukdar *et al.,* 2009) also illustrates the similar correlation pattern of micro nutrients with the changes in pH levels.

Results are indicating the scope to cut use of P and K fertilizers as 97 and 93 per cent of soils under study area were showed medium to high in available P and K content, respectively. Going by essentiality of the nutrients, it is apparent that the widespread deficiencies of Cu, B and Zn might be a constraint to harvest full yield potential of crops under cultivation in the study area.

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Characterization of Rainfall and Length of Growing Period Over North Western Zone of Tamil Nadu

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Abstract: Crop production particularly in rainfed condition depends solely on the rainfall pattern. Analyzing rainfall data to obtain specific information needed for crop planning and for carrying out agricultural operations are vital in an agricultural economy. The present study over northwestern zone (NWZ) of Tamil Nadu aims to explore the rainfall and its variability over space along with its length of growing period to make crop based decisions. Annual normal rainfall of NWZ is 811 mm. Denkanikottai (998 mm) had highest rainfall among the locations while Paramathi (518 mm) had the lowest. Among the monsoons; southwest monsoon (SWM) contributes 47 per cent of rainfall followed by Northeast monsoon (NEM) contributing 34 per cent. From July to November considerably good amount of rainfall was witnessed with peak during September over the NWZ. Annual, seasonal and monthly rainy days follow the trend of rainfall. LGP over the NWZ varied between 7 to 24 weeks irrespective of the methods employed. The location Salem had the highest LGP while Paramathi had the lowest. Comparing the methods FAO method results more number weeks than Jeevanandha Reddy method.

Keywords: Rainfall, Length of Growing Period, FAO method, Crop planning

In semiarid tropics, moisture is the major limiting factor for agriculture. The climate-triggered risks are heavy for crop production. Understanding spatiotemporal rainfall patterns has been directly implicated to combating extreme poverty and hunger through agricultural enhancement and natural resource management (IPCC, 2007). The amount of soil-water available to crops depends on variability of rainfall and growing period length, which influence the success/failure of a cropping season (Ngetich *et al.,* 2014). The variability in the rainy season onset and cessation could pose socio-economic and developmental challenges as they threaten food security and induce poverty (Cooper *et al*., 2008 and Lacombe *et al*., 2012). It thus emerges that, understanding climatic parameters, rainfall in particular, can aid in developing optimal strategies of improving the socioeconomic well being of smallholder farmers. There has been continued interest in understanding rainfall's seasonal patterns by evaluation of its variables including rainfall amount, rainy days, lengths of growing seasons, and dry-spell frequencies. Seleshi and Zanke (2004) and Tilahun (2006) noted high variations in annual and seasonal rainfall totals and rainy days and their importance in crop planning. On the other hand, the much-needed information on inter/intra seasonal variability of rainfall in the region is still inadequate despite its critical implication on soil-water distribution and final crop yield. To optimize agricultural productivity in the region, there is an urgent need to quantify rainfall variability at a local and seasonal level as a first step of combating extreme effects of persistent dry-spells/droughts and crop failure. Since rainfall that is heterogeneous, in particular, is the most critical factor determining rain-fed agriculture, knowledge of its statistical properties derived from long-term observation could be utilized in developing optimal cropping strategies in the area. Another vital analysis is length of growing period (LGP); it is the duration of growing period where in crops gets sufficient moisture for its growth continuously without any interruption. Computed LGP aids to select the suitable cropping pattern for a particular area in addition to selection of best agro techniques for identified LGP.

The agricultural activities in the North Western Zone (NWZ) are mainly rainfed dependent on monsoon rains. The rainfall characteristics in terms of quantity, distribution and length of growing season have always been uncertain due to variability of the season. The yearly variation makes the planning of sowing and the selection of the crop type and variety rather difficult. Generally, yields may suffer significantly with the length of the growing season, as well as with a high frequency of damaging dry spells within the growing season. The ability to estimate effectively the length of the growing season therefore becomes fundamental. In order to plan rainfed agriculture, rainfall amount, distribution and the length of the rainy period are important. In this study rainfall from 18 stations of NWZ are analyzed with the objective to determine the patterns of rainfall and length of growing season.

MATERIAL AND METHODS

Daily rainfall data of different places of northwestern zone is collected from India Meteorological Department and used for the study. Data was converted in to weekly, monthly and seasonal and variability over the different time series was worked out. The potential evaporation data is collected from reports of the India meteorological department.

Study area: North Western Zone (Fig.1) covers an area of 18,271 sq. kms in which 10,28,097 hectares, which is 56.3 per cent, is under cultivation. Out of total area of cultivation, only 23 per cent i.e., 2,35,828 hectares is the irrigated area. This zone has been identified as moderately drought prone. The major Rivers of this zone are Cauvery, Thenpennai and Manimuthar. Mettur and Krishnagiri are the major dams in this zone. The elevation varies from 330 to 1070 metres above mean sea level. Forest area in this zone constitutes nearly 30 percent i.e. 5,35,282 hectares of the area of the zone, which is nearly 25 per cent of the total forest area of the State.

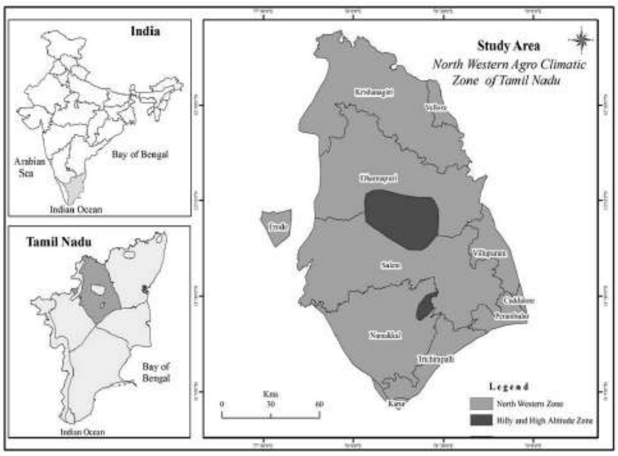


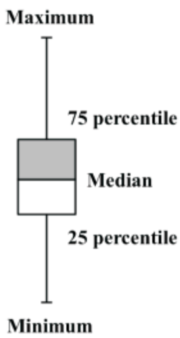
Fig. 1. Map of study area

Length of growing period (LGP): The length of growing period was worked out using FAO method and Jeevananda Reddy method.

Weekly moisture availability period based on FAO model (Higgins and Kassam, 1981): In this model, the growing period starts when precipitation exceeds 0.5 Potential Evapotranspiration (PET) and ends with the utilization of assumed quantum of stored soil moisture (100 mm) after precipitation falls below PET.

Jeevananda Reddy method (1983): This method as a simple tool to compute the length of growing period for semi arid tropics based on mean weekly rainfall and weekly PET. As the growing period is limited to 90 –100 days in dry lands, 14 weeks moving average has been suggested and based on this R/PE ratio, the following four major variables with criteria was been given below.

Climate variable	14 week moving average R/PE	Simple weekly R/PE
G –Growing period	≥0.75	≥0.50
W –wet spell	–	≥1.5
D –Dry spell	–	≤0.50
A –Crop failure	If the G period ≤5 weeks (in any year) the possibilities of growing period any crop is limited	



Box and whiskers plot: Box and whiskers plot was generally used to depict the descriptive statistics of a given set of data in the following manner. The two whiskers (vertical lines) in top and bottom represent maximum and minimum value in the data set. Upper bound of the box represents third quartile or seventy-fifth percentile. In the same way the lower bound of the box represents first quartile or twenty-fifth percentile while, the central line represents the median.

RESULTS AND DISCUSSION

Rainfall profile of North Western Zone: Annual normal rainfall of NWZ varied from 518 (Paramathi) to 998 mm (Denkanikottai) with an average of 811 mm (Table 1). Among the seasons, southwest monsoon (SWM) contributes the highest share (47 %) of rainfall to the annual rainfall. SWM rainfall over NWZ varied from 191 mm (Paramathi) to 500 mm (Salem) with a zonal average of 382 mm. Northeast monsoon (NEM) contributes the second highest (34 %) amount of rainfall after SWM, it varied from 196 (Thalli) to 353 mm (Harur) and the zonal average is 274 mm. The winter and summer seasons contributes considerably less rainfall than the monsoon seasons with an average contribution of 1 and 18 per cent of rainfall, respectively to the annual for NWZ. Though comparatively less amount of rainfall was registered during summer, the quantum of rainfall is enough to support pre-sowing operations. The summer rainfall varied from 81 (Rayakottai) to 185 mm (Denkanikottai). Alak Gadgil (1986) stated the importance of rainfall analysis and deriving these details are crucial for agricultural planning.

Distribution of rainfall over Northwestern Zone: Annual normal rainy days (Table 2) varied between 29 (Rayakottai) and 57 (Salem). Among the seasons SWM (46 %) had more number of rainy days than NEM (35 %) similar to the quantum of rainfall. During SWM, the number of rainy days varied from 13 (Rayakottai) to 28 (Salem) over the NWZ. Distribution of NEM rainfall varies over NWZ from 11 (Rayakottai and Thalli) to 19 (Attur) rainy days. Winter season had either no rainy days or 1 over all the locations studied. Summer had better distribution among the locations with 5 (Rayakottai) to 11 (Denkanikottai and Salem) rainy days.

Table 1. Annual and seasonal normal rainfall of North Western Zone

Locations	Normal rainfall (mm)					Percentage contribution to annual			
	Winter	Summer	Southwest	Northeast	Annual	Winter	Summer	Southwest	Northeast
Denkanikottai	9	185	485	319	998	1	19	49	32
Dharmapuri	12	179	440	299	930	1	19	47	32
Harur	14	141	383	353	892	2	16	43	40
Hosur	6	142	311	201	661	1	22	47	30
Krishnagiri	10	163	494	295	962	1	17	51	31
Palacode	12	153	408	299	871	1	18	47	34
Pennagaram	16	170	375	275	835	2	20	45	33
Rayakottai	7	81	264	199	551	1	15	48	36
Thalli	6	141	369	196	712	1	20	52	28
Uthangarai	15	87	353	279	734	2	12	48	38
Nammakkal	10	172	392	310	884	1	20	44	35
Paramathi	6	95	191	226	518	1	18	37	44
Rasipuram	17	143	445	234	839	2	17	53	28
Sendamangalam	6	132	353	249	739	1	18	48	34
Sankari	8	162	326	279	775	1	21	42	36
Attur	7	115	329	329	780	1	15	42	42
Omalur	10	183	460	295	949	1	19	49	31
Salem	8	172	500	297	976	1	18	51	31

Table 2. Annual and seasonal normal rainy days of North Western Zone

Locations	Normal rainy days					Percentage contribution to annual			
	Winter	Summer	Southwest	Northeast	Annual	Winter	Summer	Southwest	Northeast
Denkanikottai	1	11	27	17	56	1	20	48	31
Dharmapuri	1	9	21	17	47	1	19	44	35
Harur	1	7	20	18	46	2	15	44	39
Hosur	1	9	21	13	44	1	21	48	30
Krishnagiri	1	10	23	16	50	1	19	47	33
Palacode	1	9	21	17	48	2	18	45	35
Pennagaram	1	9	20	16	46	2	21	44	34
Rayakottai	0	5	13	11	29	1	17	45	37
Thalli	0	8	21	11	41	1	19	52	27
Uthangarai	1	6	20	16	43	2	14	46	38
Nammakkal	1	8	20	17	45	1	18	43	37
Paramathi	1	5	12	15	32	2	17	36	45
Rasipuram	1	9	23	14	47	1	19	49	31
Sendamangalam	1	8	18	15	41	1	19	44	35
Sankari	1	10	20	17	47	1	22	42	35
Attur	1	7	21	19	48	1	15	44	40
Omalur	1	9	26	16	53	1	18	50	31
Salem	1	11	28	17	57	1	19	50	30

Monthly rainfall: In all the locations, September was the wettest month over the NWZ and January was the driest month. Normal monthly rainfall reveals that the both SWM and NEM months contributes significant amount of rainfall to the NWZ. Among the months, September and October receives more than 140 mm of rainfall and the months May, August and November receives rainfall above 80 mm. All other months had less than or around 50 mm of rainfall. The months from August to November had rainfall above 80 mm; this continuous availability of moisture makes successful cropping possible in these months (Table 3, Fig. 2 and 3). During SWM, among the months, Salem had the highest monthly normal rainfall during June and August while Omalur registered highest rainfall in July and Krishnagiri recorded the highest rainfall during September. Invariably in all the SWM months, Paramathi registered the lowest rainfall. Among the NEM months, between the locations, Denkanikottai received highest rainfall during October while Harur received during November followed by Uthangarai during December. Paramathi, Thalli and Namakkal registered lowest rainfall during October, November and December respectively. Similar analysis was done for Coimbatore and Sukumar *et al.*, 2016, have noticed a similar variation.

Monthly rainy days: Rainy days ranged from 1 day to a maximum of 10 days. Normal number of monthly rainy days during September and October were 8 followed by August, November and May with 6, 5 and 5 rainy days respectively. This is almost similar to the pattern of rainfall of the months. Together the amount of rainfall and their temporal distribution confirms that the months August to November had consistent quantum and spread. Even the spatial distribution pattern also similar confirming their similar spatial pattern like that of rainfall. Paramathi was the location with least quantum of rainfall and rainy days while Salem, Denkanikottai, Krishnagiri and Harur were better quantum of rainfall and distribution (Table 4 and Fig. 4).

Length of growing period: Irrespective of the locations, the LGP (Table 5) varied from 11 (Paramathi) to 24 weeks (Salem) as derived through FAO approach while LGP varied from 7 (Paramathi) to 21 weeks (Salem) through JR approach. In both the methods of calculation, the spatial variation among the locations was similar with change in their

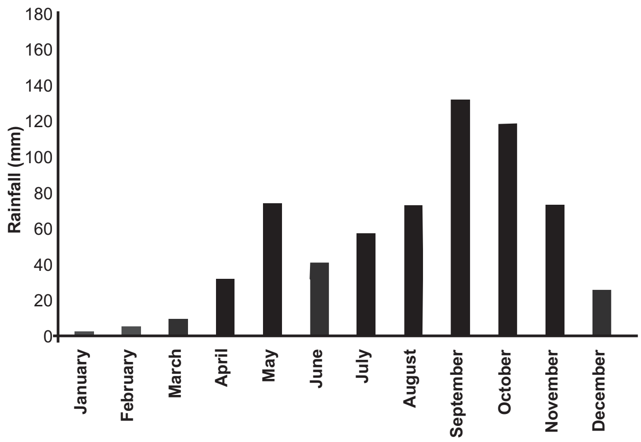


Fig. 2. Monthly rainfall distribution over the NWZ

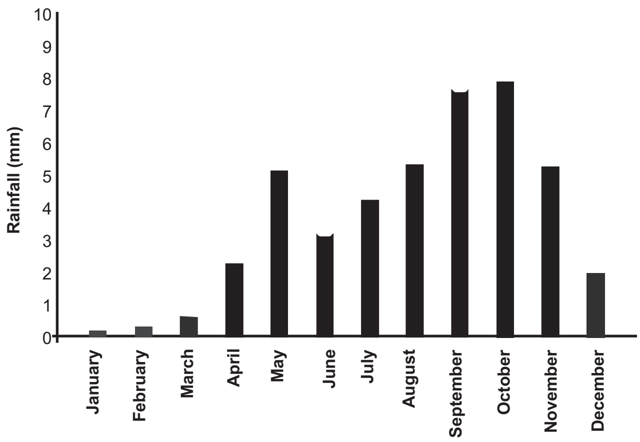


Fig. 4. Monthly rainy days over the NWZ

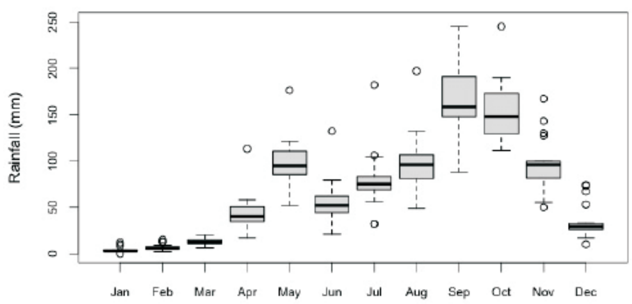


Fig. 3. Monthly rainfall variability over the NWZ

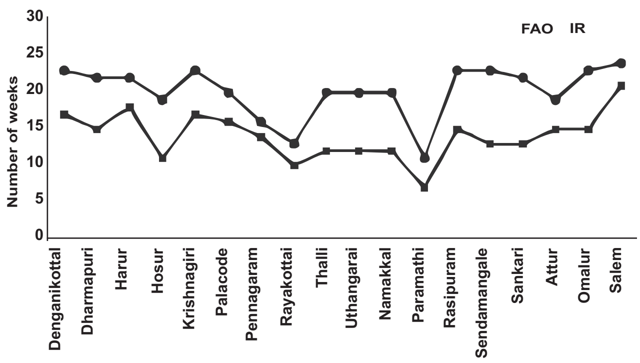


Fig. 5. Length of growing period over the locations of NWZ

Table 3. Monthly normal rainfall of North Western Zone

Months	January	February	March	April	May	June	July	August	September	October	November	December
Denkanikottai	2	7	14	50	121	66	89	104	226	190	100	30
Dharmapuri	3	8	16	46	118	63	72	100	205	170	97	32
Harur	8	7	12	36	93	59	77	96	151	143	143	67
Hosur	2	5	10	40	92	42	58	63	148	128	57	17
Krishnagiri	3	7	14	39	110	58	78	113	245	183	84	28
Palacode	3	9	12	39	102	48	67	96	197	181	90	28
Pennagaram	4	12	20	47	103	52	72	94	157	169	79	27
Rayakottai	2	6	6	23	52	29	32	53	151	122	55	22
Thalli	0	6	11	54	76	55	75	81	158	135	50	10
Uthangarai	10	5	7	17	64	40	75	92	147	117	89	73
Nammakkal	3	6	12	58	103	49	72	104	167	151	127	33
Paramathi	3	3	10	25	61	21	32	49	88	111	92	22
Rasipuram	4	13	15	34	95	61	88	125	171	130	79	26
Sendamangalam	4	2	6	35	92	50	71	89	143	122	98	29
Sankari	2	6	18	51	92	44	77	78	127	148	99	32
Attur	4	3	14	23	79	45	56	81	147	146	130	53
Omalur	3	7	14	54	116	69	106	109	177	167	97	30
Salem	4	4	12	49	111	79	104	132	185	175	96	26

Table 4. Monthly normal rainy days of North Western Zone

Months	January	February	March	April	May	June	July	August	September	October	November	December
Denkanikottai	0	0	1	3	7	5	5	7	10	9	6	2
Dharmapuri	0	0	1	2	6	3	4	6	8	8	6	2
Harur	1	0	1	2	5	3	4	5	7	8	7	4
Hosur	0	0	1	3	6	4	4	5	8	7	4	1
Krishnagiri	0	0	1	2	6	4	5	5	10	9	6	2
Palacode	0	1	1	2	6	3	4	6	8	9	6	2
Pennagaram	0	1	1	2	6	3	5	5	7	8	5	2
Rayakottai	0	0	0	1	3	2	2	3	6	6	4	1
Thalli	0	0	1	3	4	4	5	6	7	7	3	1
Uthangarai	0	0	0	1	4	3	4	5	8	7	6	3
Nammakkal	0	0	1	3	5	3	4	5	8	8	6	2
Paramathi	0	0	1	2	3	1	2	3	5	7	6	2
Rasipuram	0	0	1	3	5	4	5	7	8	8	5	2
Sendamangalam	0	0	1	3	5	4	5	7	8	8	5	2
Sankari	0	0	1	3	6	3	4	5	7	9	6	2
Attur	0	0	1	2	5	3	4	5	8	9	7	3
Omalur	0	0	1	3	6	5	6	7	9	9	5	2
Salem	0	0	1	3	7	5	7	8	9	10	5	2

magnitude. FAO invariably predicted higher LGP than JR method.

Based on FAO method, growing period over the zone starts at the earliest during the 26th week over Salem and the late start was during 37th week over Paramathi. The ending week of the LGP is as early as during 46th week at Rayakottai and Thalli while Attur, Harur and Namakkal ends on 50th week. Through Jeevanandha Reddy method, growing period starts as early as during 26th week over Salem and late over Paramathi on 37th week. The growing period ends as early on 43rd week (Hosur, Rayakottai, Thalli and Paramathi) while Denganikottai and Harur ends on 49th week. The starting week of Salem and Paramathi was same in both the methods. Among the locations Denkanikottai (6)

Table 5. Length of growing period of North Western Zone

Location	FAO Method		Jeevanandha Reddy Method					
	LGP	Weeks	LGP (G)	Weeks	Wet spell	Weeks	Dry spell	Weeks
Denkanikottai	23	27 −49	17	27 −49	6	37−40,43,44	1	48
Dharmapuri	22	28 −49	15	31 −45	5	37 −41	0	0
Harur	22	29 −50	18	32 −49	3	44 −46	0	0
Hosur	19	29 −48	11	33 −43	2	38,39	0	0
Krishnagiri	23	27 −49	17	30 −46	4	37 −40	0	0
Palacode	20	28 −47	16	31 −46	5	37 −41	1	32
Pennagaram	16	32 −47	14	32 −45	2	40,41	1	32
Rayakottai	13	34 −46	10	34 −43	2	38,39	1	35
Thalli	20	27 −46	12	32 −43	2	39,40	0	0
Uthangarai	20	28 −47	12	32 −46	0	0	0	0
Namakkal	20	28 −50	12	31−46	2	37,45	0	0
Paramathi	11	37 −49	7	37 −43	0	0	0	0
Rasipuram	23	27 −49	15	30 −44	0	0	0	0
Sendamangalam	23	29 −49	13	32 −44	0	0	0	0
Sankari	22	26 −49	13	33 −45	0	0	0	0
Attur	19	32 −50	15	33 −47	2	37,46	0	0
Omalur	23	27 −49	15	33 −47	2	37,46	0	0
Salem	24	26 −49	21	26 −46	4	38 to 41	0	0

had more number of wet spell followed by Dharmapuri (5), Palacode (5) and Salem (4). The locations Pennagaram, Palacode, Rayakottai and Denganikottai alone witnessed one dryspell each. Denkanikottai had the dryspell at the end of growing period while all other locations had dryspells during mid of the growing season. With similar interest, Mugalavai *et al*. (2008) and Lemma *et al*. (2016) analyzed the length of growing period over Africa and stated their importance and crucial role in crop planning. On comparing the methods, the starting week was nearly same in most of the locations while the ending week varied. JR method gives additional information like wet and dry spells over the locations while such information was lacking in FAO method. FAO method gives an overall indication while JR method gives a more clear status of the location for better crop planning.

CONCLUSION

Under changing climatic conditions, proper decision−making becomes imperative for successful crop production. Site−specific local scale information and assessments are still lacking and are unexplored. NWZ has wide variability in rainfall and its distribution among the locations. The locations over the northern parts such as have good amount of rainfall with good distribution while the location Paramathi witness less rainfall and more variability making it the moisture stressed location in the NWZ. Based on the rainfall status and LGP of the location, crops should be selected with irrigation support over the NWZ. The planting dates should be planned to avoid dry spells during critical crop stages. Further the crop water requirement could be matched with this information to identify better crops suitable for the locations.

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Influence of Anthropogenic Activity on Transformation of Landscapes by Natural Hazards

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Abstract: This article addresses the issues of assessment of the impact of anthropogenic, particularly mining activity on the development of hazardous natural processes and the resulted transformation of natural landscapes. The research region, a central part of the northern slope of the Greater Caucasus, namely the territory of the Kabardino-Balkar Republic near Tyrnyauz, was chosen not by accident. This is where one of Russia's largest tungsten and molybdenum deposits, the Tyrnyauz deposit, is located. Due to the fact that on the mining site, natural hazards get more intensive, studies are needed that would allow revealing the reasons of such intensification. It was found out that technogenic landscapes on which the hazards are often observed had been formed on the site of the former facilities of the Tyrnyauz tungsten and molybdenum conglomerate works. The landscapes were examined in details in the course of the field geo-ecological monitoring. Subsequent to the results, a set of activities on stabilization of the technogenic landscapes was developed.

Keywords: Natural and technogenic systems, Hazardous natural processes, Technogenic landscapes, GPS-shooting, Geo-ecologic monitoring

Mountain landscapes have a very low threshold of stability against anthropogenic impact through the extensive development of natural hazards (NHs). The most important role in this process is played by mining activity, which forms at the site of mining enterprises so-called natural and technogenic geosystems (NTGs), i.e. geosystems with certain types of a technogenic landscape, formed as a result of industrial activities and characterized by the development of certain complex of natural hazards (NHs), as well as pollution of the environment (Apazhev *et al.*, 2015 and Osipov *et al.*, 2015). In the North Caucasus, a number of such geosystems was formed in the area of the following deposits: a) Urup copper and nickel deposit in the Karachay-Cherkess Republic; b) Sadonsky lead and zinc deposit in the Republic of North Ossetia-Alania; c) Tyrnyauz tungsten and molybdenum deposit in the Kabardino-Balkar Republic (KBR) (Bortnikov *et al.*, 2013; Osipov *et al.*, 2015). And though at many NTGs mining companies do not work anymore, the negative effect of their activity not only does not decrease over time, but tends to increase. The reason is the intensification of NHs. Therefore the urgency and priority of the research is rather high. The location area of the former facilities of the Tyrnyauz tungsten and molybdenum plant (TTMP) was chosen as the target of the research. The research subject is technogenic landscapes and natural hazards and objectives are to allocate NTGs; assess the landscapes transformation degree considering NHs; elaborate activities on reduction of the negative anthropogenic impacts to an acceptable minimum. The practical significance is also considerable, since there is a number of settlements and large number of important economic objects in the TTMP operating zone (Bortnikov *et al.*, 2013).

MATERIAL AND METHODS

Field examination: The method includes field examinations (photographic and video materials, data of the GPS-shooting) of the area for 25 years, as well as on the results of the delineation in satellite images made in various years. The geo-ecological approach implying the study of geographical and ecological landscapes component was applied. When distinguishing NTGs, the catchment-based approach was applied: they are distinguished within the stream basins of various levels. The characteristics of technogenic landscapes obtained in the course of their inventory accounting (dimensions, elevation points, coordinates, etc.)

[1]All the quotations are given in the authors' edition and translated by the translator

using a “Garmin” GPS-navigator are summarized in a database in table format. This database serves as the basis for drawing special maps.

Terminology: At the same time *the terminology* of the current problem is formed. In addition to the NTG definition, the following concepts are considered as basic: a) “an NH formation factor, i.e. a threshold value of a natural and climatic condition causing NH”; b) “hazardous process, i.e. a process representing the highest degree of the danger for the territory”. Based on the classification of technogenic landscapes of the Russian Plain, or East European Plain (European Russia) developed by Fedotov (Fedotov, 1985), the following genetic types were identified*:* 1) dump (quarries dumps); 2) dump and extractive (mixed extractive and overburden rocks); 3) winning, mining sagging (on the site of mines); 4) mining sagging (on the site of mines); 5) quarry (on the site of quarries); 6) pulp tail (tailing dump); 7) road and communication (on the site of roads and utility lines); 8) water purification (purification and treatment facilities). A *l*andscape transformation ratio C_{tr} was introduced. It characterizes the ratio of transformed landscape area S_{tr} to the general area S_{gen} as %.

Stages of the work: First, according to the analysis of topographic maps and satellite images, tables with the main characteristics are compiled: 1) type of landscape system; 2) altitude; 3) form of relief; 4) type of technogenic landscape; 5) leading NH; 6) transformation ratio; 7) recommendations on stabilization of the NTG. At the field stage of the monitoring, GPS shooting of geosystems is carried out (refinement of location and indicators). At the final stage, a detailed NTG map of the territory and recommendations aimed at the reduction of NHs extent and stabilization of hazardous slopes are elaborated.

RESULTS AND DISCUSSION

The study area physically and geographically is located in the basin of the Baksan river, a right tributary of the Malka river, which, in turn, is a left tributary of the Terek river (Bortnikov *et al.*, 2013). In the hydrographic system of Russian rivers, the Terek river basin is located within the West Caspian watershed district. It comprises 7 constituent entities of the Russian Federation, including the KBR. Figures 1–2 show the orographic diagram of the Terek river basin and basic parameters of the river basins (the study area). In socio-economic terms, the basin of the Baksan river is located in the Elbrussky and Baksansky administrative and territorial regions of the KBR, within the “Prielbrusye” National Park. The NTGs (“plant facilities + technogenic landscape + NH”) are formed at the location of the TTMP facilities. They are located in an administrative district of the

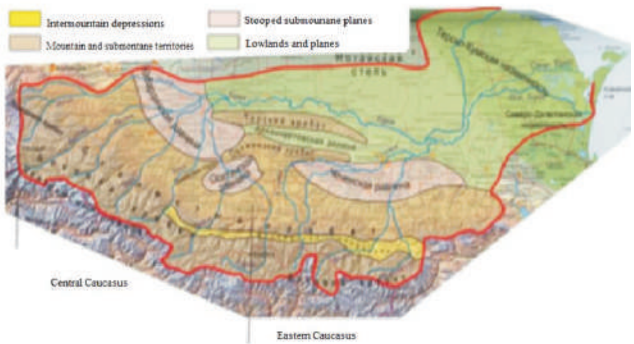

Fig. 1. Orographic scheme of the Terek river basin

KBR, the city of Tyrnyauz with the surroundings (Kyul and Borisova, 2014). It is these TTMP facilities that are the *leading factors* of the formation of technogenic landscapes and, as a consequence, destabilization of slopes and hazardous processes intensification (Table 1).

Characteristics of the main NTGs is given below (the name consists of the leading types of NHs and technogenic landscapes).

The NTGs No. 1-2. Mudflows with dump and dump and extractive types of technogenic landscapes (Table 1, Fig. 3) are located up the city of Tyrnauz on the right bank of the Baksan river. Technogenic landscapes formed on the site of mining dumps of the “Mukullan” and “Vysotnyy” quarries stockpiled in the upper gullies.

The NTG No. 3. Sagging, landslide with mining and sagging types of technogenic landscape (Table 1, Fig. 4). It is located on the left side of the Baksan river within the city of Tyrnyauz on the site of the “Molibden” underground mine (this is the main object of the TTMP). The mine is located at about 1600–1800 m (9 underground tunnels are interconnected by vertical openings, the so-called millholes).

Underground horizons are unfilled, landslide processes on a slope get more intensive. Ecological situation is aggravated by the fact that the area is situated in a tectonically active zone, which worsens this difficult ecological situation (Fig. 4). Below a brief description of landslides is provided (from the southwest to the northeast, numbering in accordance to (Kyul and Borisova, 2014)).

The landslide II is complicated, insequent, located at the bottom of the slope within a wedge graben (three cirque landslide generations in mellow sediments can be easily distinguished in the relief). The landslide I is insequent, active. It develops regressively on the body of the ancient structural seismogenic landslide. The volume of the landslide mass amounts to 180 ths m^3, while the average thickness of these deposits is 3 m. The landslides IV and V are situated between the landslides I and III in the fault zone. The volume of landslide masses amounts to 0.013 m^3. The landslides are active. They are located in the mellow diluvial deposits, the thickness of which does not exceed 1.0–1.5 m. The landslide III occupies a vast territory to the north of wedge graben between wide fault zone in the East-South-East — West-North-West. The volume of landslide amounts to 500–600 ths m^3. The landslide is ancient, structural, bedrocks stealing, seismogenic, multistage, currently suspended. According to the results of the research, several landscape and technological areas can be identified (Table 1). Let us examine the main of them characterized by a high degree of landscapes transformation (70%).

High-mountain meadow sloping dump, extractive avalanche mudflow. The NTG No. 1–2 (Fig. 3). Two anthropogenic mudflow basins, Bolshoy Mukullan (2–12) and Malyy Mukullan (2–11) (Razumov *et al.*, 2001). Mudflow activity is very high (in the case of Bolshoy Mukullan, mudflows descend once in 10 years, the most significant flows were registered in 1937, 1967 and 1970; on in the case of Malyy Mukullan, up to 40 mudslides per year are registered). At the same time, avalanches, landslides and taluses are very frequent on the right bank of the mudflow basin Bolshoy Mukullan (No. 2–12) (12 avalanche catchments in its upper part). They form one unloading zone. Over the past 15 years, anthropogenic mudflows that threaten roads, bridges and, in the case of damming of the Baksan river, the Tyrnyauz city as well, became more frequent. The mudflow flume at the mouth of the gully Bolshoy Mukullan is overloaded, that is why mudflows often reach the highway destroying the road.

Subsequent to the results of the delineation in satellite images and field surveys held on the left side of the gully Malyy Mukullan, 2 more mudflow basins (No. 2–10–8 nd 2–10–12) were distinguished. It can be stated that the NTG data testify the intensification of mudflow activity. In addition, due to the fact that the dumps surfaces are not grass-covered and occupy a large area (Fig. 3), the air is significantly polluted (Razumov *et al.*, 2001). Currently the pollution is not monitored. The landscapes are transformed to a high degree: C_{tr} = 90%. It requires substantial technical work (a set of preliminary laboratory experiments), so-called intended mudflows and additional measures on forest improvement (creation of shelter belts on alluvial fans). The organizational work should include limits on grazing.

Steppe shrub mid- and low-mountain slope sagging, landslides and steppe shrub mid- and high-mountain slope sagging landslide NTG No. 3–4 (Fig. 4). The landslide situation is quite complicated. Landslide onset at the site of

Table 1. NTG with the types of technogenic landscapes and associated NHs

NTG No.	Destabilization factor — the TTMP facilities	Landscape type	Location	NH, environment pollution
1–2	The “Vysotnyy” quarry	Dump, dump and extractive	SW slope of the “Molibden” peak, m a.s.l. more than 2000 m	Mudflows, rashes, fearthalls, rockfalls, avalanches, air pollution
	The “Mukullan” quarry		Bolshoy and Malyy Mukullan gullies	
3	The “Molibden” mine	Winning, mining sagging	SW slope of the “Molibden” peak, 1400–1800 m a.s.l.	Saggings, micromudflows
4	The “Kamyk” mine	Mining sagging	Right bank of the Kamyk river, mouth part 1600 m a.s.l.	Saggings, landslides
5	Gravel pit	Quarry	Floodplain of the Baksan river, portside, within the city of Tyrnyauz, about 1200 m a.s.l.	Landslides, less often — avalanches and snow slides
6	“Gizhgit” tailing dump	Pulp tailing	Mouth of the Gizhgit river, about 1200 m a.s.l.	Landslides, micromudflows, avalanches, snow slides. Water pollution
7	Roads, utility lines	Road and communicative	All over the slope, from 2200 to 1200 m a.s.l.	Landslides, less often — avalanches and snow slides
8–9	Purification and treatment facilities (system of artificial lakes)	Water purification	Floodplain of the Baksan river, 1200 m a.s.l.	Water pollution
			Mouth part of the Gizhgit river (up the tailing dump), 1400 m a.s.l.	

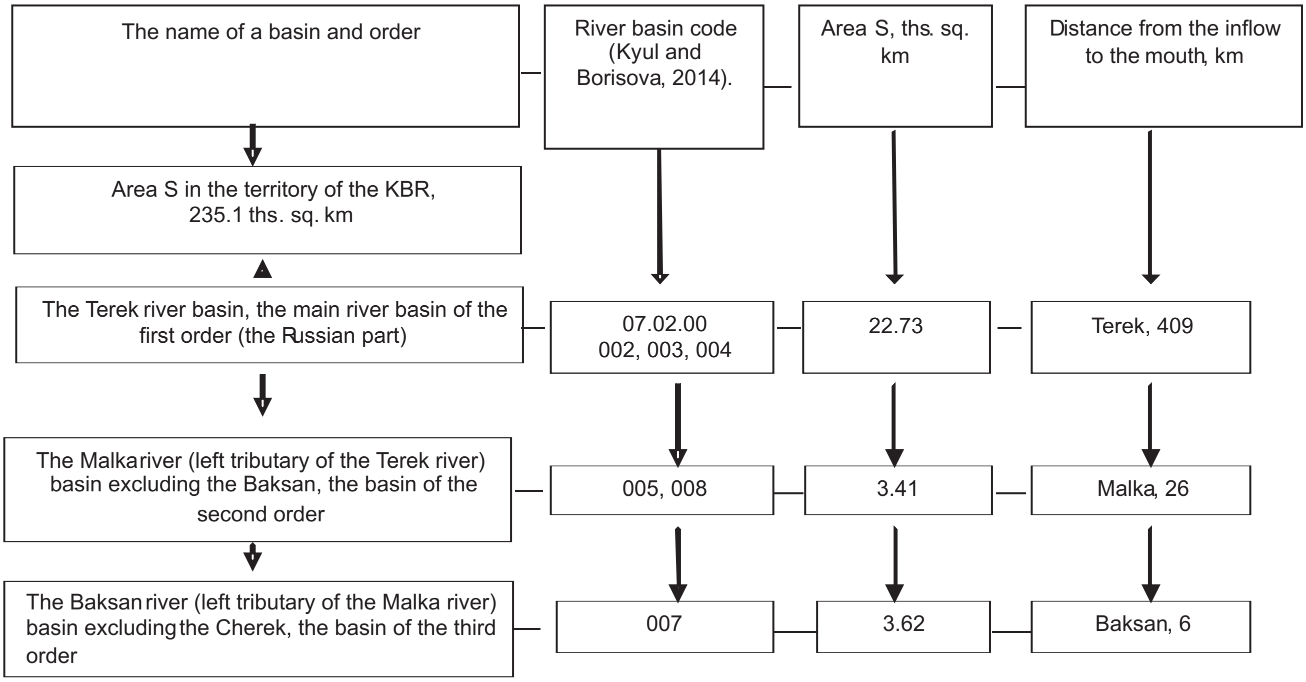

Fig. 2. Characteristics of the river basins in the study area

Fig. 3. NTG No. 1–2. Mudflows with dump and dump and extractive types of technogenic landscapes. The NHs associated with them are flow slides and avalanches. Air pollution Legend:

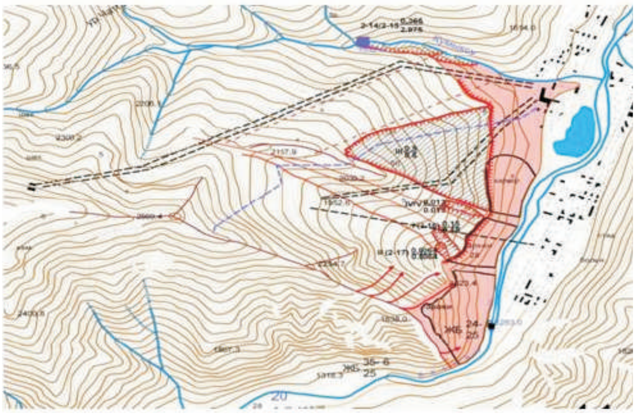

Fig. 4. Map of the subsiding landslide NTG No. 3 with mining gallery type of technogenic landscape in the area of Tyrnyauz. The scale of the original 1:50 000

Legend:

— ridges

— tectonic faults

— crushing zones

Special load:

— mud ruts

— mud beds

– landslides

- zone of the violation of a slope stability due to trimming caused by ground and road works

I 0.15/ 0.18 — landslide index: No.; the upper figure in the fraction is landslide area S, sq. km, the lower figure — volume of the landslide mass W, mln m^3.

the landslide II can cause rockfalls across the narrow thalweg reaching the bypass road passing under the slope, and the garages. Here becomes active the lower part of the ancient landslide within altitudes of 1500–1600 m. This is a bedrocks stealing flow slide, complicated by the repeated renewal of landslide shoves. Dirt road and household outbuildings get destructed. The landslides (in this case, snow slides) IV–V, passing down the hill to taluses, may threaten the garages. The landslide III is caused by saggings. In the event of further intensification, garages, the road, left-bank part of the city of Tyrnyauz up the mouth of the Kamyksu river can be endangered. Landscape transformation is significant: C_{tr} = 70–90%. In general, the landslide slope requires large-scale technical work, namely, reclamation of underground mines on the site of the mine and pit. The organizational work should include the prohibition on forests cutting and limits on grazing.

CONCLUSIONS

The anthropogenic activity, including mining, nearly always leads to the formation of landscapes with a high degree of transformation and, as a consequence, a low degree of stability and high degree of NH. Anthropogenic impact manifests not only in a complete change of relief, vegetation and soil conditions, but also in the significant environmental pollution (Reutova, 2001). This creates landscape technogenic areas with very intense environmental conditions. In order to prevent possible environmental disasters, it is necessary to develop protective legislative, financial, legal measures at the republican and, partly, federal levels.

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Influence of Phosphorus Application on Growth Pattern, Physiological Attributes and Productivity of Indian Mustard (*Brassica juncea*) Cultivars

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Abstract: The field experiment conducted to study the response of some Indian mustard (Brassica juncea) cultivars to application of applied phosphorus revealed significant increase in plant height, dry matter, leaf area index and PAR interception at different growth stages (except plant height and dry matter at 30 DAS), seed, stover and oil yields with 15 kg ha^{-1} of P_2O_5 than without its application whereas, similar increase with 30 kg ha^{-1} over 15 kg ha^{-1} of P_2O_5 was significant only for plant height and dry matter from 90 DAS up to maturity and LAI and PAR interception at 60, 90 and 120 DAS and non significant for seed, stover and oil yields. Differences among cultivars for growth and physiological attributes, seed, stover and oil yields were significant. Cultivar NRCHB 101 produced significantly higher seed and stover yields whereas for oil yield it was at par with Pusa Bold and significantly out yielded all other cultivars. Cultivars Pusa Bold, PBR 210, RL 1359, RLM 619, RLC 1, PBR 357 and PLM 2 produced statistically similar but significantly lower seed yields than NRCHB 101. Interactions between doses of phosphorus and cultivars for the different parameters including yields were non-significant.

Key Words: Cultivars, Growth, Indian mustard, LAI, Oil, PAR, Phosphorus, SPAD, Yield

Rapeseed-mustard group of crops (*Brassica spp.*) next to soybean in terms of area (22.2%) and production (22.6 %) of the total cultivated area (27.6 million hectare) and production (28.2 million tonnes) of oilseeds in India, are grown under diverse agro-ecological situations (Kumar, 2014). The present production of edible oils on the country meats less than 50 per cent of the requirements. Thus there is pressing need to boost production and productivity of oilseeds in the country. Phosphorus (P) is an essential mineral nutrient involved in a number of metabolic processes in plants. Almost half of the cultivated soils in India and that of about one third of Punjab are deficient in phosphorus. Higher fixation and low uptake of phosphorus especially during winter season requiring its direct application in higher doses and dependence on import make it an expensive input in crop production and therefore makes it imperative to exploit phosphorus efficient germplasm for developing phosphorus efficient cultivars to sustain productivity at lower doses. The proposed investigation was undertaken to study the response of widely cultivated Indian mustard cultivars across the country to phosphorus application rates under Punjab conditions to find out efficient cultivars.

MATERIAL AND METHODS

The field experiment was conducted at Punjab Agricultural University, Ludhiana (30˚56' N latitude, 75˚48' E longitude, 247 metre above the mean sea level) during *rabi* 2012-13. The soil of experimental field was loamy sand in texture, free from salts (EC 0.10 dS m^{-1}), neutral in reaction (pH 7.8) with low organic carbon content (0.37%), low in available nitrogen (245 kg ha^{-1}), low in Olsen's available phosphorus (11.7 kg ha^{-1}) and rich in $NaHCO_3$ extractable potassium (165 kg ha^{-1}) in the 0-15 cm soil depth. Three doses of phosphorus (0, 15 and 30 kg P_2O_5 ha^{-1}) in the main plots and 14 genotypes of Indian mustard (RLC 1, PBR 210, PBR 91, RLM 619, RL 1359, PBR 357, ELM 123, NRCDR 2, NRCHB 101, Pusa Bold, Varuna, MLM 19, NPJ 79, PLM 2) in the sub plots were replicated thrice as per split plot design of experiment. The gross and net plot size were 18.0 m^2 (3.0 x 6.0 m) and 9.0 m^2 (1.8 x 5.0 m), respectively. The test genotypes were sown on November 5, 2012 and harvested on April 8, 2013. Phosphorus as per treatments was applied through single super phosphate (16% P_2O_5) at the time of sowing. Nitrogen @ 50 kg ha^{-1} in the form of urea (46% N) and potassium @ 15 kg ha^{-1} through muriate of potash (60% K_2O) were also applied at time of field preparation for sowing. Another dose of 50 kg ha^{-1} of N in the form of urea was top dressed after first irrigation. The row and plant to plant spacing was 30 cm and 12-15 cm, respectively. Three irrigations were applied at 45, 90 and 120 days after sowing depending up on rainfall during crop season. Rainfall of 155.6

mm was recorded during crop season in 13 rainy days.

Plant height was measured at periodic intervals from 10 plants selected randomly from each treatment. For dry matter accumulation, plants were cut from base in the 0.5 metre row length from second outer most row in each plot, dried first under shade and later in oven at 65±2°C till constant weight. Leaf area index (LAI) and interception of photo synthetically active radiation (PAR) by plants were recorded at periodic intervals up to 120 DAS with the Digital Plant Canopy Imager (Sun Scan Canopy Analyzer model CI–110/CI–120). Observations were recorded at random from three places in each plot between 11:00 am to 2:00 pm and averaged. The SPAD 502 Chlorophyll Meter was used for non-destructive estimation of amount of chlorophyll present in the leaves. For seed and stover yield, six inner rows were separately harvested, dried and weighed for biomass yield before threshing for seed yield.

RESULTS AND DISCUSSION

Doses of phosphorus: Application of 15 kg ha^{-1} of P_2O_5 significantly increased the plant height at 60, 90 and 120 DAS and dry matter (DM) accumulation at all growth stages over control whereas such an increase in plant height with 30 kg ha^{-1} of P_2O_5 over 15 kg ha^{-1} of P_2O_5 was significant at 90 and 120 DAS and at maturity and in DM accumulation at all growth stages except at 60 DAS of the crop (Table 1). Phosphorus application promotes root development to explore more amounts of moisture and nutrients from the deeper layers of soil which aids in better growth and vigour of plant. Bhat *et al.* (2006) also reported increase in plant height of Indian mustard with application of varying doses of phosphorus. Increase in DM of Indian mustard with increasing phosphorus application was earlier reported by Sah *et al.* (2006) and Kumar and Yadav (2007). Successive increments of phosphorus up to 30 kg ha^{-1} of P_2O_5 significantly increased the leaf area index (LAI) over its lower dose at all growth stages (Table 2). Proportional increase in LAI up to 90 DAS with application of 15 kg ha^{-1} of P_2O_5 over control was greater than that discerned for 30 kg ha^{-1} over 15 kg ha^{-1} of P_2O_5 whereas reverse trend was noticed at 120 DAS. Application of 15 kg ha^{-1} of P_2O_5 increased the LAI over control by 25.0, 12.5, 8.2 and 16.7 per cent in comparison to increase of 12.0, 9.6, 6.6 and 18.8 per cent with application of 30 kg/ha over 15 kg ha^{-1} of P_2O_5 at 30, 60, 90 and 120 DAS,

Table 1. Plant height (cm) and dry matter accumulation by Indian mustard at different growth stages as influenced by doses of phosphorus and cultivars

Treatments	Plant height (cm)					Dry matter accumulation (kg ha^{-1})				
	30	60	90	120	Maturity	30	60	90	120	Maturity
Doses of phosphorus (kg P_2O_5 ha^{-1})										
0	11.1	45.5	146.8	157.2	162.9	63	702	5283	6684	7260
15	11.5	49.5	151.1	160.6	165.5	69	869	5926	7297	7933
30	11.6	52.8	154.6	163.4	168.8	75	945	6247	7688	8317
CD (p=0.05)	NS	3.7	1.1	1.4	2.8	3	129	198	247	382
Cultivars										
RLC 1	11.4	47.7	147.0	159.9	167.8	67	831	5616	6867	7528
PBR 210	11.7	51.9	152.7	163.6	166.0	71	906	5973	7404	8231
PBR 91	11.6	48.6	147.9	162.5	168.3	69	816	5845	6983	7231
RLM 619	10.5	44.2	145.2	156.0	161.8	74	846	5993	7243	7972
RL 1359	10.7	45.8	147.6	158.5	160.1	68	816	5620	7218	7880
PBR 357	11.2	50.5	148.8	157.5	165.6	71	864	5937	7124	8111
ELM 123	10.5	45.3	146.2	158.4	162.2	64	773	5664	6974	7287
NRCDR 2	12.1	55.6	157.2	163.5	168.4	70	785	5767	7074	7593
NRCHB 101	12.0	55.4	153.2	162.1	166.6	74	927	6059	8027	9194
Pusa Bold	11.1	45.5	147.0	154.1	162.4	65	807	5762	7322	7768
Varuna	11.4	47.5	144.1	152.6	160.2	70	839	5778	6735	7065
MLM 19	12.0	48.9	159.7	166.8	168.7	67	775	5501	7098	7593
NPJ 79	11.7	50.9	157.1	163.6	170.4	63	832	5959	7361	7861
PLM 2	11.8	51.8	158.0	166.9	171.6	76	927	5988	7692	8398
CD (p=0.05)	0.6	4.2	3.8	3.7	3.7	5	63	181	487	607
CD (p=0.05) Doses x cultivars	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS

respectively. Phosphorus application increased the LAI by increasing the plant height and DM accumulation (Table 1) and might have increased leaf size as well. Cheema *et al.* (2001), Bhat *et al.* (2006), Kumar and Yadav (2007) also observed increase in LAI with phosphorus application. Greater increase in LAI at 120 DAS with application 30 kg/ha of P_2O_5 over 15 kg ha^{-1} of P_2O_5 in comparison to increase in LAI with 15 kg ha^{-1} of P_2O_5 over control indicated positive role of P in retention of leaves on the plant for longer duration.

Application of 30 kg ha^{-1} of P_2O_5 significantly increased the PAR interception over 15 kg ha^{-1} of P_2O_5 at all the growth stages except at 30 DAS whereas, application of 15 kg ha^{-1} of P_2O_5 resulted in significantly more PAR interception than without its application at 60 and 90 DAS. Increase in PAR with increasing dose of phosphorus was a consequence of increased leaf area which provided platform for interception of greater amount of solar radiation. Application of phosphorus resulted in inconspicuous increase in leaf chlorophyll content (SPAD values) at all growth stages (Table 2). Sah *et al.* (2006) earlier reported non-significant increase in leaf chlorophyll content of Indian mustard with increasing phosphorus application from 20 to 40 kg ha^{-1} of P_2O_5. Phosphorus application did not influence the initiation and completion of flowering and number of days taken to maturity (Table 3). Phenophase development is under genetic control and phosphorus application seems to have no conspicuous effect on it. These results are in conformity with those of Salaria (2000) in oilseed rape (*Brassica napus*) and Tigadi (2005) in Indian mustard (*Brassica juncea*). Main shoot length recorded at maturity increased with increasing dose of phosphorus and such an increase with 30 kg ha^{-1} of P_2O_5 was conspicuous over control (Table 3).

Application of 30 kg ha^{-1} of P_2O_5 increased the seed yield by 9.9 and 2.5 per cent and stover yield by 15.1 and 4.9 per cent over control and 15 kg ha^{-1} of P_2O_5, respectively. Increase in seed as well as stover yield with phosphorus application of 15 kg/ha of P_2O_5 over control was significant (7.2%, 9.7%). Increase in seed yield due to the increased phosphorus application might be due to better growth and consequent development of larger sink. Higher seed yield with successive phosphorus doses could be attributed to the more LAI and PAR interception (Table 2) resulting in more DM accumulation (Table 1), number of siliquae per plant, seeds per siliqua and 1000-seed weight (Chouksey *et al.,*

Table 2. Influence of doses of phosphorus and cultivars on leaf area index, photosynthetically active radiation interception, and SPAD chlorophyll values of Indian mustard at different growth stages

Treatments	Leaf Area Index				PAR interception (%)				SPAD value			
	30	60	90	120	30	60	90	120	30	60	90	120
Doses of phosphorus (kg P_2O_5 ha^{-1})												
0	0.20	1.76	3.06	1.14	24.1	73.4	79.3	74.5	40.6	41.0	40.0	39.7
15	0.25	1.98	3.31	1.33	27.0	77.2	83.4	76.8	41.3	41.9	41.0	40.3
30	0.28	2.17	3.53	1.58	28.0	80.8	86.9	81.7	41.6	42.2	41.0	40.8
CD (p=0.05)	0.01	0.09	0.05	0.09	NS	1.6	3.0	4.3	NS	NS	NS	NS
Cultivars												
RLC 1	0.25	1.88	3.12	1.32	25.6	75.9	81.9	77.6	40.6	41.1	39.7	39.5
PBR 210	0.26	2.11	3.54	1.39	27.2	79.4	84.3	76.1	42.2	42.8	40.9	40.6
PBR 91	0.26	2.17	3.65	1.45	27.3	79.9	84.7	75.1	40.6	41.6	40.8	40.7
RLM 619	0.22	1.93	3.23	1.34	23.9	72.0	81.9	78.6	40.3	40.7	39.9	40.7
RL 1359	0.25	1.94	3.24	1.41	27.5	79.4	85.5	79.3	40.0	40.6	39.8	39.9
PBR 357	0.26	1.80	2.99	1.35	25.1	77.6	85.1	79.5	41.3	41.6	39.0	39.3
ELM 123	0.23	1.94	3.25	1.22	26.1	75.5	81.0	79.8	39.8	40.4	38.6	37.6
NRCDR 2	0.24	2.06	3.47	1.51	28.2	79.3	86.4	81.5	42.6	42.2	42.4	41.5
NRCHB 101	0.28	2.20	3.66	1.59	30.4	82.0	88.4	81.9	43.3	43.9	41.8	41.9
Pusa Bold	0.24	1.99	3.33	1.27	25.4	76.3	79.3	79.8	41.0	41.7	42.2	40.9
Varuna	0.24	2.07	3.46	1.41	27.6	77.4	85.2	74.9	41.2	42.0	41.5	40.8
MLM 19	0.24	1.84	3.07	1.21	24.9	72.1	81.3	75.8	40.1	41.9	40.6	41.0
NPJ 79	0.21	1.73	2.97	1.20	23.0	74.4	78.2	72.7	40.9	41.3	40.6	39.8
PLM 2	0.25	1.90	3.29	1.22	27.0	78.8	81.8	75.8	42.0	42.2	41.3	40.7
CD (p=0.05)	0.03	0.16	0.31	0.14	3.2	5.6	5.8	NS	1.4	1.7	1.7	1.8
CD (p=0.05) Doses x cultivars	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS

2016). These results are in conformity with those reported by Turk and Tawaha (2002), McKenzie *et al.* (2003), Sumeria (2003) and Mir *et al.* (2010). Increase in stover yield in response to higher phosphorus dose might be due to increased plant height, DM accumulation and leaf area. Sah *et al.* (2006) reported similar findings. Phosphorus application significantly influenced the oil yield (Table 3). The highest oil yield obtained with application of 30 kg ha^{-1} of P_2O_5 was at par with that 15 kg ha^{-1} of P_2O_5. Application of 30 and 15 kg ha^{-1} of P_2O_5 increased oil yield by 11.2 and 7.8 per cent, respectively over control.

Cultivars: Differences in plant height among cultivars at all growth stages were significant (Table 1). Cultivars NRCDR 2, PLM 2, MLM 19, NPJ 79 at all growth stages except MLM 19 and NPJ 79 at 60 DAS attained statistically similar but significantly more plant height than rest of the cultivars. Likewise NRCHB 101 at 30 and 60 DAS and PBR 210 at 30, 60 and 120 DAS were at par with above mentioned cultivars, whereas RLM 619, Varuna, Pusa Bold and ELM 123 attained shorter stature. Significant variations in cultivars of Indian mustard for plant height were reported earlier by Panda *et al.* (2004), Bhat *et al.* (2006), Siddiqui *et al.* (2008).

Cultivar NRCHB 101 accumulated statistically similar DM with PLM 2, PBR 210 and PBR 357 at 30, 60 and 90 DAS and was also at par with NRCDR 2 and Varuna at 30 DAS, with NPJ 79 and RLM 619 at 90 DAS, with PLM 2 only at 120 DAS and accumulated significantly more DM than all the test cultivars at maturity (Table 1). Cultivar ELM 123 at 30 and 60 DAS, MLM 19 at 90 DAS and Varuna at 120 DAS and maturity accumulated lowest DM. Cultivars ELM 123, MLM 19, RLC 1 and Varuna in general accumulated significantly lower DM than rest of the cultivars at different growth stages. Significant differences among cultivars for DM accumulation were also reported by Kumar *et al.* (2001) and Bhat *et al.* (2006).

Cultivar NRCHB 101 attained highest LAI whereas, NPJ 79 attained lowest LAI at all growth stages (Table 2). The highest LAI attained by NRCHB 101 was at par with PBR 91

Table 3. Days taken for initiation and completion of flowering and maturity of Indian mustard as influenced by doses of phosphorus and cultivars

Treatments	Days taken for			Main shoot length (cm) at maturity	Seed yield (kg ha^{-1})	Stover yield (kg ha^{-1})	Oil yield (kg ha^{-1})
	Flowering initiation	100% flowering	Maturity				
Doses of phosphorus (kg P_2O_5 ha^{-1})							
0	57.7	81.9	137.9	72.4	1607	5712	625
15	57.9	82.4	138.2	75.1	1723	6269	674
30	58.5	83.3	138.5	77.1	1766	6576	695
CD (p=0.05)	NS	NS	NS	3.2	75	337	28
Cultivars							
RLC 1	60.4	87.6	139.2	74.0	1728	6078	652
PBR 210	62.0	86.1	139.7	72.9	1767	6465	690
PBR 91	61.7	85.1	137.5	73.6	1663	5569	660
RLM 619	60.8	86.9	140.3	76.2	1741	6231	690
RL 1359	54.8	82.7	138.6	73.1	1743	6136	691
PBR 357	57.4	83.1	136.3	78.6	1724	6387	674
ELM 123	58.6	84.4	137.7	75.6	1694	5593	635
NRCDR 2	53.0	71.0	137.0	71.7	1650	6035	664
NRCHB 101	52.4	71.2	136.0	76.2	1907	7287	755
Pusa Bold	53.9	72.0	139.1	75.9	1793	5994	709
Varuna	52.4	77.3	136.9	75.1	1663	5679	653
MLM 19	63.0	88.8	138.9	75.5	1534	6059	590
NPJ 79	58.4	89.4	138.1	74.4	1462	6399	579
PLM 2	63.3	89.8	139.6	75.4	1711	6687	668
CD (p=0.05)	1.2	1.3	1.5	NS	111	564	46
CD (p=0.05) Doses x cultivars	NS	NS	NS	NS	NS	NS	NS

at all growth stages, with PBR 210 at 30, 60 and 90 DAS, with NRCDR 2 at 60, 90 and 120 DAS, with Varuna at 60 and 90 DAS and with RL 1359, RLC 1, PBR 357 and PLM 2 only at 30 DAS. The lowest LAI attained by NPJ 79 was at par with MLM 19, ELM 123, RLM 619 and RLC 1 at 30, 60, 90 and 120 DAS (except with RLC 1 at 30 DAS and ELM 123 and RLM 619 at 60 DAS), with NRCDR 2, Pusa Bold, Varuna at 30 DAS, with PBR 357 at 60 and 90 DAS, with RL 1359 at 90 DAS and with PLM 2 and Pusa Bold at 120 DAS. At all growth stages (30, 60 and 90 DAS), cultivar NRCHB 101 intercepted higher proportion of PAR than rest of the cultivars whereas, NPJ 79 intercepted lowest PAR at different growth stages except at 60 DAS when PAR interception by RLM 619 and MLM 19 was lower than NPJ 79 (Table 2). Cultivars PBR 210, PBR 91, RL 1359, NRCDR 2 and Varuna at all growth stages, PBR 357 at 60 and 90 DAS and PLM 2 at 60 DAS also intercepted similar amount of PAR with NRCHB 101. The lowest proportion of PAR intercepted by NPJ 79 was at par with MLM 19, Pusa Bold, RLC 1 and ELM 123 at all growth stages, with RLM 619 at 60 and 90 DAS, with PBR 357 at 30 DAS, with Varuna at 60 DAS and PLM 2 at 90 DAS.

There were significant differences in SPAD values among cultivars for leaf chlorophyll content at all the growth stages (Table 2). Cultivar NRCHB 101 registered highest SPAD value at all growth stages except at 90 DAS when highest SPAD value was recorded for NRCDR 2. Cultivars PBR 210, NRCDR 2 and PLM 2 and NRCHB 101 at all growth stages and PBR 91, Pusa Bold, Varuna at 90 and 120 DAS registered statistically similar SPAD values. Similarly RLM 619 and MLM 19 registered similar SPAD values as that of NRCHB 101 at 120 DAS. Cultivar ELM 123 registered lowest SPAD value at all growth stages and was at par with RLC 1, PBR 91, RLM 619, RL 1359, Pusa Bold, MLM 19 and NPJ 79 at 30 and 60 DAS, with PBR 357 at 60, 90 and 120 DAS, with Varuna and PLM 2 at 60 DAS, and with RL 1359 at 90 DAS.

Differences among cultivars for number of days taken for flowering initiation, flowering completion and maturity were significant (Table 3). Flowering initiation in PLM 2 (63.3) was significantly late than all other cultivars except MLM 19 (63.0). Flowering initiation in NRCHB 101, Varuna, NRCDR 2, and Pusa Bold was conspicuously earlier than rest of the cultivars. NRCDR 2, NRCHB 101 and Pusa Bold took significantly lesser number of days for completion of flowering than all other cultivars. Cultivars PLM 2, NPJ 79 and MLM 19 took significantly more number of days for completion of flowering than all other cultivars except RLC 1 which took similar number of days to that of MLM 19. Cultivars NRCHB 101, NRCDR 2, PBR 357, PBR 91 and Varuna were similar but significantly early in maturity than RLM 619, PBR 210, RLC 1, PLM 2 and Pusa Bold. Cultivars RLM 619, PBR 210, PLM 2, RLC 1, Pusa Bold and MLM 19 took similar but more number of days for maturity than rest of the cultivars. Significant differences among cultivars for onset of phenophases were also reported by Chaturvedi *et al.* (1988) and Sharma *et al.* (1997). Cultivar PBR 357 produced the longest and NRCDR 2 the shortest main shoot length though the differences among cultivars were non-significant.

Cultivar NRCHB 101 produced significantly higher seed yield (1907 kg ha^{-1}) and stover yield (7287 kg ha^{-1}) with an increase of 6.3 to 30.4 per cent in seed yield and 9.0 to 30.8 per cent, in stover yield over rest of the test cultivars. Similarly NRCHB 101 (755 kg ha^{-1}) produced oil yield at par with Pusa Bold (709 kg ha^{-1}) but significantly higher (6.5 to 30.4 per cent) than all other cultivars. Cultivar NPJ 79 and MLM 19 produced similar seed yields (1462 kg ha^{-1}, 1534 kg ha^{-1}) and oil yields (579, 590 kg ha^{-1}) which were significantly lower than rest of the cultivars except MLM 19 which was at par with ELM 123 for oil yield (Table 3). Cultivar PBR 91 (5569 kg/ha) produced the lowest stover yield which was at par with RLC 1, MLM 19, NRCDR 2, ELM 123, Pusa Bold and Varuna and significantly lower than rest of cultivars. Significant differences in seed and stover yields among cultivars of Indian mustard were reported by Rana and Pachauri (2001), Singh *et al.* (2002), Yadav and Yadav (2005). Kumar and Yadav (2007) also recorded significant differences in stover yield among Indian mustard cultivars.

Interaction: The interactions between doses of phosphorus and cultivars for all the parameters studied including yields were non significant.

CONCLUSIONS

The study reveals favourable response of application of phosphorus (15–30 kg ha^{-1} of P_2O_5) on growth parameters of Indian mustard at different growth stages over without its application. Seed, stover and oil yields obtained with application of 15 kg ha^{-1} of P_2O_5 were significantly more than that obtained without its application. Cultivar NRCHB 101 produced significantly higher seed and stover yields whereas for oil yield it was at par with Pusa Bold and significantly out yielded all other cultivars. Cultivars Pusa Bold, PBR 210, RL 1359, RLM 619, RLC 1, PBR 357 and PLM 2 produced statistically similar seed yields. Interactions between doses of phosphorus and cultivars for the studied parameters including yields were non significant.

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Effects of Short and Long Term Salinity Stress on Physiological and Oxidative Metabolism in Chickpea (*Cicer arietinum*) and Its Possible Alleviation by Nitric Oxide

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Abstract: The present study investigates the effect of both long and short term salinity stress in chickpea plants and the protective effect of exogenously applied nitric oxide (NO). Sodium nitroprusside (SNP) used as NO donor. Salinity treatments given before sowing were termed as long term stress and thirty days after germination as short term stress. Sodium nitroprusside was given as foliar spray 30 days after germination to both long and short term salinity treated plants. Increased in membrane injury %, ROS content and lipid peroxidation levels were observed under salinity stress. Sodium nitroprusside treatments decreased ion leakage and lipid peroxidation levels significantly. Salinity stress resulted in induction of antioxidatve enzymes but induction was more under short term salinity stress as compared to long term salinity stress. Nitric oxide showed its positive effect by further increasing the activities of antioxidant enzymes. Salinity stress also altered the level of antioxidant metabolites by reducing the ascorbate redox ratio (ASC/DHA) and glutathione redox ratio (GSH/GSSG). No donor treatments increased the redox ratios and showed its positive effects. Seed yield also decreased under salinity stress with more reduction under long term salinity than short term salinity. Nitric oxide had a positive effect on seed yield and biomass accumulation. On the basis of above studies, it is proposed that short term salinity stress resulted in a greater increase in membrane injury (%), malondialdehyde (MDA), reactive oxygen species and hydrogen peroxide content as compared to long term salinity stress. It activated the antioxidant defense system more pronouncedly, resulting in a lesser oxidative stress and a smaller decline in plant yield. However, long term salinity stress had a lesser effect on antioxidant defense system, thus leading to a higher oxidative stress and ultimately a higher decline in plant yield.

Keywords: Antioxidant enzymes, Lipid peroxidation, Membrane injury, Nitric oxide, Salinity, Sodium nitroprusside, Chick pea

Salinity is an ever present threat to crop yields. About 20−50 per cent of all irrigated crop lands are affected by high salt concentration that results in significant economic loss (Shrivastava and Kumar, 2015) and the level is still rising. Several physiological and biochemical processes like photosynthesis, protein synthesis, energy and lipid metabolism are affected by salinity. Salt stress disturbs intracellular ion homeostasis in plants, which leads to membrane dysfunction, alteration in metabolic activities of cell. That further result in cell death and growth inhibition (Hasegawa *et al.,* 2000; Nasrin *et al.,* 2012). Oxidative stress is a common consequence of salt stress due to overproduction of reactive oxygen species (ROS). These ROS are highly reactive and cause cellular damage through oxidation of lipids, proteins and DNA injury (Foyer and Noctor, 2000). Salinity stress also causes alterations in the antioxidative defense system of plant (Parida and Das, 2005). Exogenous application of free radical scavengers by could help in detoxification of stress‑induced free radical production (Zhang *et al.,* 2006; Hayat *et al.,* 2012). Sheokand *et al.* (2008 and 2010) also observed positive effects of exogenously applied nitric oxide and polyamines in chickpea plants. These antioxidants set a balance between generation and scavenging of free radicals and helps plant survival under stress condition.

Nitric oxide (NO) is a small highly diffusible and ubiquitous bioactive molecule that takes part in many physiological processes in plants. Its protective role is based on its ability to regulate the level and toxicity of ROS. Wendehenne *et al.* (2005) suggested that NO is involved in defense response to biotic or abiotic stresses and appear to be present in most of the stress reactions. According to earlier studies NO have been showed protective effect in response to drought stress (Farooq *et al.,* 2009), oxidative stress (Beligni and Lamattina, 2002), osmotic stress (Zhao *et al.,* 2008), salt stress (Sheokand *et al.,* 2010), heavy metal stress (Kumari *et al.,* 2010) and high light (Xu *et al.,* 2010). However most of the studies on oxidative metabolism under salt stress have been done with short term salt stress. The present study aims at investigating the effect of short term and long term salinity stress on physiological and oxidative metabolism in chickpea and its possible alleviation by nitric oxide.

MATERIAL AND METHODS

Plant material and treatments: Chickpea (*Cicer arietinum* L. cv HC‑3) seeds procured from the Pulses Section, Department of Plant Breeding, CCS Haryana Agricultural University, Hisar, were surface-sterilized with 0.2 per cent $HgCl_2$ and inoculated with a specific *Rhizobium* culture supplied by the Department of Microbiology, CCS Haryana Agricultural University. The plants were raised in earthen pots containing 5 Kg of dune sand under green house conditions. The plants were supplied with Wilson and Reisenauer (1963) nutrient solution at regular intervals. Salinity of 6dSm^{-1} was developed by saturating soil with saline water prepared by mixture of NaCl, $MgCl_2$, $MgSO_4$ and $CaCl_2$, (Na: Ca + Mg (1:1), Ca: Mg (1:3) and Cl:SO_4 (7:3) on meq basis i.e. chloride dominated salinity.Salinity treatments were applied through the rooting medium and given to two sets of plants. In the first set, salinity treatments were given before sowing and termed as long term salinity stress. In second set, salinity treatments were given after 30 days of germination and termed as short term salinity stress. Nitric oxide donor SNP (500 μM) and NO scavenger c-PTIO (100 μM) were applied after 30 days of germination through foliar spray and the pots were grouped into control, control + SNP (500 μM),salinity (6 dSm^{-1}) ,salinity (6 dSm^{-1}) + SNP (500 μM)and salinity (6 dSm^{-1}) + SNP (500 μM) + c-PTIO (100μM). Samplings were done, 24 and 72 h after treatments given 30 days after germination. Fully expanded leaves were collected and analyzed.

Relative membrane injury (RI): Relative membrane injury was analyzed according to the method of Zhang *et al.* (2006). 250 mg of leaves were rinsed with distilled water and immersed in 10 ml de-ionised water in test tubes and kept for 4 h at 25˚C. Electrical conductivity (EC) of the leaves contained water measured as EC1. The tissue along with leachate was then boiled at 100 ˚C for 30 min to completely disrupt the cell structure. The solution was cooled down and its EC was measured again as EC2. Relative injury was calculated from the equation [(EC1/EC2) × 100].

Make lipid peroxidation: Membrane injury was analyzed according to the method of Zhang *et al.* (2006). The level of lipid peroxidation in plant tissue was quantified by determination of malondialdehyde (MDA) content, a breakdown product of lipid peroxidation (Sheokand *et al.,* 2008). MDA content was determined with thiobarbituric acid reaction. The concentration of MDA was calculated using the extinction coefficient of 155 mM cm^{-1}.

H_2O_2 content: H_2O_2 content was analyzed according to the method of Sinha (1972). Extract was prepared by grinding of 1 gm tissue in 6 ml chilled 0.8 N $HClO_4$. This was centrifuged at 8000 rpm and supernatant was neutralized with 5 M K_2CO_3. The clear supernatant was used for H_2O_2 estimation. 200 μl of extract was made to 1 ml with 0.1 M phosphate buffer (pH 7.5). 2 ml of 5 per cent potassium dichromate and glacial acetic acid (1:3 v/v) was added to it. The mixture was then heated in boiling water both for 10 minutes and cooled. Its absorbance was read at 570 nm against reagent blank which was without sample extract. The quantity of H_2O_2 was determined from standard curve prepared similarly with 0-100 n mol H_2O_2.

Reactive oxygen species (ROS) content: ROS production was measured as described by Able *et al.* (2003) by monitoring the reduction of XTT (2,3-Bis(2-methoxy-4-nitro-5-sulfophenyl)-2H-tetrazolium-5-carboxanilide-inner salt), in the presence of ROS, with some modifications. 200 mg tissue ground in 50 mM K-phosphate buffer (pH 7.8) and centrifuged at 1000 rpm in cooling centrifuge. The reaction mixture contained 1 ml of 50 mM K-phosphate buffer (pH 7.8), 400 μl of supernatant and 500 μl of 0.5 mM XTT. The reduction of XTT was determined at 470 nm for 3 min. Corrections were made for the absorbance of chlorophyll. ROS production was calculated using an extinction coefficient of 2.163104 m^{-1}cm^{-1}.

Determination of enzyme activity: Cell free extract for various antioxidant enzymes viz, catalase (CAT), superoxide dismutase (SOD), ascorbate peroxidase (APX), dehydroascorbate reductase (DHAR), glutathione reductase (GR), peroxidase (POX) and monohydroascorbate reductase (MDHAR) was prepared by macerating 500 mg of leaf tissue in chilled pestle and mortar in presence of 3.0 ml of 0.1M potassium phosphate buffer (pH 7.0) containing 0.1 mM EDTA, 1 per cent (w/v) PVP and 20 per cent glycerol. The homogenate was centrifuged at 10,000×*g* for 15 min at 4˚C. The supernatant was carefully decanted and used as the crude enzyme extract.

Catalase and peroxidase: Catalase (E.C. 1.11.1.6) and peroxidase (E.C. 1.11.1.7) activity was estimated as described by Sheokand *et al.* (2008).The reaction mixture in final volume of 3 ml, contained 0.1 M phosphate buffer (pH 7.0), 10 mM H_2O_2 and 50 μl of cell free extract. Reaction was initiated with the addition of H_2O_2 and enzyme activity was determined by following the degradation of H_2O_2 at 240 nm for 2 minutes. One unit of enzyme activity corresponded to one nmol of H_2O_2 consumed during the reaction (extinction coefficient 39.4 mM^{-1} cm^{-1}). For peroxidase, the reaction mixture of 3 ml contained 0.1 M phosphate buffer (pH 7.0), 0.1 mMg uaiacol, 0.1 mM H_2O_2 and 50 μl cell free extract. Reaction was started with the addition of H_2O_2 and increase in absorbance at 470 nm was recorded for 2 min. One unit of enzyme activity was equivalent to μmol of H_2O_2 oxidised (extinction coefficient 22.6 mM^{-1} cm^{-1}).

Superoxide dismutase: Superoxide dismutase (E.C.

1.15.1.1) activity was assayed by measuring its ability to inhibit the photochemical reduction of NBT (Beauchamp and Fridovich, 1971). The reaction mixture contained a range of enzyme extracts in separate sets and to these added 0.25 ml of each of 13 mM methionine, 80 µM NBT and 0.1mM EDTA and the total volume of 3.0 ml was made with buffer in each set. Then 0.25 ml of 50 µM riboflavin was added to each set in the last. The tubes were shaken and placed 30 cm away from light source (4×40 w fluorescent lamps). The reaction was allowed to run for 20 min and the reaction was stopped by switching off the light. The absorbance was recorded at 560 nm. One unit of enzyme activity represents the amount of enzyme required for 50 per cent inhibition of NBT reduction at 560 nm.

Glutathione reductase and ascorbate peroxidase*:* The activities of glutathione reductase (E.C. 1.6.4.2) and ascorbate peroxidase (E.C. 1.11.11) were analyzed by method described by Sheokand *et al.* (2008). Incubation mixture for GR enzyme assay consisted of 0.1 M phosphate buffer (pH 7.5), 5 mM oxidized glutathione (GSSG), 0.2 mM NADPH and 100 µl enzyme extract in a final volume of 1.5 ml. Addition of GSSG, initiated the enzyme reaction. The decrease in absorbance at 340 nm due to oxidation of NADPH was monitored. One unit of enzyme activity was equivalent to one nmol of NADPH oxidised during the reaction (extinction coefficient 6.2 mM^{-1} cm^{-1}). The composition of APX assay mixture was 50 mM phosphate buffer (pH 7.0), 0.5 mM sodium ascorbate, 1.0 mM H_2O_2 and 75 µl of enzyme extract in 1.5 ml final volume. The reaction was initiated by the addition of H_2O_2. The decrease in absorbance due to oxidation of ascorbate at 290 nm was recorded spectrophotometrically for 2 min. One unit of enzyme activity corresponded to one µmol of ascorbate oxidised during the reaction (extinction coefficient 2.8 mM^{-1} cm^{-1}).

Dehydroascorbate reductase: The assay mixture of DHAR (E.C. 1.8.5.1) determination contained 100 mM potassium phosphate buffer (pH 7.0), 2.5 m MGSH, 0.2 mMDHA and 0.1 mM EDTA and 50 µl enzyme extract in a final volume of 1.5 ml. Reaction rates were measured by the increase in absorbance at 265 nm after adding the enzyme. DHAR was calculated by using extinction coefficient value of 14 mM^{-1} cm^{-1}as described by Sheokand *et al.* (2008). One unit of enzyme activity corresponded to one nmol of ascorbate produced during the reaction.

Monodehydroascorbate reductase: The MDHAR (E.C. 1.6.5.4)activity was assayed spectrophotometrically (Hossain *et al.,* 1984) by following the decrease in absorbance at 340 nm due to NADH oxidation. Reaction mixture contained 90 mM potassium phosphate buffer (pH 7.0), 0.2 mM NADH, 2.5 mM ASA, ASA oxidase (0.25 unit, 1 µmol ascorbate oxidized min^{-1} being 1 Unit) and 100 µl of enzyme extract in a final volume of 1.5 ml. The reaction was initiated by the addition of ASA oxidase. One unit of enzyme activity corresponded to one nmol of DHA reduced during the reaction (extinction coefficient 6.2 mM^{-1} cm^{-1}).

Estimation of antioxidant metabolites*:* Ascorbic acid content was determined with a modification of the procedure of Takahama and Oniki (1992) as described in detail by Kumari *et al.* (2010). Ascorbate content was calculated by using extinction coefficient 15 $mM^{-1}cm^{-1}$. Total (GSSG + GSH) and oxidized glutathione was determined by the procedure as described by Kumari *et al*. (2010). The concentration of reduced glutathione (GSH) was calculated by subtracting the concentration of GSSG from that of the total glutathione.

Plant biomass: Dry weight of different plant parts was measured at maturity.

Statistical analysis: Data was analyzed by using OP State two factorial critically randomized design.

RESULTS AND DISCUSSION

Membrane injury and lipid peroxidation: Salinity stress of (6 dSm^{-1}) significantly increased the membrane injury per cent and MDA content (Table 1). Increased MDA content corresponds to higher lipid peroxidation levels as observed in our study with both short term and long term salinity stress but short term salinity stress resulted in a higher increase. A 65 to 27 per cent increase in MDA content was observed with short term salinity stress at 24 and 72 h (Table 1). With long term salinity stress, it was maintained at 52 per cent more than control levels (Table 1). Salinity stress induced lipid peroxidation has been reported earlier (Sheokand *et al.,* 2008, 2010). Increased lipid peroxidation makes membranes leaky as is evidenced by increased electrolyte leakage. A 4.4 fold increase in MI was observed after 24h of salinity stress which decreased to 2.7 fold after 72 h of salinity stress (Table 1). With long term salinity stress the MI (per cent) was not significantly different at 24 and 72 h and was respectively observed as 2.9 to 2.4 fold higher than control. Exogenously applied NO donor SNP (500 µM) had a protective and significant effect on salinity induced membrane damage. With short term salinity stress a 46 to 35 per cent decrease in MI and a 23 to 26 per cent decrease in MDA content was observed after 24 and 72 h of application while with long term salinity stress the ameliorative effect of SNP increased with time and a 20 to 33 per cent decrease in MI and 52 to 27 per cent decrease in MDA content was observed after 24 and 72 h of application (Table 1). Nitric oxide has been reported to inhibit ion leakage from plant tissues and protect membrane damage due to lipid peroxidation under salt stress

(Sheokand*et al.* 2008, 2010), photo-oxidative stress (Beligni and Lamattina, 2002), Cd stress (Kumari *et al.,* 2010) and Pb stress (Sadeghipour, 2016).

Reactive oxygen species (ROS) content and H_2O_2 content: Salinity stress significantly increased the free radicals production in the treated plants. Maximum increase in ROS and H_2O_2 content was observed with 24 h of salinity resulting in a 75 and 98 per cent increase, respectively, however when duration of stress was increased to 72 h the ROS and H_2O_2 content was 32 and 45 per cent higher than control (Table 2). Increased production of ROS is associated with increased salinity due to imbalance in production and scavenging of ROS (Sharma *et al.,* 2012). Increase in ROS production under salinity stress has been reported in chickpea (Sheokand *et al.,* 2010).

Antioxidant function of no may be accomplished by direct removal ROS (Kopyra and Gwozdz, 2003). This hypothesis was confirmed in our studies. Sodium nitroprusside significantly decreased the total ROS and H_2O_2 content under both long term and short term salinity stress. A 21 to 39 per cent reduction in ROS content and 6 to 20 per cent reduction H_2O_2 content was observed after 24 and 72 h of SNP application with short term salinity while with long term salinity a reduction of 26 to 23 per cent for ROS and 19 to 15 per cent for H_2O_2 content was observed after 24 and 72 h of SNP treatments. A protective role of NO on H_2O_2 and total ROS content has been reported under salt stress (Sheokand *et al.,* 2010). However no significant effect of SNP was observed under salt stress in chamomile plant (Nasrin *et al*., 2012).

Antioxidant enzymes: Superoxide dismutase (SOD) is the first line of defense against oxidative stress in plants. In our study, both salinity and SNP treatments significantly affected SOD activity at short term stress. A 26 per cent increase in SOD activity was observed after 24 h, which increased to 40 per cent after 72 h with short term salinity stress and was maintained at 55 per cent above control levels with long term salinity treatments (Table 4). Salt stress induced increase in SOD activity has been observed in roots of *Lupinus luteus*, (Kopyra and Gwozdz, 2003), wheat (Mandhania *et al.,* 2006) and chickpea (Sheokand *et al.,* 2010). Over-expression of Cu/ Zn- SOD in *Arachis hypogaea* was reported to confer increased salt tolerance (Negi *et al*., 2015).

As a signal molecule NO induces/stablizes expression of

Table 1. Effect of salinity (6 dSm^{-1}) and NO donor (500 μM SNP) on the membrane injury (%) and MDA content (μmol g^{-1} DW), in chickpea leaves

Treatments	Membrane injury (%)				MDA content (μmol g^{-1} DW)			
	Short term salinity stress		Long term salinity stress		Short term salinity stress		Long term salinity stress	
	24h	72h	24h	72h	24h	72h	24h	72h
C	15.21	21.39	15.21	21.39	28.90	25.52	28.90	25.52
C+SNP	24.48	26.34	24.48	26.34	23.05	22.45	23.05	22.45
S	67.29	58.66	43.75	52.36	47.73	32.30	43.98	28.76
S+SNP	36.64	38.03	38.53	35.01	36.63	23.12	21.33	20.91
S+SNP+SCA	40.65	59.68	59.16	41.27	35.89	29.05	24.20	25.98
CD (p=0.05)	H-2.035; T-3.218; HxT-4.550		H-NS; T-4.028; HxT-5.696		H-3.091; T-4.887; HxT-6.911		H-2.054; T-3.247; HxT-4.592	

*H, hours after treatment; T, treatment; H×T, interaction of both hours and treatments

Table 2. Effect of salinity (6 dSm^{-1}) and NO donor (500 μM SNP) on total ROS content (μmol g^{-1} DW) and H_2O_2 content (μmol g^{-1} DW) in chickpea leaves

Treatments	ROS Content (μmol g^{-1} DW)				H_2O_2 content (μmol g^{-1} DW)			
	Short term salinity stress		Long term salinity stress		Short term salinity stress		Long term salinity stress	
	24h	72h	24h	72h	24h	72h	24h	72h
C	7.10	7.05	7.10	7.05	0.537	0.564	0.537	0.564
C+SNP	7.98	7.29	7.98	7.29	0.708	0.660	0.708	0.666
S	14.0	10.2	10.2	7.96	0.939	0.743	0.835	0.693
S+SNP	11.0	7.27	7.57	6.15	0.886	0.597	0.677	0.594
S+SNP+SCA	14.8	7.57	8.72	7.27	1.091	0.838	1.067	0.668
CD (p=0.05)	H-0.797; T-1.260; HxT-1.182		H-0.334; T-0.528; HxT-0.747		H-0.050; T-0.079; HxT-0.112		H-0.060; T-0.095; HxT-0.135	

*H, hours after treatment; T, treatment; H×T, interaction of both hours and treatments many antioxidative enzymes including SOD (Frank *et al.,* 2000). SNP application further increased the SOD activity (Table 4). Nitric oxide can readily react with the superoxide anion-radical (O_2^-) to form peroxynitrite ion ($ONOO^-$), which is unstable and results in formation of peroxodioxonitric acid, a source of nitrogen dioxide (NO_2) and a hydroxyl radical (OH^-) (Wendehenne *et al.,* 2004). SNP induced increase in SOD activity under salt stress has also been reported by Kopyra and Gwozdz (2003) and Shi *et al.* (2007). Sadeghipour (2016) observed 81 per cent more activity under combined treatment of SNP and Pb than Pb stress alone. Significant increased in POX and CAT activity was observed with salinity stress and a higher increase was obtained with short term stress as compared to long term stress. A 135 to 156 per cent increase in CAT activity was observed after 24 and 72 h (Table 3) with short term salinity treatments and with long term salinity treatments CAT activity was found between 37 to 44 per cent more than control values. Peroxidase activity increased by 41 to 76 per cent with short term salinity treatment after 24 and 72 h, respectively (Table 3) while with long term salinity stress POX activity was 20 to 31 per cent higher than control levels. Increase in CAT and POX activity with salt stress has been reported by Sheokand *et al.* (2008).

Sodium nitropursside treatments lead to further increasein the activities of CAT and POX (Table 3). A 3 to 15 per cent and 14 to 17 per cent increase in CAT activity was observed with short term and long term salinity treatments, respectively after 24 and 72 h while a 15 to 18 per cent increase in POX activity was observed with short term salinity, however no further increase was recorded with long term salinity treatment. Using SNP as NO donor, Beligni and Lamattina (2002) demonstrated a three-fold increase in CAT activity in diquat+SNP treatment as compared to diquat treatment. As shown by means of c-DNA microarray in plants treated with NO the expression of genes of neutral peroxidase and catalase were induced (Huang *et al.,* 2002).Stimulation of CAT and POX activity by NO has been reported earlier under salt stress (Sheokand *et al.,* 2008), heavy metal stress (Kumari *et al.,* 2010) and osmotic stress (Farooq *et al.,* 2009) .The APX activity also increased with short term and long term salinity stress. Short term salinity stress of 24 h resulted in 25 per cent increase of APX activity as compared to control plants while the increase was 61 per cent after 72 h of stress. With long-term salt treatments the increase in APX activity was maintained between 24 to 40 per

Table 3. Effect of salinity (6 dSm^{-1}) and NO donor (500 µM SNP) on catalase and peroxidase activity in chickpea leaves

Treatments	Catalase activity (units mg^{-1} proteins)				Peroxidase (units mg^{-1} proteins)			
	Short term salinity stress		Long term salinity stress		Short term salinity stress		Long term salinity stress	
	24h	72h	24h	72h	24h	72h	24h	72h
C	37.35	33.99	37.35	33.99	0.206	0.152	0.206	0.152
C+SNP	36.50	45.73	36.50	45.73	0.161	0.181	0.161	0.181
S	87.98	75.6	51.20	48.95	0.291	0.267	0.248	0.199
S+SNP	90.97	93.53	58.33	57.10	0.334	0.316	0.251	0.204
S+SNP+SCA	80.18	87.03	57.57	53.89	0.290	0.246	0.204	0.187
CD (p=0.05)	H-NS; T−6.965; HxT−9.850		H-NS; T−4.099; HxT−5.797		H-0.018; T−0.029; HxT−NS		H-0.017; T−0.027; HxT−0.038	

*H, hours after treatment; T, treatment; H×T, interaction of both hours and treatments

Table 4. Effect of salinity (6 dSm^{-1}) and NO donor (500 µM SNP) on ascorbate peroxidase and superoxide dismutase SOD activity in chickpea leaves

Treatments	APX (units mg^{-1} proteins)				SOD (units mg^{-1} proteins)			
	Short term salinity stress		Long term salinity stress		Short term salinity stress		Long term salinity stress	
	24h	72h	24h	72h	24h	72h	24h	72h
C	0.392	0.306	0.392	0.306	11.6	8.6	11.6	8.6
C+SNP	0.416	0.384	0.416	0.384	12.6	8.7	12.6	8.7
S	0.548	0.593	0.481	0.493	14.6	12.	18.1	13.3
S+SNP	0.717	0.726	0.529	0.549	22.2	12.2	18.8	15.8
S+SNP+SCA	0.525	0.589	0.384	0.438	10.4	11.1	14.9	11.0
CD (p=0.05)	H-NS; T−0.098; HxT−NS		H-NS; T−0.100; HxT−NS		H-1.327; T−2.099; HxT−2.968		H-1.566; T−2.467; HxT−NS	

* H, hours after treatment; T, treatment; H×T, interaction of both hours and treatments

cent (Table 4). Eyidogan and Oz (2007) suggested that the induction of APX activity in leaves of chickpea plants under salt stress may be modulated by the over production of H_2O_2 under CAT deactivation. However, in the present case CAT activity increased thus suggesting that increased levels of H_2O_2 under salt stress was inducing all H_2O_2 scavenging enzymes. Induction of APX and CAT activity under salt stress has been reported earlier *(Sheokand et al.,* 2008; Negi *et al*., 2015). SNP treatments had positive effect on APX, activity under salt stress. Exogenous NO alleviated the APX activity under drought stress (Farooq *et al*., 2009), heavy metal stress (Kumari *et al*., 2010; Sadeghipour, 2016) and salt stress (Sheokand *et al*., 2008, 2010). The effect of SNP also increased with the duration of treatments under both control and salinity treatments.

Glutathione reductase (GR) plays an essential role in defence against reactive oxygen metabolites under stress conditions. Additionally, over expression of GR increases antioxdant activity and improves tolerance to oxidative stress (Chawla *et al.,* 2013, Hamada *et al*., 2016). Salinity treatment of 24 and 72 h resulted in 49 to 82 per cent increase in GR activity while long term salinity caused only a 3 to 11 per cent increase in GR activity (Table 5). However the interaction between salinity and treatment found non-significant. Similarly increase in GR activity under salt stress has been observed by many workers in different plant species (Khan and Patra, 2007; Hamada *et al*., 2016). No significant changes in GR activity under salt stress has been reported by Hamada *et al*. (2016) in maize young leaves and Sheokand *et al.* (2008) in chickpea.

Sodium nitropursside treatments further increased the GR activity by 9 to 14 per cent with short term salinity stress and 37 to 18 per cent with long term salinity stress, after 24 and 72 h of application (Table 5). Increase in GR activity with exogenous NO treatment has been reported under water stress (Sang *et al*., 2008), salt stress (Sheokand *et al*., 2010), Cd stress (Kumari *et al*., 2010), high light stress (Xu *et al*., 2010) Pb stress (Sadeghipour, 2016). The DHAR activity exhibited a significant increase of 35 to 43 per cent after 24 and 72 h with short term salinity stress and an 11 to 26 per cent increase was observed with long term salinity stress (Table 5). DHAR contributes significantly in enhancing plant tolerance to oxidative stress, as in absence of sufficient DHAR activity; DHA undergoes irreversible hydrolysis to 2, 3−diketoglunic acid. DHAR allows the plant to recycle DHA; thereby capturing AsA before it is lost.

Sodium nitropursside treatments further increased the DHAR activity in salinity stressed as well as control plants. A 17 to 12 per cent increase was observed with short term salinity and 13 to 9 per cent increases with long term salinity stress (Table 5). Nitric oxide induced increase in DHAR activity has been reported under salt stress in wheat seedlings (Hasanuzzaman *et al.,* 2011) and chickpea leaves (Sheokand *et al.,* 2008).

Monodehydroascorbate reductase also plays an important role in maintaining reduced pool of AsA and ascorbate redox state. Recent studies showed that both MDHAR and DHAR are equally important in regulating AsA level and its redox state under oxidative stress condition (Wang *et al.,* 2010). Asignificant increase of 82 to 64 per cent was observed at 24 and 72 h with short term salinity stress. With long term salinity stress the activity increased by 76 to 109 per cent (Table 5). Sodium nitropursside treatments hada positive effect on MDHAR activity in the control as well in salinity treated plants. The effect, however, increased after 72 h and a 30 per cent increase was observed with short term salinity stress and a 10 per cent increase was observed with long term salinity stress Table 5. Hasanuzzaman *et al.* (2011) reported a NO induced increase in MDHAR activity in salt treated wheatseedlings.

Antioxidant metabolites: Ascorbic acid (AsA) is the most abundant antioxidant and maintains the cellular redox state

Table 5. Effect of salinity (6 dSm^{-1}) and NO donor (500 μM SNP) on Glutathione reductase (GR), DHAR and MDHAR activity in chickpea leaves

Treatments	GR (units mg^{-1} proteins)				DHAR (units mg^{-1} proteins)				MDHAR(units mg^{-1} proteins)			
	Short term salinity stress		Long term salinity stress		Short term salinity stress		Long term salinity stress		Short term salinity stress		Long term salinity stress	
	24h	72h	24h	72h	24h	72h	24h	72h	24h	72h	24h	72h
C	0.077	0.072	0.077	0.072	23.23	19.38	23.23	19.38	17.32	15.04	17.32	15.04
C+SNP	0.082	0.076	0.082	0.076	27.28	21.78	27.28	21.78	20.18	24.54	20.18	24.54
S	0.122	0.131	0.079	0.080	31.41	27.70	25.81	24.57	31.49	24.52	30.42	31.41
S+SNP	0.130	0.141	0.108	0.094	36.66	31.00	29.27	26.68	32.12	31.60	34.33	34.60
S+SNP+SCA	0.118	0.120	0.092	0.084	30.88	19.84	28.80	20.42	30.75	19.65	30.78	24.23
CD (p=0.05)	H−NS; T−0.014; HxT−NS		H−NS; T−0.016; HxT−NS		H−3.231; T−5.108; HxT−NS		H−2.533; T−4.005; HxT−NS		H−NS; T−1.218; HxT−1.722		H−NS; T−1.725; HxT−NS	

*H, hours after treatment; T, treatment; H×T, interaction of both hours and treatments and protects plant against oxidative damage resulting from a range of biotic and abiotic stress. A 27 to 29 per cent decrease in Asc redox ratio as compared to control plants was observed after 24 and 72 h of salinity stress while with long term salinity stress decline was 11 to 32 per cent (Table 7). The ratio decreased with the increase in duration of stress. Sodium nitropursside treatments increased the redox ratio (ASC/DHA) by 8 to 14 per cent with short term and 15 to 32 per cent increase with long term salinity stress (Table 7). Glutathione redox ratio (GSH/GSSG) also decreased with salinity stress. A 29 to 42 per cent reduction was observed with 24 and 72 h salinity stress. With long term salinity stress, it decreased up to 36 per cent as compared to control levels. Sodium nitropursside treatments in combination with salinity resulted in a time dependent increase in GSH/GSSG ratio. A 52 per cent increase was observed at 24 h, which further increased to approximately 2.3 fold after 72 h with short term salinity stress. Similar trend was observed with long term salinity stress (Table 1). Sheokand *et al.* (2010) and Hasanuzzman *et al*. (2011) also reported an increased GSH/GSSG ratio with exogenous application of NO in chickpea and wheat seedlings subjected to salt stress. An increase in GSH/GSSG ratio indicates a compensatory mechanism in which there is increased recycling of glutathione to keep it in its active reduced form. SNP treatments increased the ratio under normal conditions and partially alleviated the effect of salinity treatments. The fact that NO maintains the ASC and GSH content in reduced state under salt stress might be because of increased activities of enzymes GR, APX, DHAR and MDHAR. This results in the increased capacity of the antioxidant system to scavenge H_2O_2. The protective effect of NO on AsA content has been reported under salt stress (Sheokand *et al.,* 2010) and heavy metal stress (Kumari *et al.,* 2010).

Plant biomass: Exposure to high salinity can affect all the major plant processes, including photosynthesis, protein synthesis, energy and lipid metabolism (Parida and Das, 2005). Due to the adverse effects of salinity stress on plant growth the dry weight of different plant parts decreased significantly at maturity. A 47, 72, 24, 33, 35 and 61 per cent decrease in dry weight of root, nodules, stem, leaves, pod covering and seed was observed, respectively as compared to control plant with long-term salinity treatments and with short-term salinity a 46, 86, 13, 22, 49 per cent reduction in

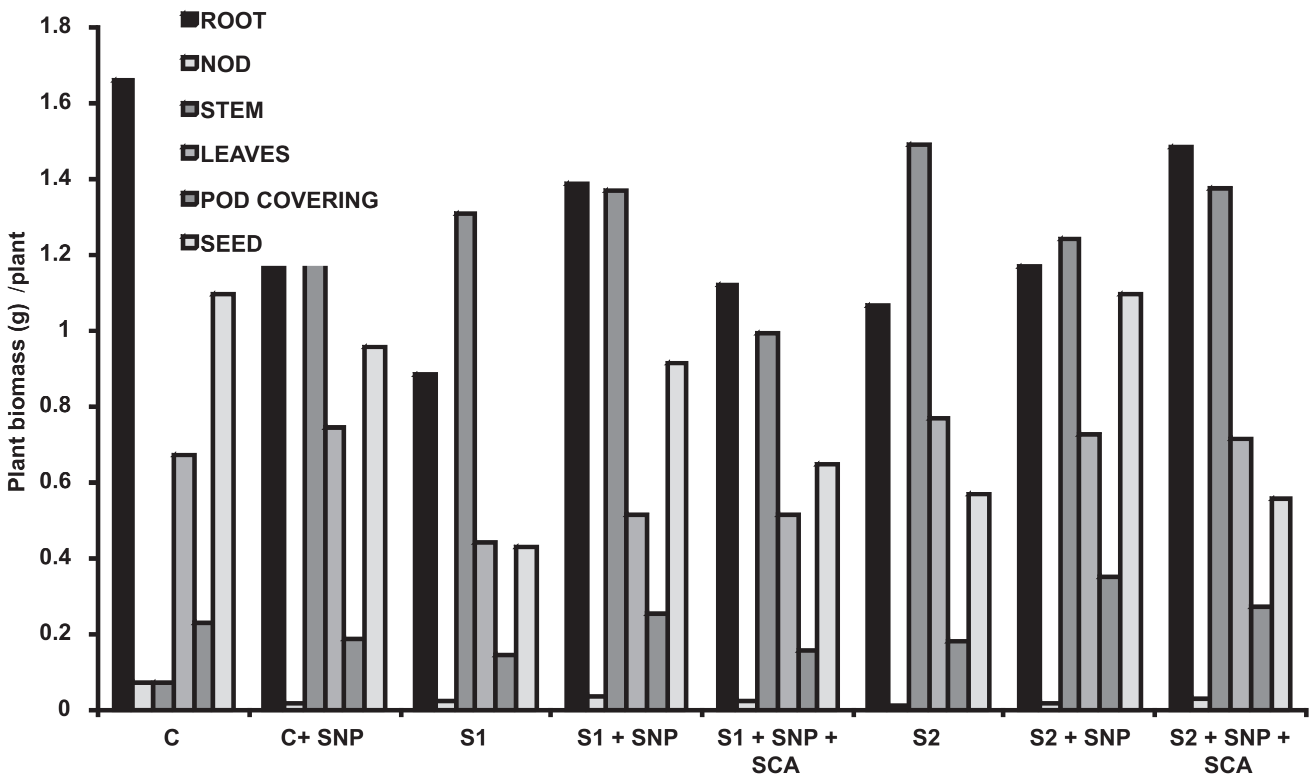

Fig. 1. Effect of salinity (6 dSm^{-1}) and NO donor (500 μM SNP) on the plant biomass (g) $plant^{-1}$ at maturity. (S1 = long term salinity stress, S2 = short term salinity stress)

Table 6. Effect of salinity (6 dSm^{-1}) and NO donor (SNP, 500 μM) on ascorbate redox ratio (ASC/DHA) and glutathione redox ratio (GSH/GSSG) in chickpea leaves

Treatments	Short term salinity stress				Long term salinity stress			
	24h		72h		24h		72h	
	ASC/DHA	GSH/GSSG	ASC/DHA	GSH/GSSG	ASC/DHA	GSH/GSSG	ASC/DHA	GSH/GSSG
C	4.70	2.97	4.49	3.30	4.70	2.97	4.49	3.30
C+SNP	3.82	3.41	5.13	4.79	3.82	3.41	5.13	4.79
S	3.44	2.11	3.17	1.93	4.18	2.65	3.08	2.11
S+SNP	3.71	3.21	3.53	4.47	4.80	3.41	4.08	4.22
S+SNP+SCA	3.58	2.66	2.68	2.09	4.28	3.07	3.02	3.36

dry weight of root, nodules, stem, pod covering and seed was observed, respectively (Fig.1). Li (2008) have reported a 73 per cent reduction in dry weight of seedlings of *Limonium bicolor* with 200 m mol/l NaCl salt stress treatment. Alam*et al.* (2007) have also observed a decrease in dry weight purslane plants when exposed to NaCl stress.

SNP treatments had a positive effect on plant biomass in salinity treated plants (Fig.1). A significant increase in seed yield was observed with SNP treatments as compared to salt stressed plants and about 2-fold increase with long term and short-term stress was observed. Shi *et al.* (2007) have also reported an increase in dry weight of both root and shoot with SNP treatment under salt stress. In all parameters studied above, the positive effects of SNP were confirmed by c-PTIO as it is a scavenger of NO.

CONCLUSION

Based on above studies short term salinity stress resulted in a greater increase in MI, MDA, ROS, H_2O_2 content as compared to long term salinity stress. It also activated the antioxidant defense system more pronouncedly, thus resulting in a lesser oxidative stress and a smaller decline in plant yield. However long term salinity stress had a lesser effect on antioxidant defense system, thus leading to a higher oxidative stress and ultimately a higher decline inplant yield. Sodium nitroprusside treatments were effective in reducing salinity stress induced membrane injury, ROS content and further activating the antioxidant defense system.B esides this SNP treatment also had a positive effect on plant biomass and seed yield which could be attributed to the fact that NO acts as a growth regulator. Thus the protective role of NO is based on its antioxidative and growth regulator effect under salinity stress.

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Yield and Nutrient Uptake of Potato as Influenced by Different Weed Management Approaches

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Abstract: Field experiment was established to evaluate the effect of different weed management on weed dynamics, yield and nutrient uptake of potato. The hand weeding plot recorded minimum weed population and biomass followed by paraquat dichloride @ 2.0kg a.i./ha. Potato tuber yield was maximum in weed free which was significantly higher than the others treatment for both the year. The next best result obtained in hand weeding (32.75 t ha^{-1}) which was statistically at par with oxyfluorfen @ 200 g a.i. ha^{-1} (31.77 t ha^{-1}). All other treatments resulted in significantly lower yield than hand weeding and weed free. The maximum N, P, K uptake by potato and the minimum uptake by weeds emerged in the potato field under hand weeding at 20 days after planting which was closely followed by paraquat dichloride @ 1 and 2.00 kg a.i. ha^{-1}.

Keywords: Weed, Herbicides, Yield, Nutrient uptake, Potato

Potato (*Solanum tuberosum* L.) is one of the most important crops and it emerged as a fourth most important food crop in the world after rice, wheat and maize (Jaipaul *et al*., 2011). There are several constraints in potato production, of which weeds often pose a serious problem. Even though potato plants have robust growing and quick spreading nature but it turns as a weak competitor with weeds (Mukherjee *et al*., 2012). Uncontrolled weed growth reduces the tuber yield of the tune of 55.7 per cent depending on types of weed flora, their intensity and duration of crop-weed competition (Yadav and Kumar, 2011). The quality of produce is also reduced by weed infestation. Though manual weeding is quite effective, but it is time consuming, costly, tedious and because of shallow root system in potato, may cause root injury and disturbs root system in the later stage of crop growth (Yadav *et al*., 2015). Hand weeding is expensive, time consuming, difficult and often limited by scarcity of laborers in time. On the other hand, herbicides offer economic and efficient weed control if applied at proper dose and stage (Poddar *et al*., 2014). Under such circumstances, chemical weed control becomes the best alternative solution. In order to control the weed, there is a need for selection of new molecules of herbicides to achieve the optimum level of production. However, continuous screening of other molecules is essential to avoid the development of resistance in weed species against one or two most commonly used herbicides for effective control of weeds in the long run (Kumar *et al*., 2009). However, continuous use of chemicals drastically reduces the soil fertility along with reduction in productivity and residual problem. This necessitates the introduction of some other new herbicide options with different modes of action. Considering all these views, the present investigation was undertaken to find out the occurrence of major weed flora in potato cultivation, the effect of different weed control measures on weed management, yield of potato and the uptake of different nutrients by the potato crop and weeds.

MATERIAL AND METHODS

The experiment was conducted at Chandamari, Kalyani, Nadia, West Bengal (latitude: 22˚57'E, longitude: 88˚20'N and altitude: 9.75 m). The crop was planted on November 21 and 11 during 2012 and 2013, respectively. There were eight treatments replicated thrice with plot size of 5m x 4m. The soil of the experimental field was typically of Gangetic alluvium (Entisol) type with sandy clay loam in texture (sand-52.8%, silt-23.5% and clay-23.7%) having good water holding capacity and moderate soil fertility status with neutral soil pH (6.82). Spraying was done with knapsack sprayer with flood jet deflector WFN-040 nozzle with 500 litre of water ha^{-1}. The variety used in this experiment was *Kufri* Chandramukhi. Potato was sown with the fertilizer dose @ 150:100:150 kg ha^{-1} of N, P_2O_5 and K_2O. A uniform basal dose of nitrogen @ 75 kg ha^{-1} through urea along with full phosphorus through single super phosphate and full potash through Muriate of Potash, were applied as basal during final land preparation. The remaining nitrogen was top dressed at 30 DAP after earthing up operation. One day before transplanting, the tubers were treated by using *Trichoderma viridis* @ 4 g kg^{-1} of potato tubers. The treated tubers were kept under shade for overnight before transplanting in the main field. Excluding the weed management practice all the recommended improved package of practices of potato was followed in this experiment including the plant protection measures. The population and dry weights of dominant weeds were recorded at 50 DAA. For recording both density and dry weight of the weed flora, 50 cm x 50 cm quadrate was placed thrice per plot for evaluating the relative efficacy of the test products and the data were presented on m^{-2} basis. The labeled samples were then sun dried for 24 hours and then oven dried at 70°C for 72 hours. The dry weight of weeds was then taken and recorded separately. Tuber yield and grading of potato was recorded at the time of harvest. Weed control efficiency (WCE) and weed index (WI) as suggested by Gill and Vijay Kumar (1969) were calculated by the following formula:

Weed Control Efficiency (WCE):

$$\text{WCE} = \frac{\text{Dry matter of weeds in control plot} - \text{Dry weight of weeds in treated plot}}{\text{Dry matter of weeds in control plot}} \times 100$$

Weed Index (WI):

$$\text{WI} = \frac{\text{Crop yield in weed free plot} - \text{Crop yield in treated plot}}{\text{Crop yield in weed free plot}} \times 100$$

The weed dry biomass and density datawere further used to compute the weed and crop efficiency indices (Misra and Misra 1997).

Weed persistence index (WPI):

$$\frac{\text{Dry matter of weeds in treated plot}}{\text{Dry matter of weeds in control plot}} \times \frac{\text{Weeds population in control plot}}{\text{Weeds population in treated plot}}$$

Weed management index (WMI):

$$\text{WMI} = \frac{\text{Per cent yield over control}}{\text{Per cent control of weeds}}$$

At maturity, potato tuber samples were collected from each plot, oven dried at 70°C to constant weight and ground to pass through a 0.5mm sieve for chemical analysis. The nitrogen (N) content was deter-mined by the semi-micro Kjeldahl method [AOAC 1995, method No. Ba 4b-87(90)], after the plant tissues (0.2 g) were oxidized and decomposed by concentrate sulphuric acid (10ml) with digestion mixture (K_2SO_4 : Cu-SO4 = 5:1) heated at 400°C temperature for two and half hours. Phosphorus and Potassium contents were determined by the Vanado-Molybdate yellow method and flame pho-tometry (Jackson, 1973) respectively.

RESULTS AND DISCUSSION

Weed species and infestations: Among the broadleaf weed *Gnaphalium luteoalbum* ranked first, where as *Echinochloa colona, Cynodon dactylon* and *Cyperus rotundus* was the major grass and sedge weed. In the controlled plot, the percentage of occurrence of different categories of weeds (Fig. 1) showed that *Gnaphalium luteoalbum* occurrence was 24 per cent whereas *Chenopodium album* (13.47%) and *Cyperus rotandus* (11.54%) ranked second and third respectively.

Weed density and biomass: Weed density was significantly influenced by different weed management practices (Table 1). The highest weed density 194.17 m^{-2} at 50 DAA was recorded in weedy check plot for both the year which was significantly higher over rest of the treatment. The weed density in higher doses of Paraquat dichloride 24% SL @ 1000 and 2000 g a.i. ha^{-1} were also found statistically different among them self. Weed density at Paraquat dichloride 24% SL @ 1000 g a.i. ha^{-1} and Oxyfluorfen 23.5% EC @ 200 g a.i. ha^{-1} were statistically identical. The lowest weed density (24.33 m^{-2} at 50 DAA) was recorded from the plots where hand weeding were done at 20 DAP in both the years and it was significantly lower than all the herbicide spraying treatments. Suresh and Reddy (2010) also found that weedy check treatment recorded the highest weed densityduring both the year of investigation.

The highest weed biomass of 88.80 g m^{-2} at 50 DAA were in weedy check (Table 1). Weed biomass in general has direct relationship withweed densities. Hence, the highest weed dry weight was recorded under weedy check treatment followed by other weed management practices (Kumar *et al*., 2010). The lowest weed biomass 14.63 g m^{-2} at 50 DAA were recorded from hand weeding and it was significantly lower from all others treatments. Weed biomass were found statistically at par where herbicides of Paraquat dichloride 24% SL @ 1000 g a.i. ha^{-1} and Oxyfluorfen 23.5% EC @ 200 g a.i./ha were applied.

Weed control efficiency, weed index and other indices in weed management: The weed control efficiency at 50 DAA among the weed management practices due to different herbicides ranged from 68.87 to 100 per cent. The herbicidal control efficiency was comparable with the hand weeding. The highest weed control efficiency was in weed free plots followed by hand weeding (83.55% at 50 DAA). Applications of herbicides effectively control weeds in which paraquat dichloride @ 2000 g a.i. ha^{-1} results best (77.33% at 50 DAA). These findings are in agreement with the previous work of Hashim *et al.* (2003) who observed that weed biomass decreases due to herbicidal application in potato crop. Weed index as a measure of weed management revealed that highest weed index was in weedy check for both the year and lowest in hand weeding plot (Fig. 2). Weed persistence index were highest in hand weeding plot followed by 2,4-D Amine Salt 58% SL @ 2000 g a.i. ha^{-1} (Fig. 3) where as weed

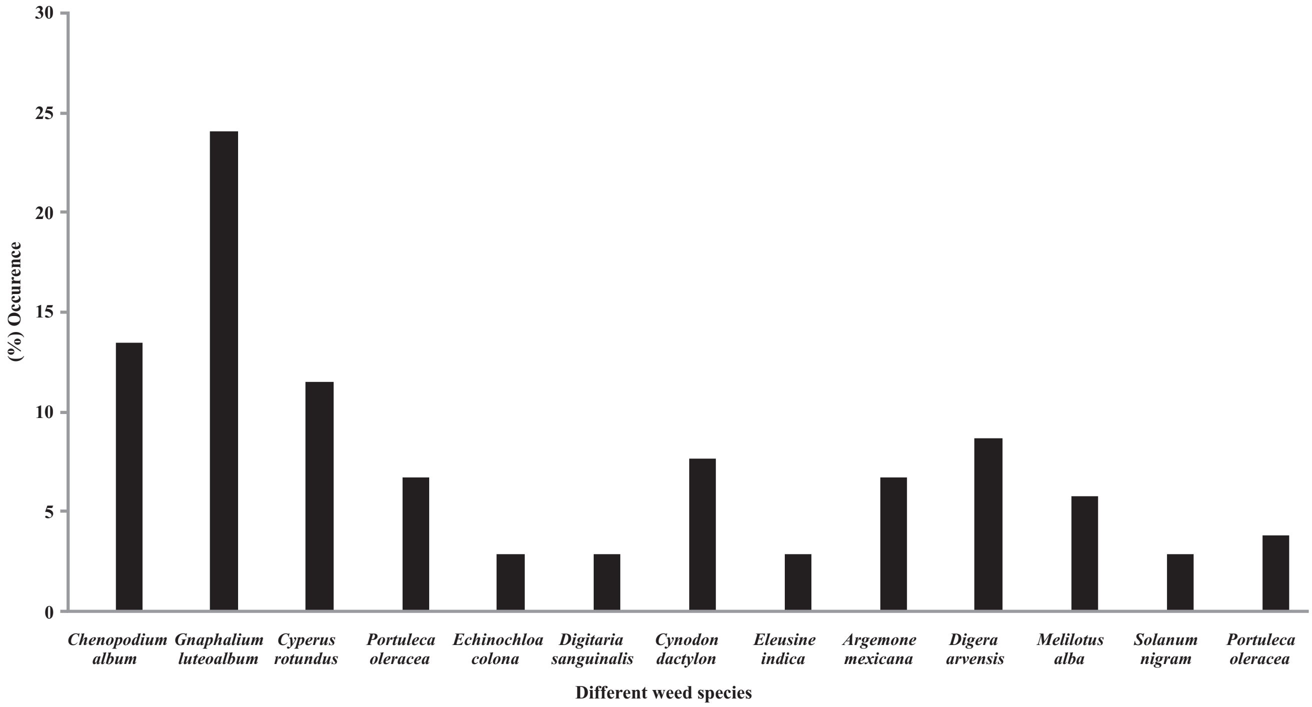

Fig. 1. Occurrence of different categories of weed m^{-2} in control plot

Table 1. Weed density, weed biomass, WCE, growth parameter and tuber yield as influenced by different weed management (Pooled data)

Treatment	Weed density (No. m^{-2})	Weed Biomass (g m^{-2})	Weed control efficiency (%)	Leaves plant^{-1} (Nos.)	Fresh leaves biomass plant^{-1} (g)	Tuber yield (t ha^{-1})
	50 DAA	50 DAA	50 DAA			
T_1	194.17 (13.95)	88.80	0.00	18.00	37.33	19.42
T_2	81.00 (9.03)	27.63	68.91	25.00	53.70	26.05
T_3	77.67 (8.84)	24.33	72.62	26.83	58.10	30.56
T_4	58.50 (7.68)	20.13	77.33	27.83	67.07	30.89
T_5	67.17 (8.22)	27.40	69.19	24.83	57.18	27.08
T_6	82.33 (9.09)	27.62	68.87	26.33	58.60	31.77
T_7	24.33 (4.98)	14.63	83.55	31.17	71.55	32.75
T_8	0.00 (0.71)	0.00	100.00	36.17	92.44	34.99
CD (p=0.05)	5.06	2.49	–	1.647	3.75	1.02

T_1–Weedy check, T_2–Paraquat dichloride 24% SL @ 500 g a.i./ha, T_3–Paraquat dichloride 24% SL @ 1000 g a.i./ha, T_4–Paraquat dichloride 24% SL @ 2000 g a.i./ha, T_5–2,4–D Amine Salt 58% SL@ 2000 g a.i./ha, T_6–Oxyfluorfen 23.5% EC @ 200 g a.i./ha, T_7–Hand weeding at 20 DAP, T_8–Weed free plot.

*Figures in the parenthesis are square root transformed value $\sqrt{(x+1)}$.

management index ware found highest in the plot of Oxyfluorfen 23.5% EC @ 200 g a.i. ha^{-1} followed by weed free plot for both the year (Fig. 4). This variation may be due to differences in weed density and biomass accumulation in different treatment.

Crop growth and tuber yield: Differences among the treatments for number of leaves/plant were found statistically significant during both the years. Maximum number of leaves (36.17 plant^{-1}) were noted in plots with weed free which were statistically higher thanall others treatments. Hand weeded plots also enhanced plant growth by producing 31.17 leaves plant^{-1} as compared to 18.00 leaves plant^{-1} counted in un–weeded plots throughout growing season. In herbicidal treated plot maximum number of leaves were found in the plot where paraquat dichloride @ 2000 g a.i. ha^{-1} was applied in both the year though it was statistically at par with its lower dose paraquat dichloride @ 1000 g a.i. ha^{-1}. Since lowest number of leaves produced in plots with weedy check,

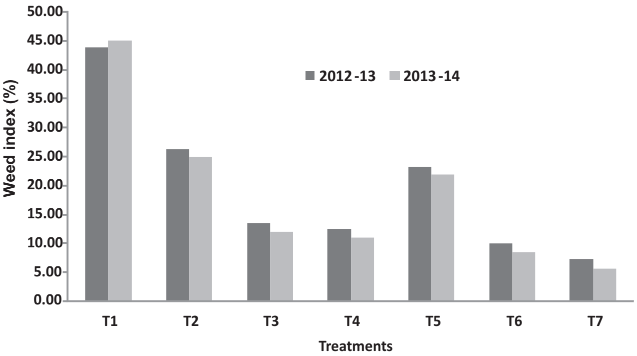

Fig. 2. Weed Index (%) as influenced by different weed management

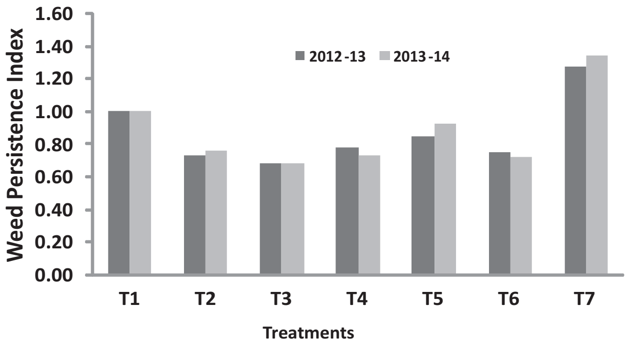

Fig. 3. Weed Persistence Index as influenced by different weed management

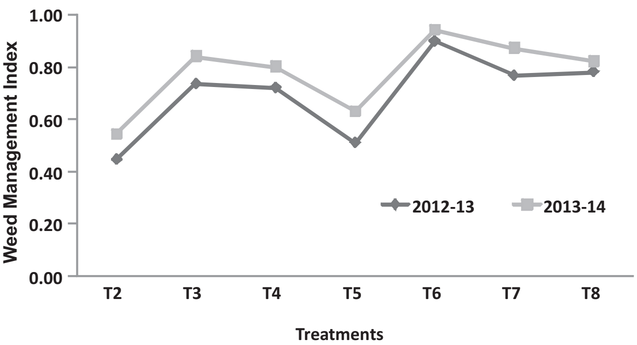

Fig. 4. Weed Management Index as influenced by different weed management

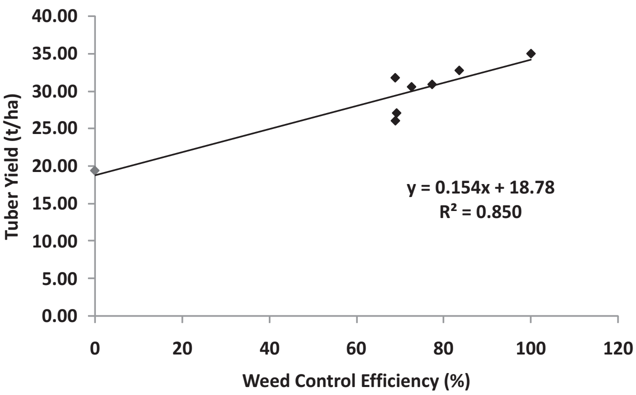

Fig. 5. Regression curve fitting between WCE and tuber yield

Table 2. Nutrient uptake by potato and weeds as influenced by different weed management (pooled data)

Treatment	Nutrient uptake by potato			Nutrient uptake by weed		
	N	P	K	N	P	K
T_1	53.24	7.21	62.14	70.66	18.50	31.79
T_2	65.49	20.54	76.41	40.02	10.44	19.90
T_3	70.69	22.30	86.11	35.37	9.07	16.74
T_4	77.50	24.05	95.16	30.04	6.82	13.26
T_5	72.93	20.73	75.98	33.44	8.36	17.90
T_6	79.05	21.31	94.16	29.74	7.81	13.44
T_7	84.19	21.62	108.42	22.01	6.21	10.23
T_8	98.89	26.74	125.54	0.00	0.00	0.00
CD (p=0.05)	2.51	1.63	3.05	1.83	0.31	0.71

See table 1 for treatment details

thefresh leaves biomass was also minimum in that plot. Weedy check plots resulted in only 37.33 g of leaves biomass which was significantly lower than the biomass produced in all other weed control treatments (Table 1). While maximum leaves biomass was recorded in plots with weed free (92.44 g plant^{-1}), which was statistically higher than all other treatments. The rest of the herbicide treated plots resulted in more or less similar leaves biomass though plots with herbicide Paraquat dichloride 24% SL @ 2000 g a.i. ha^{-1} resulted higher among them. Higher number of leaves and dry biomass in herbicide treated plots might be the result of their phytotoxicity on weeds (Khan *et al*., 2009). Hashim *et al.* (2003) who observed that as weed bio-mass decreases potato plant growth.

During both the year the differences among the treatments for marketable yield were significant statistically. The highest tuber yield was recorded in weed free plots (34.99 t ha^{-1}) followed by hand weeding plots (32.75 t ha^{-1}). Plots sprayed with Oxyfluorfen 23.5% EC @ 200 g a.i. ha^{-1} resulted in higher tuber yield (31.77 t ha^{-1}) among the herbicidal treated plots though it was statistically at par with paraquat dichloride @ 2000 g a.i. ha^{-1} and its lower dose i.e. 1000 g a.i. ha^{-1}. Averaged over the years, weed condition resulted in 46.04 per cent reduction in tuber yield. Allowing the weeds to grow for a full crop season significantly reduced the tuber yield to 19.42 t ha^{-1}. There was a huge percent increase in tuber yield over control ranges from 34.14 to 80.18 (Table1). Tuber yield was less when the weeds were allowed to compete with the crop throughout the crop periodin the weedy check plots but the yield increased identically when the weeds were controlled either by herbicides or hand weeding. The relationship between WCE and tuber yield is presented in Fig. 5 clearly indicated that higher WCE will result in higher tuber yield. Differences in

Table 3. Correlation matrix between weed parameter, different growth, yield parameter of potato and nutrient uptake of weed and potato as influenced by different weed management

	Weed density	Weed biomass (g)	WCE (%)	Potato leaves (Nos.)	Fresh leaves biomass (g)	Tuber yield (t ha^{-1})	N uptake by potato (kg ha^{-1})	Puptake by potato (kg ha^{-1})	K uptake by potato (kg ha^{-1})	N uptake by weed (kg ha^{-1})	P uptake by weed (kg ha^{-1})	K uptake by weed (kg ha^{-1})
Weed density	1											
Weed biomass (g)	.98**	1										
WCE (%)	-.98**	-1.00**	1									
Potatoleaves (Nos.)	-.95**	-.91**	.91**	1								
Fresh leaves biomass (g)	-.92**	-.86**	.86**	.99**	1							
Tuber yield (t ha^{-1})	-.91**	-.92**	.92**	.93**	.89**	1						
N uptake by potato (kg ha^{-1})	-.91**	-.86**	.86**	.97**	.97**	.93**	1					
P uptake by potato (kg ha^{-1})	-.94**	-.98**	.98**	.86**	.83*	.91**	.83*	1				
K uptake by potato (kg ha^{-1})	-.87**	-.81*	.81*	.97**	.96**	.92**	.97**	.77*	1			
N uptake by weed (kg ha^{-1})	.97**	.94**	-.94*	-.97**	-.97**	-.94**	-.98**	-.92**	-.93**	1		
P uptake by weed (kg ha^{-1})	.96**	.95**	-.95*	-.97**	-.96**	-.94**	-.97**	-.93**	-.92**	1.00**	1	
K uptake by weed (kg ha^{-1})	.94**	.92**	-.92*	-.98**	-.98**	-.95**	-.99**	-.89**	-.96**	.99**	.99**	1

* and ** denotes significant correlation at 5% and 1% level of significance, respectively

tuber yield due to different weed control measure were also reported by Yadav *et al*. (2015).

Nutrient uptake by potato and weeds: The removal of NPK (kg ha^{-1}) by weeds 70.66, 18.50 and 31.79 was maximum in unweeded check. The lowest removal wasin hand weeding (NPK–22.01, 6.21 and 10.23 kg /ha). Unweeded check was significantly superior to all other treatments in nutrients removed by weeds. Among the different herbicidal weed control methods, application of oxyfluorfen @ 200 g a.i. ha^{-1} was recorded significantly lowest nutrient uptake (N, P and K) by weeds than all other treatments but it was statistically at par with paraquat dichloride @ 2000 g a.i. ha^{-1}. This was mainly due to decreased weed population and weed dry weight when compared to other treatments. All other weed control methods were at par with each other.

All the weed control treatments registered a significant improvement in the uptake of nutrients by potato as compared to unweeded check (Table 2). The maximum nutrient uptake was noticed in weed free check (NPK−98.89, 26.74 and 125.54 kg ha^{-1}) which was closely followed by hand weeding. Among the different herbicides sprayed plot Oxyfluorfen 23.5% EC @ 200 g a.i. ha^{-1} and Paraquat dichloride 24% SL @ 2000 g a.i. ha^{-1} uptook more nutrient and they were statistically at par with each other. Others treatments resulted statistically similar result and this might be due to the higher efficiency of these treatments in suppressing the weeds, which ultimately resulted in reduced competition from weeds for nutrients. The increased uptake of major nutrients is primarily responsible for improved growth characters and yield attributes culminating into increased yield (Krishnamurthy *et al.*, 2011).

Correlation matrix: Weed density recorded significantly positive correlation with weed biomass (r=0.98), N uptake by weed (r=0.97), P uptake by weed (r=0.96) and K uptake by weeds (r=0.94) whereas it showed highly negative correlation with weed control efficiency (r= -0.98), number of potato leaves (r= -0.98), fresh leaves biomass (r= -0.95), tuber yield (r= -0.91) and nutrient uptake (N, P and K) by potato plant (Table 3). Weed biomass had almost negative correlation with all character like WCE (r= -1.00), no. of potato leaves (r= -0.91), fresh leaves biomass (r= -0.86), tuber yield (r= -0.92) and nutrient uptake (N, P and K) by potato plant where as positive correlation was noticed with nutrient uptake by weeds like N uptake by weed (r=0.94), P uptake by weed (r=0.95) and K uptake by weeds (r=0.92). Weed control efficiency showed highly positive correlation with all variables except nutrient uptake by weeds. Similarly all others variable like no. of potato leaves, fresh leaves biomass, tuber yield, and nutrient uptake (N, P and K) by potato plant showed positive correlation among themselves but when nutrient uptake by weed comes in consideration it showed negative correlation. N uptake by weed had a positive correlation with P uptake by weed (r=1.00) and K uptake by weeds (r=0.99), whereas, P uptake by weed had a positive correlation with K uptake by weed (r=0.99). Correlation matrix varies due to different variable in weed management experiment also reported by Srivastava *et al*. (2005).

The findings of the present research reveal that weed management practices improved the growth and yield of potato as compared to weedy check. In weedy check plots, there was an intense competition between crop plants and weeds for soil and climatic resources. Overall, the tuber yield was higher in Paraquat dichloride 24% SL @ 1000 g a.i. ha^{-1} or Oxyfluorfen 23.5% EC @ 200 g a.i. ha^{-1} than conventional hand weeding. Therefore, it can be concluded that the use of herbicides namely Paraquat dichloride 24% SL @ 2000 g a.i. ha^{-1} or Oxyfluorfen 23.5% EC @ 200 g a.i. ha^{-1} also offers a good alternative in case of skilled labour scarcity for potato production.

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Physico-Chemical and Biological Characteristics of Mountainous Streams Under Different Land Uses of Mid Hills of Himachal Pradesh

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Abstract: Studies on surface water of Darlaghat region (district Solan) of mid hills of Himachal Pradesh for seasonal variation (rainy, winter and summer) in quality parameters, impact of different land uses (urban, forest and agriculture) on quality of water, diversity of aquatic insect fauna and faecal contamination in water were conducted during the year 2011-2012. Highest BOD (1.53 mg l^{-1}) and COD (18.89 mg l^{-1}) were observed under urban landuse during summer and rainy season, respectively. Highest Ca, Mg and Cl− content was under urban landuse, whereas, NO3−content (4.92 mg l^{-1}) was statistically higher for agriculture). A total of 461 aquatic insects/m^2 belonging to 5 insect orders and 10 families were recorded, the maximum numbers were recorded under forest land use (164/m^2) and during summer season (187 m^{-2}). Maximum numbers (11 m^{-2}) belonged to the family Heptageniidae (Ephemeroptera). EPT index was maximum under forest land use (109), maximum *E.coli* count in surface water was under urban land use and during rainy season. All the quality parameters except calcium were within the permissible limits, density of total coliform bacteria and total coliform count were above permissible level.

Keywords: Land use, Water quality monitoring, Aquatic insects, Biotic indices

Water pollution is a major global problem limiting the amount of fresh water available for human use. The quality of any body of surface or ground water is a function of either or both natural influences and human activities (Sharma and Choudhary, 2016). Pollutants, trace metals and nutrients discharged through the sewage and industrial effluents into water bodies brings change in the physic− chemical characteristics of water (Zutshi *et al.,* 2015). Addition of organic matter, land surface washing, industrial and sewage effluent, anthropogenic modification of land cover such as agriculture, afforestation, mining, urbanization, industrialization and intervention on hydrological regimes like irrigation and damming has resulted in marked changes in water quality. The effluents from the industries are directly moving into water bodies. The physico-chemical characteristics of an aquatic body reflects the type and diversity of aquatic biota as well as the water quality (Mir *et al*., 2004). Anthropogenic sediment in fresh water, which is the by product of several activities increases the drift fauna, decreases benthic densities and alters community structures. Physico-chemical parameters of water play important role in maintaining the fragile ecosystem that maintain various life forms, therefore, monitoring quality parameters of water is essential. Therefore, the present study was undertaken with the objective to assess seasonal variation in surface water quality under different land use patterns and record aquatic insect fauna in surface water under different land-use patterns.

MATERIAL AND METHODS

The study area falls under Kunihar block of Solan district of Himachal Pradesh. Himachal Pradesh situated between North latitude of 30° 22' 40" to 33° 12' 40" and East longitude of 75° 45' 55" to 79° 04' 20" is wholly mountainous with altitude ranging from 350 to 6975 meter above mean sea level, average total annual rainfall 1459 mm and temperature ranging from freezing to 42°C. In the state, agriculture, forest and urban areas are the dominant land use systems. For collection of water samples and aquatic insects micro-level hydrological survey was conducted and the water sources under different land uses i.e. urban/sub urban, forest and agriculture were identified and inventorized. Water samples were collected in glass bottles under different land uses during (rainy, winter and summer season) from different locations in three replications and analyzed for physical, chemical and biological characteristics. The samples were stored in the refrigerator at 4°C for further analysis.

Physico-chemical Parameters: The various physico− chemical parameters like temperature , pH, EC TDS, BOD, COD Ca, Mg, Cl^- and $NO3^-$ were analyzed using the standard methods (APHA, 2005).

Aquatic insects: Aquatic insects collected according to the method of Subramanian and Sivaramakrishnan (2007), preserved, cleared and mounted in Hoyer's medium (Baker and Wharton 1952). Aquatic insects were identified up to family level by using the keys of different workers (Brues *et* *al*., 1954; Pescador *et al*., 1995; Pfeiffer *et al*., 2008). Simpson's Diversity Index (Kirsch, 1999; Mandaville,1999), Family Biotic index (Hilsenhoff,1977) EPT index (NCDEHNR,1997) and EPT biotic index were calculated. Isolation of *E. coli* was carried out as per the method of Kanwar *et al*. (1997). The microbiological quality was determined by standard most probable number (MPN) method.

RESULTS AND DISCUSSION

The average mean values of pH ranged from 6.59 to 7.53 under different landuses. The average mean values of EC, irrespective, of season were also statistically high for urban land use (370.83 dS m^{-1}) followed by agriculture (373.87 dS m^{-1}) and in summer season (346.98 dS m^{-1}) followed by rainy season. The mean average values for TDS were also statistically highest for urban (301.81mg l^{-1}) followed by agriculture land use. The seasons differed statistically from each other in TDS, maximum being during rainy season (292.79) (Table 1). Turbidity was maximum in urban (7.56 NTU) and lowest for land use, highest being during rainy season (6.20 NTU). Statistically, highest pH, EC and TDS values during summer season may be due to urban runoff, discharge of sewage and dumping of waste which increases the soluble inorganic substances in the water and decreased volume of water by evaporation and higher atmospheric temperature leading to increased concentration of ions in the water body (Nkwocha *et al.,* 2011). Gupta and Singh (2000) also reported high concentration of TDS in the Damodar river due to mixing of sewage and industrial water. Higher concentration of suspended load coming through anthropogenic activities leads to high turbidity (Mathur *et al.,* 2008). Maximum turbidity under urban land use during rainy season has been reported by Utang and Akpan (2012) due to the discharge of surface runoff filled with organic matter and other effluents with high suspended matter content into the river. Statistically highest BOD (1.53 mg l^{-1}) and COD (18.89 mg l^{-1}) were observed under urban followed by agriculture landuse. Maximum BOD was under summer season (1.33 mg l^{-1}) followed by rainy and winter season, whereas, COD was highest during rainy season (17.47mg l^{-1}) but statistically similar to summer season (Table 1). High values of BOD and COD under urban land use may be due to enrichment of organic waste, domestic waste, soaps and detergents which lead to low oxygen concentration and addition of effluents containing oxidizable organic matter and consequent biodegradation and decay of vegetation at higher temperature leading to consumption of oxygen from water (Chauhan and Thakor, 2012; Mathur *et al.,* 2008). Low O_2 concentrations were associated with heavy contamination of organic matter. Raveen *et al*. (2008) also recorded maximum BOD under urban land use. Decrease in BOD during winter season may be due to higher solubility of oxygen at lower temperature which resulted in low BOD. Significantly maximum Ca (85.71mg l^{-1}), Mg (7.50 mg l^{-1}) and Cl (5.63 mg l^{-1}) were under urban landuse followed by agriculture and forest landuse. Whereas, NO3− content was statistically highest for agriculture (4.92 mg l^{-1}) followed by urbanand forest. Statistically, highest Ca (72.54 mg l^{-1}) content, Mg (6.35 mg l^{-1}) and Cl (4.44) were in summer season, whereas, NO3−statistically highest in rainy season (4.28 mg l^{-1}) (Table 1). Highest calcium and magnesium content observed during summer season may be due to water loss by evaporation which increases the concentration of calcium ions and Mg2+ besides urban runoff, and sewage disposal waste (Gupta and Paliwal, 2010). Higher chloride content under urban land use may be due to city sewage and domestic waste, man and animal excreta, which contain higher quantity of chloride. Maximum chloride during summer season may be due to high organic waste of animal origin.

Impact of land uses on aquatic insects of surface water during different seasons: A total of 461 aquatic insects m^{-2} belonging to 5 orders and 10 families were recorded in surface water of Darlaghat region during study period (Table 2). Maximum numbers were recorded under forest (164 m^{-2}) and during summer season (187 m^{-2}) and minimum under agriculture (153 m^{-2}) and during rainy season (121 m^{-2}). Variable number of aquatic insects belonging to orders Ephemeroptera, Trichoptera, Plecoptera, Coleoptera and Odonata are reported in Behta river of Ponta Sahib in Himachal Pradesh (Sharma *et al.,* 2006). Maximum numbers (11 m^{-2}) belonged to the family Heptageniidae of order Ephemeroptera in summer season.

Maximum numbers were recorded during summer season (187 m^{-2}) and minimum during rainy season. EPT index was maximum under forest land use (109) followed by agriculture land use which could be due to clean environment under forest land use (Table 3). Lowest EPT index during rainy season may be due to high loads of organic and inorganic suspended materials and sewage disposal which lead to environmental stress. Members of EPT were reported to be sensitive to environmental stress (Gupta *et al.,* 2014). EPT biotic index for urban, forest and agriculture land use indicated good water quality.

Family biotic index: Family biotic index (FBI) of aquatic insects of surface water under urban land use was 4.12 followed by forest land use and agriculture land use. Highest FBI was recorded during rainy season followed by summer and winter season. The surface water at both the locations was rated as good during different seasons and land uses.

Table 1. Physico-chemical properties of surface water samples from Darlaghat region of mid hills.

Landuses	Season					Season					
	Rainy	winter	Summer	Mean	CD (p = 0.05)		Rainy	winter	Summer	Mean	CD (p = 0.05)
pH						BOD (mg l^{-1})					
Urban/Sub-urban	7.64	7.37	7.59	7.53	Land use=0.02 Season=0.02 land use X Season=0.04	Urban/Sub-urban	1.4	0.78	2.40	1.53	Land use=0.32 Season=0.32 land use x Season=0.55
Forest	6.36	6.86	6.56	6.59		Forest	0.43	0.29	0.80	0.51	
Agriculture	7.46	7.26	7.45	7.39		Agriculture	0.59	0.52	0.80	0.64	
Mean	7.15	7.16	7.20			Mean	0.81	0.53	1.33		
EC (dS/m)						COD (mg l^{-1})					
Urban /Sub-urban	412.63	233.47	466.40	370.83	Land use=0.91 Season=0.91 land use x Season=1.57	Urban /Sub-urban	19.53	17.60	19.53	18.89	Land use=0.35 Season=0.35 land use x Season=0.61
Forest	246.53	302.63	262.70	270.62		Forest	15.50	12.57	15.50	14.52	
Agriculture	367.5	322.27	311.83	333.87		Agriculture	17.37	16.33	17.30	17.00	
Mean	342.22	286.12	346.98			Mean	17.47	15.50	17.43		
TDS (mg l^{-1})						Ca (mg l^{-1})					
Urban /Sub-urban	345.90	268.90	290.63	301.81	Land use=0.94 Season=0.94 land use x Season=1.6	Urban/ Sub-urban	86.40	82.47	88.26	85.71	Land use=0.21 Season=0.21 land use x Season=0.36
Forest	236.07	187.23	212.90	212.07		Forest	44.47	43.87	58.20	48.86	
Agriculture	296.40	213.20	243.60	251.07		Agriculture	69.07	56.43	71.17	65.56	
Mean	292.79	223.11	249.04			Mean	66.64	60.92	72.54		
Temperature (^{0}C)						Mg (mg l^{-1})					
Urban /Sub-urban	23.00	12.17	28.10	21.09		Urban/ Sub-urban	6.63	7.80	8.06	7.50	Land use=0.18 Season=0.18 land use x Season=0.31
Forest	21.00	11.50	24.80	19.10		Forest	4.33	4.90	4.93	4.72	
Agriculture	21.87	11.83	26.47	20.06		Agriculture	4.60	5.07	6.07	5.26	
Mean	21.96	11.83	26.46	17.80		Mean	5.19	5.92	6.35		
Turbidity (NTU)						C l(mg l^{-1})					
Urban	9.23	6.60	6.83	7.56	Land use=0.31 Season=0.31 land use x Season=0.54	Urban	5.70	5.05	6.13	5.63	Land use=0.17 Season=0.17 land use x Season=0.29
Forest	3.67	2.93	3.30	3.30		Forest	2.27	1.77	2.53	2.19	
Agriculture	5.69	5.50	5.53	5.58		Agriculture	4.70	4.27	4.67	4.54	
Mean	6.20	5.01	5.22			Mean	4.22	3.69	4.44		
$NO3^{-}$(mg l^{-1})											
Urban	4.97	4.27	4.00	4.41	Land use=0.18 Season=0.18 land use x Season=0.31						
Forest	2.40	1.42	1.43	1.75							
Agriculture	5.47	4.42	4.87	4.92							
Mean	4.28	3.37	3.43								

Table 2. Effect of land use on distribution and abundance of aquatic insects (individual/m^2) of surface water during different seasons

Land use	Order	Family	Rainy	Winter	Summer
Urban	Trichoptera	Polycentopodidae	0	8	7
		Helicopsychidae	0	4	6
		Hydropsychidae	6	8	4
		Hydroptilidae	0	5	6
	Odonata	Euphidae	8	5	7
		Gomphidae	1	7	9
	Ephemeroptera	Heptagenidae	7	6	8
		Batidae	5	6	8
	Hemiptera	Gerridae	9	0	4
	Plecoptera	Leuctridae	0	0	0
Forest	Trichoptera	Polycentopodidae	0	6	8
		Helicopsychidae	0	7	6
		Hydropsychidae	8	9	7
		Hydroptilidae	0	8	4
	Odonata	Euphidae	5	6	7
		Gomphidae	6	7	8
	Ephemeroptera	Heptagenidae	9	7	8
		Batidae	8	6	4
	Hemiptera	Gerridae	8	0	8
	Plecoptera	Leuctridae	4	0	0
Agriculture	Trichoptera	Polycentopodidae	0	6	8
		Helicopsychidae	0	7	6
		Hydropsychidae	4	5	8
		Hydroptilidae	0	5	8
	Odonata	Euphidae	7	6	8
		Gomphidae	4	5	3
	Ephemeroptera	Heptagenidae	8	9	11
		Batidae	6	5	7
	Hemiptera	Gerridae	8	0	9
	Plecoptera	Leuctridae	0	0	0
Total	5	10	121	153	187

Total; Urban Landuse= 144 individuals m^{-2}, Forest Landuse =164 individuals m^{-2}, agriculture Landuse= 461 individuals m^{-2}

Simpson's biodiversity index: Simpson's biodiversity index of surface water during rainy and summer season was 0.96 and 0.97, respectively, whereas, there was no difference among the three land uses.

Escherichia coli: Maximum *E.coli* count in surface water was in urban land use (15.33x10^5cfu/ml) followed by agriculture and forest land uses (Table 4). Maximum number of coliforms under urban land use may be due to anthropogenic activities. Presences of coliforms have positive relation with anthropogenic activities (Sadat *et al*., 2011). Maximum *E. coli* count (10.33x10^5cfu ml^{-1}) was recorded during rainy season which could be due to improper disposal of refuse, contamination of sewage and surface runoff. Similar results of high coliform counts during spring season were indicated by Reddy *et al*. (2014) and Latief *et al*. (2003).

Most Probable Number (MPN) for total coliform count of the surface water varied between 7.37 to 330 MPN/ml under different land uses and 76.87 to 155.07 MPN/100 ml during different seasons. The MPN count varied between 4.6 to 430 MPN/100ml during different season under different land uses which was due to human.

CONCLUSION

The quality analysis of samples of surface water from different sources under different land uses of Darlaghat region of Himachal Pradesh indicated that all the quality parameters except calcium were within the permissible limits. Density of

Table 3. Impact of different land uses on biotic indices

Land use											
Urban	Forest	Agriculture	Urban	Forest	Agriculture	Urban	Forest	Agriculture	Urban	Forest	Agriculture
EPT index			EPT biotic index			Family biotic index			Simpson biodiversity index		
88	109	103	4.12	3.77	4.10	4.12	3.74	4.08	0.89	0.89	0.89

Table 4. Impact of land uses on microbial count of *E. coli* and MPN of surface water

Landuse	Season							
	Rainy		Winter		Summer		Mean	
	Total coliform count	*E. coli* count	Total coliform count	*E. coli* count	Total coliform count	*E. coli* count	Total coliform count	*E. coli* count
Urban	430.0	19.0	210.0	11.0	350.0	16.0	330.0	15.3
Forest	9.2	1.3	4.6.0	1.3	8.3	4.3	7.4	2.3
Agriculture	26.0	10.7	16.0	6.0	21.0	8.0	21.0	8.2
Mean	155.0	10.3	76.8	6.1	126.0	9.4		
CD (p=0.05)	Land use : 0.99 Season : 0.99 Land use X Season : 1.72							

E. Coli count: cfu (coliforming unit) ml^{-1} Total coliform count: Most Probable Number (MPN)

total coliform bacteria and the most probable number were above permissible level. Further, the EPT and biotic indices indicated good surface water quality of the region.

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Evaluation of the Moderately Halophilic Bacteria Resistant to Mercury from Saline Soil

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Abstract: The present study carried out on isolating and identifying mercuric resistant halophilic bacteria from Gavkhuni wetland in Iran. The nutrient agar medium with 5% (w/v) NaCl was used for isolation. As total 21 bacterial strains which has been isolated from soil. Minimum inhibitory concentration (MIC) of the strains was detected for $HgCl_2$ using agar dilution method. Among the 21 halophilic and halotolerant strains isolated from Gavkhuni wetland, four were resistant to mercuric chloride (125‑400 µM). According to phylogenetic analysis of 16S rRNA gene sequences and phenotypic characterization, the strains belonged to phyla Fermicutes and Proteobacteria. Consequently, these microbial isolates could be potentially used in bioremediation of mercury‑contaminated environment.

Keywords: Halophilic bacteria, Mercuric resistant, Bioremediation, Mercury

Mercury is one of the toxic heavy metals and occur naturally in the environment at low levels and is the sixteenth rare earth element. Human activities releasing mercury in the environment are the pharmaceutical, paint, paper and disinfectants industries. The mercury is also available in fungicides. The use of fossil fuels is another main source of mercury in nature. The mercury is considered one of the most important environmental pollutants, and exists in the environment for a long time. It is estimated to remain in nature about 0.5 to 2 years, which can accumulate in biological tissues and affect the food chain. In addition to human resources, natural processes cause global rise in mercury concentration, such as volcanic eruptions, geothermal activities, soil erosion, water cycle and forest fires (Dash and Das., 2012).

Microorganisms are the first living organisms that are directly and indirectly influenced by heavy metals. Metals affect microorganisms by reducing the number, biochemical activity and diversity as well as changing in microbial community structure. However, exposure to the metals results in the creation of tolerant microbial populations (Piotrowska‑Seget *et al.,* 2005). To investigate the effects of heavy metal pollution on soil systems, most of the bacteria are isolated from such environments (Xiong *et al.,* 2008). The metals tolerant bacteria that are able to survive in this environment can be isolated, identified and selected for potential applications in bioremediation of contaminated sites (Voica *et al.,* 2016).

One of the significant natural ecosystems registered in the international Ramsar convention (1975) is Gavkhuni wetland 15' 32° ‑22' 32° N and 45' 52° ‑59' 52°E in Iran. Nevertheless, the ecosystem of this wetland is destroyed and even the quantity and quality of its incoming fresh water have been lowering . The water quality of this wetland has been dropped due to the frequently discharge of ntreated industrial and domestic wastewaters from Isfahan. In addition, climate‑change droughts have exacerbated this environmental disaster. Altogether, this natural important wetland in the country has become a salt pan because of suffering from hydrologic regime variations caused by above mentioned issues, resulting in disappearance of fauna and flora (Sarhadi and Soltani., 2013). The present study was conducted to isolate and identify of mercuric resistant halophilic and halotolerant bacteria and tolerance to a range of mercuric chloride was determined for bacteria which had been isolated by agar dilution method from Gavkhuni wetland in Iran.

MATERIAL AND METHODS

In the present study, serial dilutions were prepared from soil samples. Five ml of each of them was mixed with 50 ml of nutrient broth (NB) medium with the pH7.5 and 5 % (w/v) NaCl, and then were placed in incubator shaker at a temperature of 35 ˚C and 150 rpm for 48 hours. The purification of isolated strains were performed on nutrient agar (NA) supplemented with 5 % (w/v) NaCl using plate streaking technique (Amoozegar *et al.,*2008). Agar dilution method was used to determine mercury resistance, so that a certain concentration of mercury was added to the flask containing 20 ml melted nutrient agar. The contents of the flask were then poured onto 8-cm plates. Control samples had mercury free medium. By using pipette sampler, 10 µl of study bacteria at a concentration of 0.5 Mc Farland (1.5×10^{8} cfu/ml) was cultured on agar media. The plates were examined after incubation at 34 ˚C for 72 hours. The lowest concentration of metal compounds that quite inhibited the growth of bacteria was considered as minimum inhibitory concentration (MIC). The experiments were carried out with three replications. All procedures of MIC were performed for concentrations of 10 and 15 % NaCl (Abou-Shanab *et al.,*2007).

The standard criteria for microbiology like pigmentation, shape, colonial elevation and opacity under light microscopy were recruited to examine morphological, physiological and biochemical features of the isolated bacteria. KOH test confirmed the Gram staining result. Bacterial motility was tested via wet-mount method (Smibert *et al.,*1994). The identification process for mercury-resistant soil bacteria were carried out by 16S rRNA gene sequencing after extracting bacterial genomic DNA using Kit (Sigma) from the cultures grown in Luria Bertani medium. The universal bacterial primers 27F (5'-AGAGTTTGATCMTGGCTCAG-3') and 1492R (5'-ACGGCTACCTTGTTACGA-3') were applied to amplify 16S rRNA gene of the strains (Amoozegar *et al.,*2007). Macrogen Company in South Korea performed purification and sequencing of PCR products. The obtained sequences were arranged using Chromas Pro software, and compared by sequences recorded in GenBank databases using BLAST software to determine the closest related strains with the 16S rRNA sequences similar to strains selected by PCR. A phylogenetic tree was drawn after finding sequences of 16S rRNA in related strains using BLAST software, aligning and calculating evolutionary distances with Clustal X software and Neibour-Joining algorithm. The phylogenetic tree also was drawn using MEGA version 5 software (Saitou *et al.,*1987; Thompson *et al.,*1997). The phylogenetic tree branches were validated using Bootstrap analysis algorithms with 1000 times sampling (Felsenstein,1985).

RESULTS AND DISCUSSION

From soil samples collected from Gavkhuni wetland in Iran, 21 bacterial strains were isolated. All isolated strains identified by Gram staining showed that Gram-positive bacilli (n=12), Gram-positive cocci (n=5) and Gram-negative bacilli (n=4) were isolated with a much lower frequency. No Gram-negative cocci were found among the isolates.

The ability of microorganisms to grow in the presence of relatively high concentrations of metal ions is a necessary adaptation in a wide range of microbial groups and even microbial strains isolated from non-contaminated sites. This adaptation to the environment rich in heavy metals in microorganisms is indicative of activities for bioadsorption, biodeposition, extracellular accumulation, and transfer mechanisms or chelatin. Such resistance mechanisms are the principle of using microorganisms in the bioremediation techniques (Anyanwu *et al.,*2011). The resistance range of strains in medium with 5% (w/v) NaCl were 0-400 µM. Four strains were resistant to mercury with resistance range between 125 and 400 µM Hg. None of the strains grew in concentration over 400 µM. The effects of toxic metal mercury on these bacterial strains enhances with increasing concentration. The tolerance to a range of mercury ions was determined for bacteria which had been isolated by agar dilution method from Gavkhuni wetland. In total, 20 ml of melted nutrient agar plus various concentrations of mercury (0.005 up to 0.5 mM) were poured into 8 cm plates. Then 10 µl of the bacterial suspension (1.5×10^{8} cfu ml^{-1}) were inoculated on each plate using a sampler followed by incubation at 34 ˚C for 7 days. Minimum inhibitory concentration (MIC) for mercuric choloride was determined. Each plate was prepared in triplicates (Washington, 1980).

The bacteria isolated for resistance to mercury were Gram-positive and Gram-negative isolates. However, the highest MIC value was in a Gram-positive bacterium, strain MN8. Greater MIC presence of Gram-positive bacteria in media containing mercury may be attributed to their higher ability to absorb, and then acquire resistance over time. In addition, these bacteria have naturally higher resistance to toxic metals. In the present study, a large number of Gram-positive bacteria can be ascribed to thicker cell wall of the bacteria, and higher intrinsic resistance compared to Gram-negative bacteria. In most previous studies, more mercury-resistant Gram-negative bacteria have been isolated than Gram-positive bacteria. In a study conducted in Japan on sediment contaminated with mercury, the mercury resistant isolates were Gram-negative bacteria (Nakamura *et al.,*2001). The partial sequence of 16S rRNA gene of strains were submitted at NCBI GenBank (Table 1). The evaluation of minimum inhibitory concentration (MIC) for mercury-resistant strains in different concentrations of NaCl showed that the MIC rate decreased in some strains, such as MN8 and MN16 with increasing concentrations of NaCl. However, the MIC rate elevated in MN12 and MN18 strains with increasing concentrations of NaCl (Fig. 1). With increasing

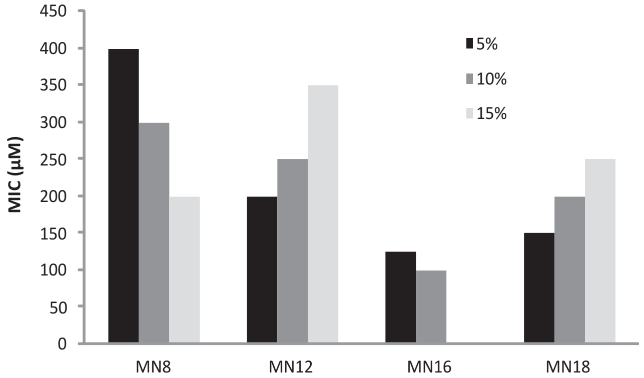

Fig. 1. MIC of 4 mercury resistant isolates in culture medium containing

concentrations of NaCl, the MIC rate reduced in some strains, while this rate was increased in some other strains. This issue can be due to differences in strains in terms of the optimal level of NaCl required for growth. The phylogenetic tree for 16S rRNA sequences of strains shown in Fig.2. Based on the results of sequencing, nucleotide sequence of four mercury-resistant isolates was belonged to the two bacterial phyla of *Firmicutes* and *Proteobacteria*. The two strains belonged to the phylum *Firmicutes*. The Gram-positive bacilli isolated in this phylum are in the *Bacillales* order included two the genera *Bacillus* and *Halobacillus*. The two Gram-negative bacilli of the genus *Halomonas* are in the class *Gammaproteobacteria* in *Proteobacteria* phylum. All

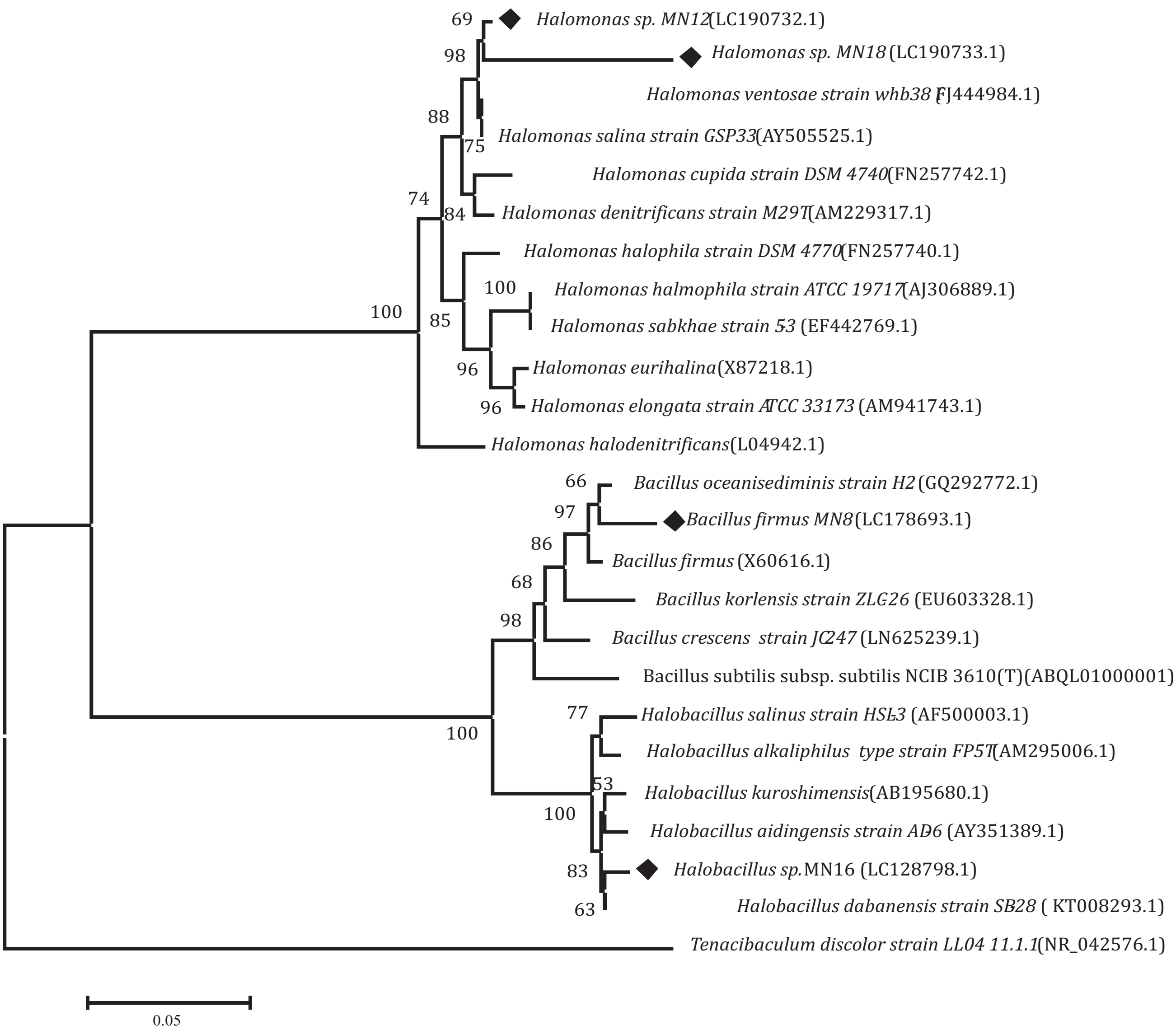

Fig. 2. Neighbor-joining tree for 16s rRNA sequences of mercury resistant halophilic bacteria ( ) from Gavkhuni wetland (salin soil) in Iran and reference strains. The numbers at branching points are bootstrap values based on 1000 replicates. The outgroup in the tree is the sequence of *Tenacibaculum discolor strain LL04 11.1.1,* Bar, 0.05 substitutions per nucleotide position

Table 1. Isolation and identification of the moderately halophilic bacteria resistant to mercury from Gavkhuni wetland in Iran

Isolate	Phylogenetically related genera	Accession number	Size	MIC*(μM)
MN8	*Bacillus*	LC17 8693	1230 bp	400
MN12	*Halomonas*	LC190732	1290bp	200
MN16	*Halobacillus*	LC128798	1305 bp	125
MN18	*Halomonas*	LC190733	1269 bp	150

* Minimum inhibitory concentration

selected isolates that were resistant to mercury were studied in terms of colony shape and characteristics, cell shape and microscopic arrangement, Gram reaction, presence of spores, motion, react to KOH, catalase test and oxidase reaction (Table 2). Vetriani *et al.* (2005) conducted sampling from deep-sea hydrothermal vent extreme environments. The hydrothermal vent fluids are rich in heavy metals. They identified seven genera of bacteria resistant to mercury. Among them, five mesophilic genera were belonged to *Pseudoalteromonas, Halomonas, Pseudomonas, Marinobacter,* and unclassified *Rhizobiales* .

Table 2. Morphological and cultural characteristics of mercury resistant isolates

Characteristics	MN8	MN12	MN16	MN18
Morphology	Rod shaped	Rod shaped	Rod shaped	Rod shaped
Gram staining	+	–	+	−
Color	Creamy	Yellow	White	Yellow
KOH reaction	+	−	+	−
Motility	+	+	+	+
Catalase	+	+	+	+
Oxidase	+	+	+	+
Spore formation	+	−	+	−

Positive + ; Negative −

According to the obtained findings, the study isolates can be used as candidates suitable for bioremediation of harsh environments contaminated by mercury metal, for example due to contamination caused by industrial waste waters.

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Impact of Soil on Corrosion of Pipes on Basis of Construction

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Abstract: Studies selected object seamless pipes with a wall thickness of 15 mm, used for the construction of pipelines. The results of experimental studies of corrosion and corrosion-mechanical characteristics of the main oil pipelines in the corrosive environments, graphics have been built according to the analysis of corrosion and mechanical processes. The unfavourable environmental and mechanical factors determine the pipeline wall deterioration.

Keywords: Metal corrosion, Pourbaix diagram, Soil pollution, Air creep kinetics, Environment chemical tension

Industrial wastewater contains a complex mixture of pollutants. Wastewater is characterised by a range of factors such as composition, pH, precipitates and other. As a consequence, wastewaters even generated by the same industry can differ significantly. Even permissible levels of wastewater harm the environment and beyond the permissible quotas, manufactures are required to pay fines. To protect the environment, various filters and treatment facilities can be used. However, wastewater's impact may be changed even further by choosing in form of which compounds wastewater will enter the ecosystem. In our work, Pourbaix diagrams were used for analytical representation. Wastewater's impact may be altered by changing acidity. Possible compounds can be calculated by constructing E-pH graphs. Pourbaix diagrams (potential/pH diagram, EH-pH diagram) map out dependences between thermodynamic potential and pH calculated by the Nernst equation. Diagrams show thermodynamical stable phases for elements, ions, molecules, atomic crystals and metals in solutions for different pH and E levels. The diagrams were invented by Marcel Pourbaix.

MATERIAL AND METHODS

A newly developed computerized device RKN-1 based on the MV-1K device was used to research the corrosion processes under tension. The tests of the pipeline samples in the air and in the liquid environments were conducted under a static clear bend load with the automatic registration of the sample bending and the changes in the electrode potential using the computer with the 24-bit analogue-to-digital conversion of the number of values. Flat samples of the various parts of the mainline piplelines were used. Such technology ensures high accuracy and set roughness of the surfaces. The parameter of the δ sample, which can be used to determine the bend deflection, is being constantly measured under the static load and creep deformation. The parameters of δ, length of the working segment l_p and the minimum curvature radius of the sample ρ_{min}correlate according to the following equation:

$$P_{min} = \frac{l_p^2}{8\delta} + \frac{\delta}{2}$$

The relative deformation of the fringe fibers was determined using the formula:

$$\varepsilon = \frac{1}{\frac{2p_{min}}{b} + 1}$$ where b is the thickness of the sample.

The prognostication of the corrosion behavior of the pipelines requires a complex analysis of the internal and external factors related to the corrosion of the pipe material in the exploitation environment. The penetration depth is the main factor determining the corrosion speed both in case of partial and uniform corrosion. In both cases, regardless of the metal or alloy type, the depth of the corrosion is measured in millimeters per year.

The corrosion speed is determined using the following formula:

$$VBM = \frac{n\,(m_1 - m_0)}{St}\ \frac{kg}{M^2} \text{ per year}$$

where m_0 – is the starting mass of the sample in kilograms; m_1 – is the mass of the sample with the corrosion byproducts in kilograms; S – is the area of the sample in square meters; t – is the length of the experiment in years, n – is the coefficient determined by the composition of the corrosion byproducts.

Sample preparation includes mechanical cleaning with the fine abrasive and degreasing with the organic solvent (acetone, toluene, or benzene) and weighing using analytical balance. The samples are placed into the glass containers with the solutions representing corrosive environment. At the end of the experiment, the samples were removed from the solutions, the areas subjected to corrosion were quickly measured and the insoluble corrosion byproducts were removed with a wet rubber. The samples are washed with distilled water and carefully dried with filter paper, then weighed again using analytical balance. A chlorine-silver reference electrode was used during the electrode potential measurements. In order to ensure accurate modeling of the corrosion process under stress, an analysis of the stratal waters and waters under the pipelines at the various stages of crude oil transportation was conducted. Based on this research, 3 model environments were chosen corresponding to the stratal water of the oil extraction site, and ground waters of the transportation and pump station sorting stages.

The overall deformation increase ₦ε over time=t can be determined using the formula: $\Delta\varepsilon=\Delta\varepsilon_{pr}+\Delta\varepsilon_{pt}+\Delta\varepsilon_{p}$

where ₦ε_{pr} and ₦ε_{pl} are elastic and plastic deformation increases respectively, and ₦ε_{p} is creep increase. The electrode potential kinetics was compared at $\sigma = 1{,}6\sigma_{0,2}$, 1,35 $\sigma_{0,2}$and 1,05 $\sigma_{0,2.}$

RESULTS AND DISCUSSION

The soil mass causes the pipeline to experience pressure which can cause various structural changes including deformation and stress relaxation. Due to this fact, research into the changes of the mechanical qualities of the pipeline materials during the long-term exploitation can help determine the remaining operating life of the existing pipelines with more accuracy. Currently, a significant part of the pipelines have been exploited for 15 to 20 years and are supposedly nearing the end of their operating lifespan. Research into the mechanical and corrosive changes caused to the pipelines by the environment is a relevant scientific task. The rated deformation diagrams were created using stage-by-stage loading and unloading of the sample (Fig. 1) with the clear bend when the load is not decreased when the resistance of the sample falls.

With the change of the load by one stage, the nominal tensions shifted by the value ₦σ = 20 MPa over $t_{н\text{-}р}$ = 1 sec. The delay at each stage counted $t_{в}$ = 19s and the time total counted ₦t = $t_{н\text{-}р}$ + $t_{в}$ = 20s. This way, the experiment can account for the delay between the deformation and tension and provide in depth information about strain hardening and creep.

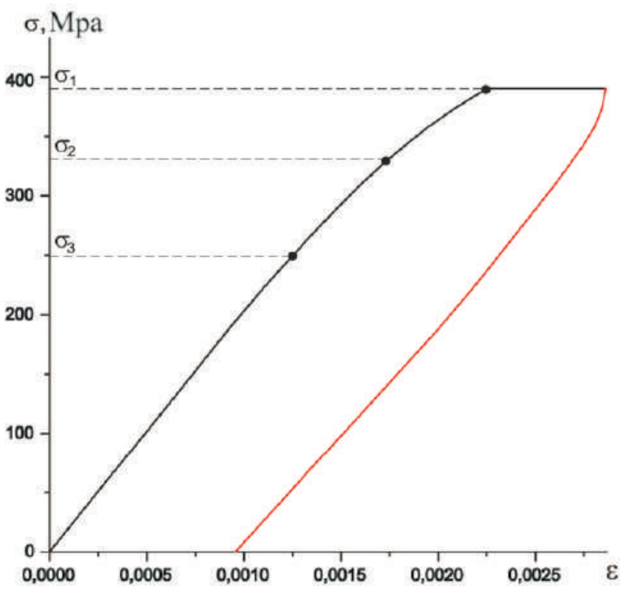

Fig. 1. Pipeline steel samples deformation in the open air

Creep research, being referred in the engineering calculations and during pipeline optimization, is mostly being conducted under stretching load. The metal creep is often being viewed as slow metal yield. It is widely known that the theory of plastic yielding is based on the notion of yielding surface. During a static bend, the yielding surface regularly moves, which means it evolves.

Characteristic creep curves in the coordinate system yield gain ₦ε_{μ}–time t are depicted in figures 2-4. The length of the open air tests was determined by the type and kinetic characteristics of the process in each separate case, which allowed us to determine the parameters of the low-temperature creep area in a relatively short time.

It was determined that the primary metal creep both in the open air and in the corrosive environment was phasic in its nature. The influence of the environment can be observed both during the transient and steady-state creep stages. As the research indicates, the pipeline steel is most susceptible to the low-temperature corrosive creep in MS2 and most resistant in MS3. The length of the first phase depends more on the nominal tensions and less on the chemical composition of the environment. The research into the relations between the increase of the corrosive creep and the strength of the nominal tensions and the chemical composition of the environment shows that their synergistic

Table 1. Mobile environments composition

Model environment	Sample source	pH	SO_4^{2-}	NO_3^-	Cl^-
1 (Surface soillayer)	Pump station sorting stages	6,2	2,8	4,8	4,0
2 (Fertile soillayer)	Stratal water	6,0	3,6	7,6	5,1
3 (Pipeline covering soillayer)	The ground water	6,1	7,5	5,3	5,1

effect is the strongest in MS2 and weakest in MS1. In order to better study the chemical aspect of the internal pipeline steel corrosion under stress and determine the most chemically dangerous exploitation environment, electrode potential kinetics analysis was conducted. It is known that the low metal potential and high speed corrosion increase the risk of

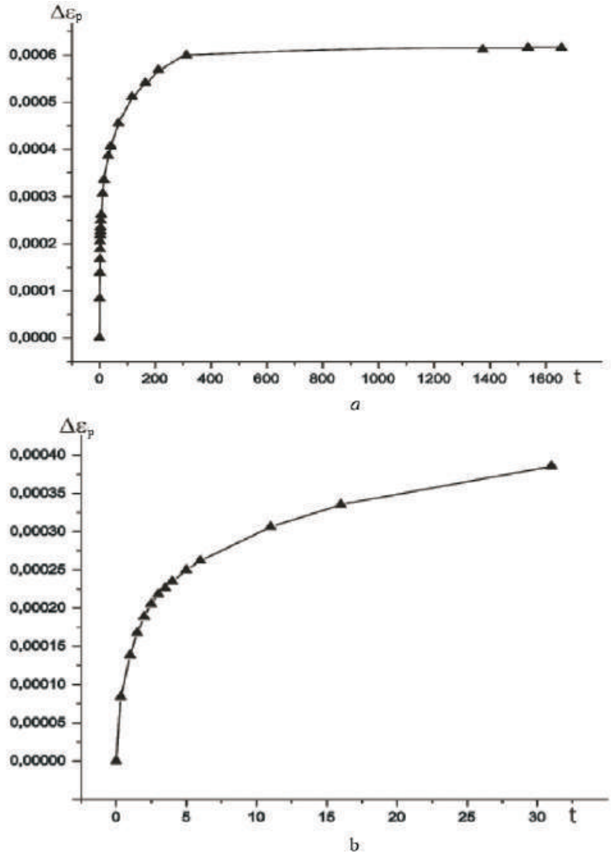

Fig. 2. Pipeline steel open-air creep kinetics: general (a), at the starting stage(b): T = 293 K; σ = 390 MPa

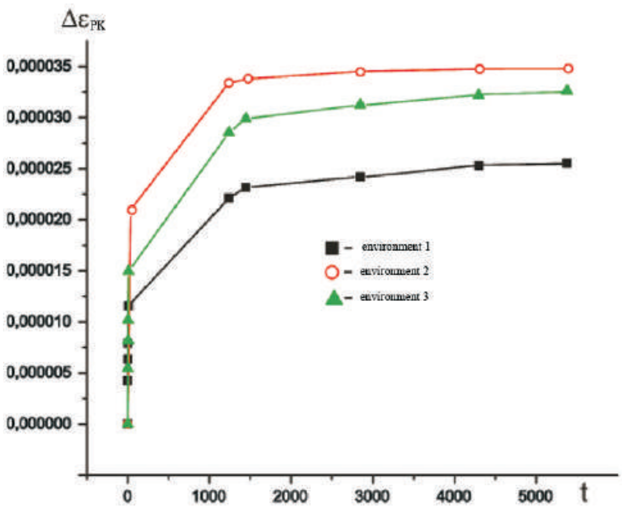

Fig. 3. Pipeline material creep under normal 250 MPa tension

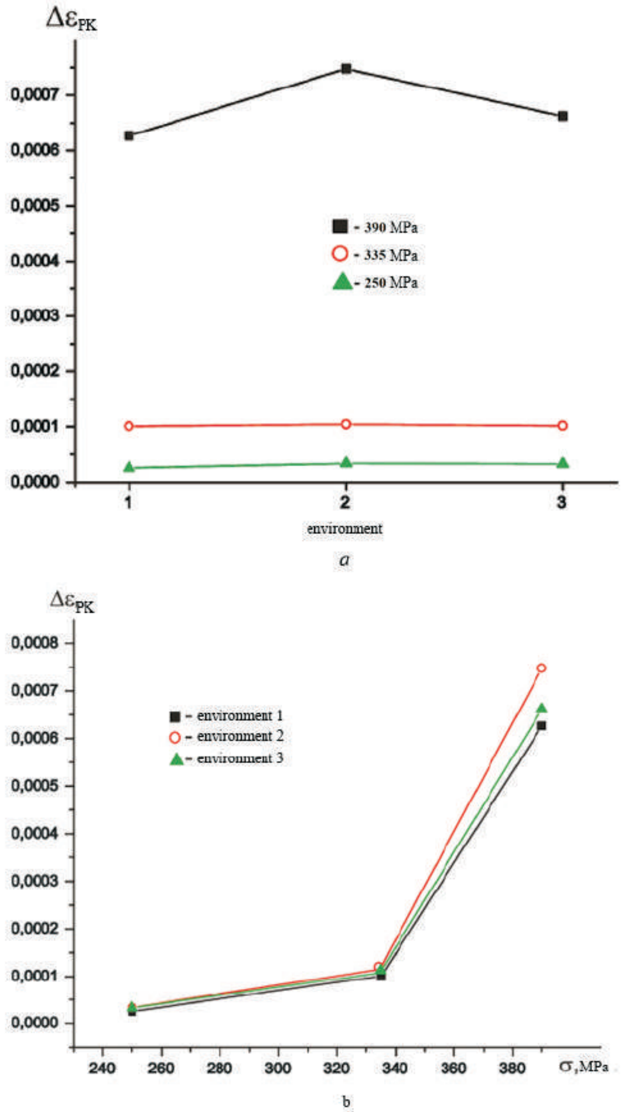

Fig. 4. Relation between the creep increase and the environment chemical tension level (b) t = 5000 min

the corrosive decomposition and related damage. The graphs show that the synergistic effects of the corrosive environment and mechanical strain take effect in this case as well.

The research results indicate that with the decrease of the nominal strain level, the speed of the corrosive process in the MS2 remained almost unchanged, while in the MS3 and especially MS1, it decreased significantly. MS2 is the most dangerous environment from a chemical standpoint since the corrosive decomposition process is regulated by the corrosive factor and If the mechanical strain is relatively minor, the corrosive processes will be rather intensive. In MS1, the mixed regulation with a focus in the mechanical factors was observed. From a chemical standpoint that environment is the safest of the three. MS3 demonstrated similar qualities but the corrosive decomposition itself was less intensive. This environment demonstrated medium corrosivity levels. The relation between the stabilizing potential of the pipeline steel and its strain-deformation state is shown in the figure 5.

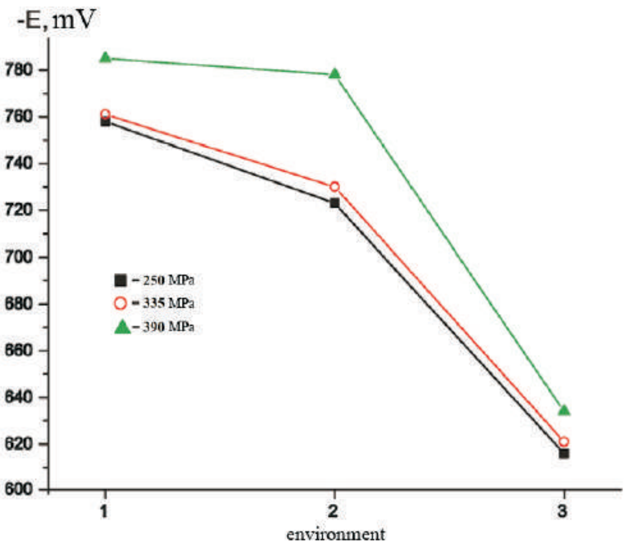

Fig. 5. Influence of the mechanical factor on the stabilizing potential of the pipeline steel

The influence was considerable, especially in the MS1 and MS2 and according to the potential kinetics, the maximum corrosion speed was observed in the MS2 and the minimal in the MS1. Slow corrosion in the last case proves our assumption that the steep decrease of the electrode potential in the MS1 is mainly related to the plastic deformation processes, which unavoidable is accompanied by the appearance of the juvenile surfaces and submicro fissures, the newly created surfaces of which creates much lower potential, as well as the highest relative concentration of chloride ions which inhibit its fast passivisation. Thus even at minimal tension levels, the pipeline walls can grow thinner by 0,125–1,25 mm a year depending on the chemical composition of the environment and the level of nominal strain (Fig. 6).

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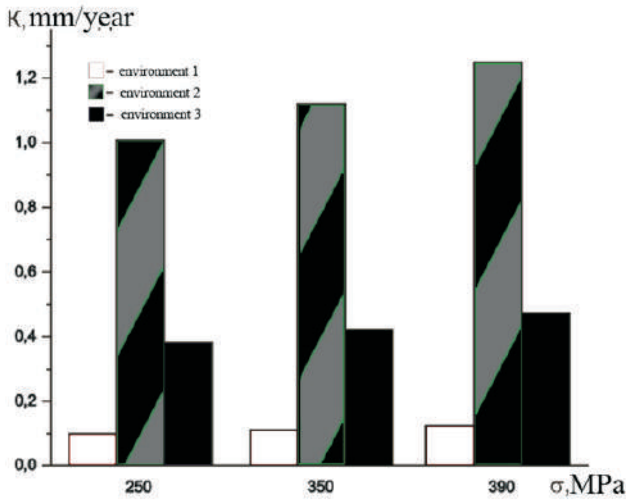

Fig. 6. Relation between the pipeline walls growing thinner and the chemical composition of the environment

CONCLUSION

With the increase of the normal tensions from $1{,}05\sigma_{0,2}$ to 1,6 $\sigma_{0,2}$, the increase of the overall corrosion speed in the model environments can reach 25 per cent which indicate not to overlook the mechanical factors when calculating the remaining life span of the existing pipelines and engineering new ones. It is also necessary to take into account the constant intensive movement of the corrosive environment, which means that constant removal of the insoluble corrosion byproducts causes slower surface passivation and there is tendency towards localized corrosion processes since the initially damaged spot does not passivate and has lower potential compared to the surrounding undamaged surface. The galvanic elements are created, when the damaged area becomes an anode and the surrounding surface becomes a cathode and speed of the localized corrosion can be 2–8 times faster compared to the overall corrosion speed. Considering that in the unfavorable conditions the mechanical factors and the movement of the environment amplify each other, can easily calculate that the speed of the local corrosion and, consecutively, the speed of the pipeline wall deterioration can speed up 2,5–10 times.

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Community Dynamics: Competition and Facilitation Studies of Tree Species in Temperate Forest of the Indian Himalaya

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Abstract: In present study, distance independent and indirect indices for identification and assessment of competition and facilitation between species of the Indian temperate forest ecosystem have been developed. We found broken stick rank/abundance model. Hump-back relationship was obtained between Importance Value Index and Total Biomass Cover. Based on present approaches, *Abies spectibilis, Myrica esculanta, Pyrus pashia* and *Aesculus indica* were identified as potential competitive species. Higher competition index value was recorded between *A. spectibilis-M. esculanta* followed by *Quercus glauca -M. esculanta*, while minimum was recorded for *Rhododendron arboreum - A. indica*. Community Competition Value (CCV) was 1.96, while, Facilitation Index Values ranged from 0.07-0.9. Study provides list of species for enhancing success of habitat restoration and afforestration programmes. Thus, our new approaches have the potential to evaluate interactive mechanisms specifically inhabiting at hilly terrain where position of relative angular placement of different species, height or other parameters are difficult to estimate.

Keywords: Temperate forest, Community dynamics, Competition, Facilitation, IVI and PCA

A fundamental characteristic of mountain ecosystems is the drastic change in vegetation as well as in climate from the base to the summit of mountain. In general, growth rates may decline with altitude because of reduced air and soil temperatures (an adiabatic effect), shorter growing seasons, increased exposure to wind, and reduced supply of nutrients. Various studies have been carried out to access the impact of elevation on structural and functional dynamics of forest species and some of the representative studies pertain to diameter growth of *Nothofagus solandri var. cliffortioides* in New Zealand (Coomes and Allen, 2007), recruitment patterns in the Mediterranean mountains (Benavides *et al.,* 2013), distribution patterns of trees in eastern Himalaya, India, (Acharya *et al.,* 2011), vegetation patterns along altitudinal gradient in sub-alpine zone of west Himalaya India (Gairola *et al.,* 2008), vegetation structure, composition and diversity in Garhwal Himalaya, India (Sharma *et al.,* 2009), regeneration patterns of *Larix kaempferi* in central Japan (Nagaike, 2010).

Tree-tree interactions are an important structural mechanism for forest community dynamics (Kunstler *et al.,* 2011; Fichtner *et al.,* 2012; Coates *et al.,* 2013) and these interactions can be competitive or facilitative and complementary, and the direction of biotic interactions may shift with different environmental conditions (Forrester *et al.,* 2011; Río *et al.,* 2013; García-Cervigón *et al.,* 2013; Forrester, 2014).

These phenomena can be evaluated at various temporal events, for example if the competition is current then there is to possibilities that pertain to either intense competition (competition coexistence) and weak competition (non-competitive coexistence or partial niche separation) and similarly intense competition in the past represent co-evolutionary niche separation. Further, gradients of bottom up (community factors, light resources) and top down (soil) factors (He *et al.,* 2013; Forrester, 2014; Forrester and Albrecht, 2014; Coates *et al.,* 2014) are considered important drivers for such types of interaction.

Irrespective to the altitudinal gradients, many efforts have been put forth to quantify competition/facilitation between tree-tree species. In these studies, parameters like distance between species, height, DBH, basal area, neighbourhood factor, radius of influence zone, relative spacing, crown overlap, opening angles, angular height and angular radial growth, incident light per unit ground area, and parameters (α, β and γ) estimated through regression analysis were utilized (Oelmann *et al.,* 2010; Kaitaniemi and Lintunen, 2010; Contrears *et al.,* 2011; Maleki *et al.,* 2015; Badea *et al.,* 2015; Fichtner *et al.,* 2015; Bulleri *et al.,* 2016; Kefi *et al.,* 2016; Metz and Tielborger, 2016). These parameters are important components of many distance dependent and distance independent indices (Kaitaniemi and Lintunen, 2010; Contrears *et al.,* 2011), which are more accurately implies for plain land surfaces compared to elevated terrains.

From the India temperate mountain region, exploration had been restricted to quantification of community compositions and their compartments with different elevation only. Knowing the above scientific knowledge and gaps, present study was aimed to quantify the community dynamics of forest tree species at different altitudes and quantify the existing competition and facilitation for tree species in the Indian temperate forest by formulating the distance independent indices whose parameters can easily and correctly be apply for hilly terrains.

MATERIAL AND METHODS

The study area lies in temperate zone of Garhwal Himalaya in Uttarakhand State of India. The study was carried along the altitudinal gradient of the Ansuiya devi forest (knowing for their religious significance, Pala *et al.,* 2014) tract in Mandal area of Chamoli district. The study site was purposefully selected owing to its altitudinal variation. First the entire area was surveyed and then purposefully divided into three altitudinal ranges (1650–1850m, 1900–2150m and 2200–2450m) a.s.l. by using Garmin GPS. The coordinates of the study area are N 30º 27' 39" to 31º 28' 42" and E 79º 16' 25" to79º 31' 58". The climate in the study area can be divided into three distinct seasons; cool and relatively dry winter (November to March); warm and dry summer (mid–April to June); rainy (July to mid–September). The rainfall pattern in the region is largely governed by the monsoon rains (July–September), which account for about 60–80% of the total annual rainfall.

Stratified random sampling technique was applied and quadrats were laid down in forest and were spatially distributed so as to minimize the autocorrelation in the vegetation. Twenty quadrats were laid down at each altitude to quantify density, frequency, abundance and Importance value index (IVI) by following Phillips (1959). The GBH (girth at breast height, 1.37 m) was used to calculate the basal area. Species richness, Shannon diversity index and evenness were calculated by following Ludwig and Reynold (1988).

Tree height was measured using a Ravi multi–meter. Density was calculated using the formula given by (Mishra, 1968). The growing stock density (GSVD) was estimated using volume tables or volume equations based on the Forest Research Institute (FRI) and Forest Survey of India (FSI) publications for the respective species (FSI, 1996). The estimated GSVD (m^3 ha^{-1}) was then converted into above ground biomass density (AGBD) of tree components, which was calculated by multiplying GSVD of the tree species by appropriate biomass expansion factors (BEF) (Brown *et al.,* 1999). The BEF for hardwood and pine was calculated using the following equations BEF = exp {1.9 − 0.34×lnG} where, G is the growing stock density (G $\geq$200 m^3 ha^{-1}). BEF = 1.0 (G>200 m^3 ha^{-1}). The BEF for pine was calculated as follows: BEF = 1.68 Mg m^{-3} (G < 10 m^3 ha^{-1}), BEF = 0.95 (G = (10−100) m^3 ha^{-1}); BEF = 0.81 (G > 100 m^3 ha^{-1}). Using the regression equation of Cairns et al. (1997) the below ground biomass density (BGBD) was estimated for different tree species as follows: BGBD = exp{− 1.059 + 0.884× ln A + 0.284}. AGBD and BGBD were added to get the total biomass density (TBD).

Rank/abundance plot is a effective method of illustrating changes in communities through succession. In present study, this analysis was carried out by Bio–Diversity Pro Software. Regression analysis between exploratory (IVI) and dependent variables (total basal cover and total biomass density) were carried out with Curve–Expert Software.

PCA is an ordination technique that constructs the theoretical variable that minimizes the total residual sum of squares after fitting straight lines to the data. PCA was carried out according for biomass density of different species occurred at various altitudes by using Pearson correlation coefficient. The interpretation of the correlation circle was carried out under following criteria, when two variables are far from the center, then if they are: close to each other, they are significantly positively correlated (r close to 1); if they are orthogonal, they are not correlated (r close to 0); if they are on opposite side of the center, then they are significantly negatively correlated (r close to –1). Squared cosines were used to link the variable with the corresponding axis and the greater the squared cosine, the greater the link with the corresponding axis.

Four new indices were developed for accessing the competitive or facilitation interactions between species. These new mathematical expressions are different from previous approaches, which are generally relay on DBH, height, distance between species and their angular proximity. Basically in addition to mathematical approaches, the value of a competition or facilitation index also depends on the method used to define competitors for the subject tree (Maleki *et al.,* 2015). In present study, following criteria's were used for identification of subject and competitor/ facilitation species (a) competition or facilitation between species identified on the basis of their relative position on PCA bi–plot corresponding to correlation matrix (b) in competition phenomena, competitor and subject tree species were identified on the basis of their IVI in the community. Since the diversity indices (Shannon–Weaver) indicate non–dominance of any species in the community, indicating higher system stability and resilience and currently not facing advance stage of competition. Thus, Higher the IVI value of species designate as subject tree, while lesser IVI value species regarded as competitor one (c) species only with IVI values >15 treated as potential subject or competitor species and (d) IVI values of subject or competitor species at different altitudes summed.

$$Competition\ Index\ = \sum_{j=1}^{n} \left(\frac{B_c}{B_S}\right) \arctan\left(\frac{B_C}{Eigen\ value\ \ difference\ B_{CS}}\right)$$

$$Community\ Competition\ Value = \frac{\Sigma\, SSC}{N_C}$$

$$Faciliation\ Index = arctn(BS_1 + BS_2)\, x \left(\sum_{EV} BS_{1\&2}\right)$$

$$Community\ Faciliation\ Value = \frac{\Sigma\, SSC}{N_C}$$

$$Community\ Faciliation\ Values = \left(\sum SSFxA_F\right)$$

In above equations, B_C = Biomass of competitor tree species, B_S =Biomass of subject tree species and B_{CS} = Eigen value difference between competitor and subject tree species obtained through PCA; SSC = sum of species specific computation values, N_C is the number of competitor species in study, BS_1 and BS_2 are the biomass of species 1 and 2, and ₦$_{EV}$ BS_1 &$_2$ are sum of Eigen values of BS_1 & BS_2 SSF = sum of species specific facilitation value and A_F is the altitude factor where facilitation occurs and in this study a score of 2 assigned for facilitation occurred at all three levels i.e. A_1+A_2+A3 and similarly 1.75, 1.50, 1.25, 1.0, 0.5 and 0.25 values were assigned for facilitation occurred at A_1+A_2, A_2+A_3, A_1+A_3, A_1, A_2 and A_3, respectively .

RESULTS AND DISCUSSION

Total twenty seven tree species were recorded at different altitudes (13, 18 and 17 at A1, A2 and A3, respectively). Different diversity parameters like species richness, Shannon diversity index and evenness at different altitudes are depicted in Table 1. Shannon index represent the equal distribution of different species at different altitude and shows high diversity and lack of dominance of any species. Distribution patterns of these species revealed that four species namely *Alnus nepalensis, Daphniphyllum himalayense, Qurcus leucotrichophora* and *Rhododendron arboretum* were presented at all three altitudes, while *Persea duthiei* was presented at A1 and A3. Eight species namely, *Abies spectibilis, Acer Oblongum, Baxus Wallichiana, Fraxinus micrantha, Ilex dipyrena, Q. glauca, S. macrophylla* and *Taxus baccata* were restricted only at A3 level. Trends of other species are depicted in fig. 2.

Table 1. Diversity parameters at various altitudes

Parameters	Altitudes		
	1650–1850	1900–2150	2200–2450
Species richness	13	18	17
Shannon and weaver diversity index	2.4	2.7	2.6
Evenness	0.97	0.96	0.93

Among different species at various levels, highest IVI value was recorded for *D. himalayense* at A1 level followed by *Q. leucotrichophora* at A3 level. However, IVI values of *D. himalayense* shows decreasing trends with increasing height, while reverse of this trend showed by *Q. leucotrichophora* and *R. arboretum* (Table 2). Species that were presented only at A1 and A2 i.e *C. torulosa, F. auriculata, J. regia, L. ovalifolia, M. esculanta, P. roxburghii* and *Q. florbunda* showed decreasing trends from A1 to A2, while exception of this trend exhibited by *A. indica.* Maximum and minimum TBC were showed by *Q. glauca* and *P. roxburghii* at A3 and A2 altitudes, respectively.

In community ecology, shape of the rank/abundance plot is often used to infer which species abundance model best describes the data. Steep plots signify assemblages with high dominance, such as might be found in a geometric or log series distribution, while shallower slopes imply the higher evenness consistent with a log normal or even a broken stick model. In present study, broken stick type models were brought at all the altitudes (Fig. 3).

Regression analysis between sum of IVI and TBC of different species at various altitudes showed quadratic relationship that can be written as (y=a+bx+cx^2) TBC of species at different altitudes = =46.30+12.82 x IVI of species at different altitudes + =0.19 x IVI of species at different altitudes$^{\wedge 2}$ (R^2 =0.66**± 57.95). Regression curve (Fig. 4) depicted humpback relationships between these two parameters and suggested monotonic increase in TBC with certain level of IVI and beyond a threshold limit, TBC started to decline. Maximum (634.0) and minimum (37.8) estimated total biomasses were recorded for *Q. leucotrichophora* and *A. caesium*, respectively (Table 4). Estimated biomass for *Q. leucotrichophora* and *R. arboretum* showed declined trends with increasing altitudes, while reverse of this was observed for *A. nepalensis.* Linear positive relationship (y=a+bx) was calculated between IVI and total biomass covers of different species presented at various altitudes and can be expressed as total biomass of species at various altitudes = 94.92 + 3.97 x IVI of different species at various altitudes, R^2 = 0.84**± 77.64 (Fig. 5).

According to Wei *et al.* (2008) PCA was considered useful if their cumulative percentage of variance approached 80 per

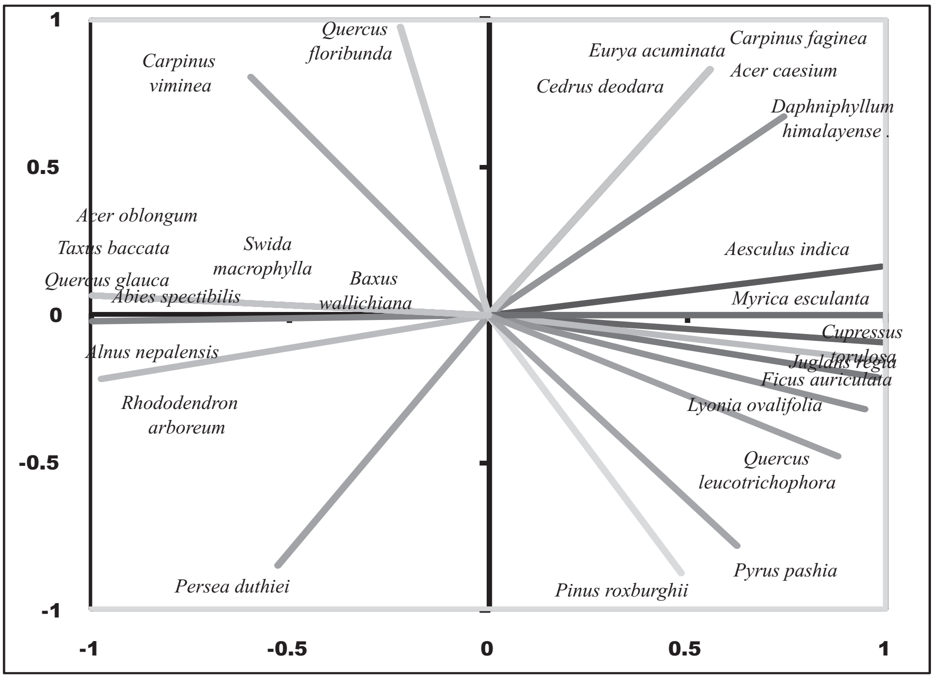

Fig. 1. Bi-plot of principal component analysis

cent. In present study, first two axes together accounted 100 percent variability. Plotting of correlation between species (Fig. 1) on PCA bi-plot revealed that all the species are well distributed at all the axes and there is no arching problem found in present study. Score of factor loading for different species at Bi-plot are presented in (Table 6). PCA bi-plot suggested that *Acer oblongum-Taxus baccata- Quercus glauca - Abies spectibilis-Baxus wallichiana-Swida macrophylla*; *Eurya acuminate-Carpinus gaginea-Cedrus deodara-Acer caesium*; and *Ficus auriculata- Juglans regia-Cupressus torulosa* are closely and positively associated with each other that suggested ongoing facilitation actions among them. However, species located on opposite direction at PCA bi-plot like *Cupressus torulosa-Abies spectiblis; Alnus nepalensis; Abies spectiblis-Myrica esculanta; Rhododendron arboretum-Aesculus indica* indicating competition mechanism between them. Both these mechanisms are quantitatively evaluated with new indices as described above.

Results of competition between subject and competitor species are depicted in Table 3. Present study identified only four potential competitor species and that were *A. spectibilis, M. esculanta, P. pashia* and *A. indica*. Higher CI value was recorded for competition between *A. spectibilis-M. esculanta* followed by *Q. glauca-M. esculanta*. Minimum competition was recorded for *R. arboretum-A. indica*. In present study Community Competition Value (CCV) was 1.96. Total 15 facilitation species were identified in present study. Values of facilitation index calculated for different species are presented in table 5 and these values ranges from 0.07-0.95, while CFV was 2.15.

Species richness is the basic measure of biodiversity at any spatial scale. Based on abundance information and distribution of each species, species-accumulation curves, species-abundance distributions (SAD) and diversity indices are usually calculated to compare species richness among communities or treatments. Many SAD models have been developed to understand the statistical structure of biological communities and to be able to predict un-sampled parts of the communities (Unterseher *et al.,* 2011). For example, geometric series predict extremely uneven abundances of organisms and found in species poor, often harsh environments, where a few species dominate in the community. Broken-stick distributions represent extremely even abundances; and lognormal and log-series models predict very low and very high proportions of rare species, respectively. In present study, altitude factor not affecting on rank/abundance model type and these results are opposite to the study as discussed by Gwali *et al.* (2010). Broken stick model in present study can be explained by the absence of rare species at all altitudes and such finding confirmed with study of Jose *et al.* (2014) and due to protective nature of sites (Vahid *et al.,* 2013).

The regional patterns of species richness are a consequence of many interacting factors, such as plant productivity, competition, geographical area, historical or

Table 2. Importance value index and total basal cover of various species

Name of the tree species	1650–1850		1900–2150		2200–2450	
	IVI	TBC	IVI	TBC	IVI	TBC
Abies spectibilis (D.Don) Mirl.	–	–	–	–	24.96	153.5
Acer caesium Wallich ex Brandis	–	–	7.74	24.5	–	–
Acer oblongum Wallich. Ex DC.	–	–	–	–	8.99	31.8
Aesculus indica (Wall. Ex Camb.) hook.f	16.64	78.1	21.45	96.0	–	–
Alnus nepalensis D. Don	39.39	155.0	16.24	40.2	18.01	191.1
Baxus wallichiana Baill,	–	–	–	–	11.70	57.7
Carpinus faginea Lindl.	–	–	7.29	37.9	5.85	28.9
Carpinus viminea Lidle.	–	–	22.37	63.2	17.78	49.6
Cedrus deodara	–	–	12.61	122.6	–	–
Cupressus torulosa D. Don in Lambert	20.71	111.1	10.29	95.0	–	–
Daphniphyllum himalayense Wall. Ex Steud.	53.07	70.5	49.31	185.8	15.78	47.4
Eurya acuminata DC	–	–	6.76	25.3	5.09	50.0
Ficus auriculata Lour.	7.58	53.9	3.80	24.0	–	–
Fraxinus micrantha Lingelsheim	–	–	–	–	8.51	22.8
Ilex dipyrena Wallich	–	–	–	–	10.97	33.7
Juglans regia L.	20.48	131.2	9.50	85.5	–	–
Lyonia ovalifolia (Wallich) Drude,	22.14	80.5	19.73	54.3	–	–
Myrica esculanta Buch–Ham. Ex D.Don,	9.11	38.0	7.06	56.4	–	–
Persea duthiei (King ex Kook.f.)	10.43	44.0	–	–	9.21	36.0
Pinus roxburghii Sargent	31.02	155.3	16.27	13.1	–	–
Pyrus pashia Buch–Ham, ex. D. Don	12.92	29.4	12.66	25.3	–	–
Quercus floribunda Lindley ex Rehder	–	–	30.72	14.6	33.85	158.5
Quercus glauca Thunb.	–	–	–	–	31.51	307.7
Quercus leucotrichophora A. Camus	34.40	220.5	20.70	13.1	51.21	257.6
Rhododendron arboreum Smith, Exot.Bot.	22.22	177.8	25.48	214.4	28.32	258.1
Swida macrophylla (Wallich) Sojak	–	–	–	–	4.13	21.7
Taxus baccata L.SSP	–	–	–	–	14.11	173.9

Table 3. Values of competition indices and community competition value

Subject Species	Competitor Species	CI	CCV
Cupressus torulosa	*Abies spectibilis*	1.17	1.96
Abies spectibilis	*Myrica esculanta*	2.52	
Alnus nepalensis	*Myrica esculanta*	1.08	
Carpinus viminea	*Pyrus pashia*	0.97	
Quercus glauca	*Myrica esculanta*	2.12	
Rhododendron arboreum	*Aesculus indica*	0.54	

evolutional development, regional species dynamics, regional species pool, environmental variables, and human activity. The variation of species richness along elevation gradients has been documented for a variety of taxa and geographical areas (Bhattarai and Vetaas, 2006). Two general patterns have emerged: a monotonic decrease in species richness (Stevens, 1992); or a hump-shaped relationship with a peak in species richness at intermediate elevations (e.g. Grytnes and Vetaas, 2002). From a review of the literature, Rahbek (1995) concluded that hump-shaped relationships are most common in both tropical and non-tropical biome. Rapoport's elevation rule (decreasing species richness towards higher elevations) suggested that species occurring at higher elevations must be able to withstand a broad range of climatic conditions and this leads to a wide elevation range. Contrary to this, Colwell and Hurt (1994) proposed a different hypothesis called 'hard boundary' or 'mid-domain effect' to explain mid-elevation peaks in species richness. They suggested that mid-elevation peaks in species richness arise because of the increasing overlap of species ranges towards the centre of the domain, as the extent of the elevation ranges of species is bounded by the highest and lowest elevations. Contrary to Rapoport's rule, the hard boundary hypothesis predicts that species ranges at higher elevations are narrow. In present

Table 4. GSVD and estimated total biomass of species at various altitudes

	A1		A2		A3		Total biomass
Species Name	GSVD	Biomass	GSVD	Biomass	GSVD	Biomass	
Abies spectibilis	–	–	–	–	93.71	170.42	170.4
Acer caesium	–	–	9.01	37.82	–	–	37.8
Acer oblongum	–	–	–	–	13.88	49.89	49.9
Aesculus indica	25.51	73.76	39.11	97.1	–	–	170.9
Alnus nepalensis	51.24	115.53	47.23	109.63	94.60	171.46	396.6
Baxus wallichiana	–	–	–	–	71.26	142.87	142.9
Carpinus faginea	–	–	51.68	116.16	–	–	116.2
Carpinus viminea	–	–	48.28	111.19	67.35	137.77	249.0
Cedrus deodara	–	–	14.46	50.45	–	–	50.5
Cupressus torulosa	51.39	115.76	48.92	112.13	–	–	227.9
Daphniphyllum himalayense	74.56	147.23	98.93	176.48	66.95	137.24	461.0
Eurya acuminata	–	–	56.03	122.37	–	–	122.4
Ficus auriculata	69.56	139.94	52.60	117.5	–	–	257.4
Juglans regia	91.96	168.36	80.07	151.76	–	–	320.1
Lyonia ovalifolia	49.92	113.61	30.77	83.22	–	–	196.8
Myrica esculanta	63.11	131.45	70.56	141.7	–	–	273.2
Persea duthiei	65.42	135.21	–	–	62.07	130.7	265.9
Pinus roxburghii	223.14	279.34	8.81	16.19	–	–	295.5
Pyrus pashia	58.66	126.04	18.8	28.7	–	–	154.7
Quercus floribunda	–	–	5.86	181.9	67.57	138.05	320.0
Quercus glauca	–	–	–	–	130.39	210.83	210.8
Quercus leucotrichophora	159.7	239.76	103.69	214.43	1018	179.83	634.0
Rhododendron arboreum	77.71	151.06	58.94	126.437	130.73	211.19	488.7
Swida macrophylla	–	–	–	–	54.87	120.74	120.7
Taxus baccata	–	–	–	–	100.58	178.36	178.4

study, higher species richness at the mid altitudinal levels was recorded and which is supported by study of Bhattarai and Vetaas (2006) where they reported higher richness at mid-elevations, and lesser at both ends of the gradient. However, different to their study, we found only slight decrease at the higher elevation level.

Shannon diversity index (H) values were also in consonance with the previously reported values for other temperate forests (1.69 to 3.40) by Gairola *et al.* (2011). In this study, altitude variables were non-significant for diversity (H index) and evenness. Previously Gairola *et al.* (2011) studied the structure and composition of tree vegetation along an altitudinal gradient in Garhwal Himalaya, India. In their study, highest and lowest TBA were recorded for *Aesculus indica* and for *Alnus nepalensis,* respectively and they summarized that anthropogenic disturbances like lopping, stem cutting, grazing, fuel wood collection, etc. are largely controlling TBA pattern in the Uttarakhand Himalaya. In present study highest TBA was recorded for *Quercus glauca* (307.7) followed by *Quercus leucotrichophora* and *Rhododendron arboretum* at A3 elevation that suggested higher productivity as well as limitation of anthropogenic impacts. Differ to Gairola *et al.* (2011) studies, in present study *Aesculus indica* TBA increases from lower to mid elevation but interestingly disappear at higher elevation however, TBA of *Alnus nepalensis* and *Quercus leucotrichophora* recorded higher at lower and higher elevations and surprisingly a declined was recorded at mid elevation. Such types of patterns suggested higher anthropogenic activities at mid level which largely affected to these two species. Across the Himalayan region distribution of *A. nepalensis* facing threats due to encroachment, degradation, over-exploitation and over-grazing as these are known threats to Himalayan moist montane forests. As this species is an important source of fuel wood and it burns well it may be threatened by over-collection by locals (Shaw *et al.* 2014). In present study IVI of *A. nepalensis* corroborate with studies of Sharma *et al.* (2009) from the Garwal Himalaya

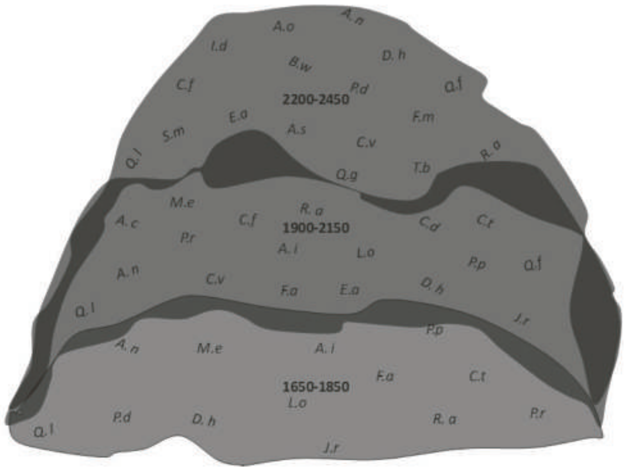

Fig. 2. Location of different species at three altitudes (names are correspond to table 2)

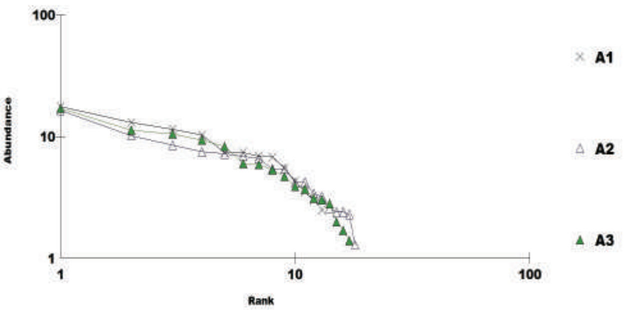

Fig. 3. Rank/abundance plot of species present at various altitudes

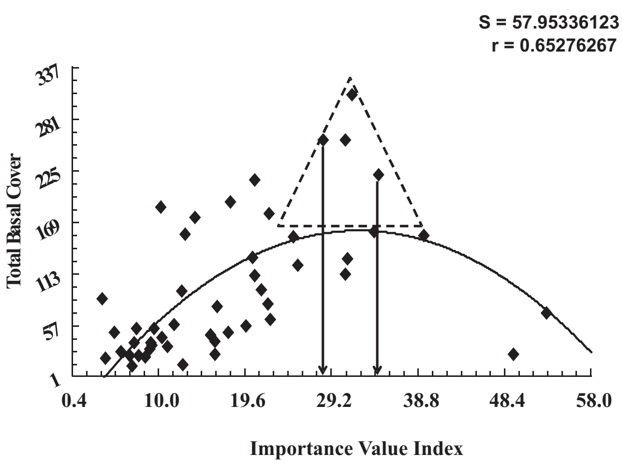

Fig. 4. Regression curve between importance value index and total basal cover

region and found higher IVI up-to 1700 altitude which depleted (16.57) at 2100 altitude.

Bhandari *et al.* (2000) found linear positive relationships between IVI and TBC of tree species at different altitudinal gradients in a montane forest of Garhwal Himalaya. Similarly polynomial relationships can be extracted between IVI and TBC from studies of Kumar *et al.* (2011) conducted for ethno-medicinal and ecological status of plants in temperate region of the Garhwal Himalaya, India. However, in present study humpback relationship between IVI and TBC was found indicating that TBC of different tree species increase with certain levels of IVI of different species and after a particular threshold TBC started to decline. In studies of Singh *et al.* (1994) and Gairola *et al.* (2011) on different forest types of the Kumaun region in Uttarakhand Himalaya, it was observed that live tree biomass of *Daphniphyllum himalayense, Quercus leucotrichophora* declined with altitudes. However, exception of this trend was exhibited by *Alnus nepalensis* and *Rhododendron arboreum* whose biomasses decreases from lower to mid level and further increases from mid to higher altitude.

Generally, interactions shift towards facilitation as stress increases (He *et al.,* 2013). For example, if the availability of a given soil resource declines along a spatial or temporal gradient, then facilitation or complementarily could increase if the plants interact in ways that improve the availability or uptake of that resource (Forrester, 2014). As productivity and leaf area increases, competition for light is also likely to become more intense and complementarily can increase if the plants interact in ways that improve light absorption (Forrester and Albrecht, 2014). Moreover, competitive interactions often become less severe in mixed-species communities (Mölder and Leuschner, 2014), and the negative effects of competition on adult tree growth are on average greater for shading than for crowding (Coates *et al.,* 2014). Associations among *Abies pindrow, Quercus semecarpifolia, Q. floribunda, Acer acuminatum. Q. semecarpifolia* and *Alnus nepalensis* in moist tropical montane valley slopes of the Garhwal Himalaya was reported Gairola *et al.* (2011).

Based on our criteria i.e. species with IVI values >15 treated as potential subject or competitor species; we got only four potential competitor *A. spectibilis, M. esculanta, P. pashia* and *A. indica*. Tree architecture, which can be represented by allometric relationships, is defined as the overall shape of the tree and the spatial position of its components, expressing morphological aspects, such as plant height, stem diameter and crown characteristics (Batista *et al.,* 2014). Thus, this component can be use to interpret the outcome of competition between subject and

Table 5. Facilitation indices and community facilitation value

Species		FI	CFV
Abies spectibilis	*Acer oblongum*	0.074436	2.15
	Baxus wallichiana	0.075062	
	Quercus glauca	0.075171	
	Swida macrophylla	0.075001	
	Taxus baccata	0.075129	
Acer oblongum	*Baxus wallichiana*	0.075062	
	Quercus glauca	0.075171	
	Swida macrophylla	0.075001	
	Taxus baccata	0.075129	
Acer caesium	*Carpinus faginea*	0.952941	
	Cedrus deodara	0.946108	
	Eurya acuminata	0.953202	
Carpinus faginea	*Cedrus deodara*	0.952941	
	Eurya acuminata	0.953202	
Cedrus deodara	*Eurya acuminata*	0.953202	
	Juglans regia	0.741509	
Ficus auriculata	*Juglans regia*	0.735238	
Swida macrophylla	*Taxus baccata*	0.751295	

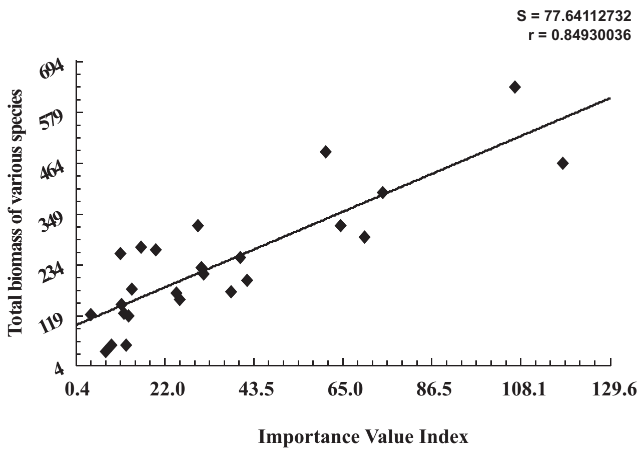

Fig. 5. Regression curve and total biomass of various species

Table 6. Variables of principal component analysis

Parameters	F1 axes	F2 axes
Eigen value	17.593	7.407
Per cent variance	70.372	29.628
Cumulative %	70.372	100.000
Abies spectibilis	-0.998	0.067
Acer caesium	0.557	0.831
Acer oblongum	-0.998	0.067
Aesculus indica	0.986	0.165
Alnus nepalensis	-1.000	-0.020
Baxus wallichiana	-0.998	0.067
Carpinus faginea	0.557	0.831
Carpinus viminea	-0.597	0.802
Cedrus deodara	0.557	0.831
Cupressus torulosa	0.996	-0.094
Daphniphyllum himalayense	0.743	0.669
Eurya acuminata	0.557	0.831
Ficus auriculata	0.977	-0.215
Juglans regia	0.988	-0.156
Lyonia ovalifolia	0.947	-0.322
Myrica esculanta	1.000	-0.002
Persea duthiei	-0.532	-0.847
Pinus roxburghii	0.487	-0.873
Pyrus pashia	0.626	-0.780
Quercus floribunda	-0.222	0.975
Quercus glauca	-0.998	0.067
Quercus leucotrichophora	0.877	-0.480
Rhododendron arboreum	-0.976	-0.218
Swida macrophylla	-0.998	0.067
Taxus baccata	-0.998	0.067

competitor species. Tree architecture may be an important factor and for example *Abies spectibilis* having more spreading and open canopy compared to *Cupressus torulosa* while *Myrica esculanta, Pyrus pashia* and *Aesculus indica* are broad leaf tree species and high canopy area compared to their subject species. Among the subject species *Alnus nepalensis* having cylindrical stem without any lateral extension. *Abies spectibilis* having needle leaves compared to *Myrica esculanta* and this structural deference's in photosynthetic unit reflected in biomass of their respective trees and thus we got highest competition index value (2.52). Similarly, *Rhododendron arboretum* and *Aesculus indica* having more or less similar tree architecture and that's why they have minimum competition.

Two mechanisms have been proposed to be associated with positive interactions. The first is facilitation, i.e. one species promoting the growth or survival of the others (e.g. improvement of abiotic conditions), and the second is niche complementarity (or niche segregation), i.e. a better or less competitive use of ecosystem resources between species having different functional traits (e.g. a shade-tolerant species growing with an intolerant one). Study of Rio *et al.* (2013) evidenced the presence of significant temporal shifts between competition and facilitation in mixed forests of beech–oak and beech–spruce in Central Europe. In high growth years there was an increase in between-species competition in mixed stands, while in low-growth years inter-specific interactions tended towards facilitation or/and complementarity, resulting in lower growth reduction than in the respective pure stands. These shifts agree with the general pattern predicted in the 'stress gradient hypotheses, but using a temporal stress gradient instead a spatial one. Further, Gimeno *et al.* (2015) suggested that the net effect of facilitation under different stress levels depends on the competitive ability of the interacting plants, i.e. tolerant vs. competitive, and the type of stress imposed, i.e. resource vs. non-resource. In present study, facilitation between species can concluded with their structural and functional trait values. Further these species having the niche sharing or niche partition tendencies which ultimately unable them to associate with each other and thus leading to more stable habitat.

CONCLUSION

The distance independent and indirect indices approaches have potential to evaluate such interactive mechanisms specifically inhabiting at hilly terrain where position of relative angular placement of different species, height or other parameters are difficult to estimate. Further identification and quantification of such interactions have practical values for habitat management and for restoration programmes.

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Wild Edible Plants: A Viable Option for Sustaining Rural Livelihood in Western Himalaya

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Abstract: The present study aims to provide information on widely used wild edible plants by rural inhabitants of Western Himalaya. Information was collected from rural inhabitants on various uses of wild edible plants classified as processed parts, vegetables cooked, cold drinks, condiment, chutneys, raw fruits and grain or seed. In total, 41 wild edible plant species were recorded into 30 families and 36 genera that have been traditionally consumed by the rural inhabitants of the study area. *Moraceae* and *Rosaceae* were the most dominant families used as wild edibles by rural inhabitants. The most commonly used plant part was fruit while nectar and bulb was consumed least.

***Keywords*:** Provisioning service, Traditional knowledge, Nutritional value, Wild leafy, Local culture

Wild edible plants (WEPs) are the plants that grow within natural or semi-natural situations and can exist independently of direct human interference (Shumsky *et al*., 2014). Wild edible plants are locally utilized to supplement diet on the premise of indigenous knowledge (Pardo-De-Santayana *et al.,* 2005) that have been an fundamental part of daily routine of human diet all through history and worldwide (Schulp *et al.,* 2014; Reyes-Garcia *et al.,* 2015). The tradition of gathering plants for various uses exists among different native groups around the world (Maikhuri *et al.,* 2004). WEPs are a low-input, alternative for nutrition and reduce the need to spend limited capital assets (Shackleton and Shackleton, 2004) as they provide more advantages to vulnerable populations (Grivetti and Ogle, 2000), who are often influenced by climatic adversities (Eriksen and O'brien, 2007). WEPs serves a part of diet and are still consumed along with staple food crops in countries such as China, India, Thailand and Bangladesh (Mazhar *et al.,* 2007). Wild edibles have crucially contributed in filling food gaps during hardships and nutritional security of people living in harsh climatic conditions (FAO, 2004).

Many ethno-botanical investigations on WEPs reported that more than 7,000 species have been utilized as nutrient supplement throughout the human history (Grivetti and Ogle, 2000). Role of WEPs as source of energy and micronutrients (Afolayan and Jimoh, 2009) illustrate the intimate association between utilization of WEPs and the diets of human beings, consequently wild edibles can be considered as useful resources to accomplish food security (Shumsky *et al*., 2014). Since traditional knowledge of wild edibles is disintegrating through cultural assimilation and the loss of plant biodiversity with indigenous people and their cultural background, it is therefore essential to encourage research on wild edible plants with a specific goal to preserve the information for coming generations (Giday *et al.,* 2009). The aim of the present study was to document ethno-botanical knowledge related to traditionally used wild edible plants for food and nutrient supplement.

MATERIAL AND METHODS

Study area: Uttarakhand (28˚43' and 31˚28' N latitude and 77˚49' and 81˚03' E longitude) a mountainous state situated in the central part of the India, shares its boundary with China in the north and with Nepal in the east. The state encompasses an area of 53,483 sq. km, which represents almost 15.5% of the total geographical area of Western Himalaya and 1.63% of the country. According to FSI (2015) the forest area of the state is 24,240 km^2 which represent 45.32% of its geographic area. The present study was conducted in Pauri Garhwal district of Uttarakhand. The climate of the study area can be differentiated into three particular seasons, namely summer (April–June), rainy (July–September), and winter (November–February). The rainfall pattern in the region is generally administered by the monsoon rains (July–September), which represent around 60-80% of the annual rainfall (Sharma *et al*., 2009). The inhabitants of the area have agro lifestyle and depend mainly on long-established practice of rainfed cropping system. Vegetation varies with respect to elevation and climatic conditions, from tropical deciduous forest in the foothills to Himalayan temperate forest at middle altitudes, coniferous, sub-alpine and alpine forest at higher elevations.

Sampling technique: The study was carried out to understand the role of wild edible plants in supporting livelihoods of rural people of Western Himalaya. Multistage random sampling technique was used to gather information by conducting interviews with regard to wild edibles consumed by inhabitants of villages in close proximity to the forest. The interviewers selected were elderly people who had spent most of the time in the area, and were traditional farmers. The information on 41 wild edible plants consumed by inhabitants was recorded after regular field visits and by interacting with the people in between May 2014 and June 2015.

Semi-structured interviews: Primary data was collected from 230 randomly selected households by using different tools such as semi-structured interviews supplemented by field notes followed by group discussions and field observations. In each household, data was collected from the household head or oldest person by making them aware of the scope of the study through prior oral consent. The interviews were conducted at the informant's house in Hindi or local dialect (Garhwali) by the first author supported by second author, depending on the informant's language, in which the first author was conversant. The questions were based on the requirements of the study and on information extracted from general discussions with inhabitants. The interviewees were asked to speak freely about the local name of plants, plant parts used, frequency of use, form of consumption and mode of consumption to document information on wild edible plant species from the local culture to improve knowledge on food and medicinal uses of the species.

Botanical identification: The herbarium specimens were gathered from adjoining forests with the assistance of local inhabitants having sound learning of the plants. Collector number was assigned to each of the gathered plants beginning from 101 in the field itself. To verify the authenticity of claims, collected plant specimens were cross-checked in different areas from local inhabitants either by showing the plant specimen or telling local names of plants and were rechecked for proper identification using available literature (Gaur, 1999). The conservation status of the species has been provided according to Nayar and Sastry (1987).

RESULTS AND DISCUSSION

The result of the present study shows that people residing in rural Himalayan region consume a wide variety of wild fruits, vegetables, and roots and tubers from nearby forest areas. The present study provides information on about a total of 41 wild edible plants were recorded into 30 families and 36 genera that have been traditionally consumed in the area by rural inhabitants with most of the plants belonging to family *Moraceae* and *Rosaceae* (Table 1). Most wild edibles and their parts were gathered and prepared during rainy season, while other wild food plants particularly fruits were collected during winter and summer. The most commonly used plant part was fruit while nectar and bulb was least consumed by the inhabitants (Fig. 1). The study results also revealed that 24 wild edible species were used frequently while 12 species were rarely used and 5 species were used occasionally. On the basis of form of consumption most used part was fruit (24 species) followed by vegetable (13 species), grain, flower, chutney (2 species each), kernel, nectar, condiment (1 species each). The use of wild edibles on the basis of mode of consumption were consumed fresh/raw/salad (27 species) followed by cooked part (14 species), dried, processed part (6 species each), drink, pickle (2 species each), roasted, sale (1 species each).

Most commonly utilized plant based on consumption mode was *Mangifera indica* followed by *Phyllanthus emblica*, *Carrisa opaca*, *Cannabis sativa*, *Rhododendron arboreum*, *Ficus palmata*, *Ficus roxburghii*, *Myrica esculenta* and *Rubus ellipticus.* In addition to nutritional value, some of the species such as *Diplazium esculentum*, *Ficus spp.*, *Myrica esculenta*, *Rhododendron arboreum* and *Morchella esculenta* are marketable and might offer the opportunity to complement household income in the study area. Bhati and Jain (2016) in their study also reported that the people in tribal localities utilize forest produce not only just for consumption purpose but also for selling in the local market to generate income and sustain livelihood. But however because of lack of awareness in the study area about the economic value of WEPs, has restrained their use to only consumption need.

Homervergel *et al.* (2015) has also mentioned in his study that mostly young plant parts such as leaves and shoots are preferred as vegetables for their more pleasant flavor and delicate texture. Ryang *et al.* (2004) has highlighted that most of the plants used by people are gathered from open fields while few are collected from nearby mountainous areas. The collection of wild leafy edibles has been also reported to be collected in early spring in various studies (Hadjichambis *et al.,* 2008; Homervergel *et al.,* 2015). WEPs offers various advantages to maintain household food security which vary by the type of foods collected and the reasons for their harvest due to seasonal availability and nutrition (Nordeide *et al.,* 1996). Wild edible plants persist to be consumed in many parts of the world, not only in subsistence-oriented economies but often also in rural and even in urbanized countries (Bharucha and Pretty, 2010) for income generation (Lukasz *et al.,* 2013) and food security (Redzic, 2010; Vinceti *et al.,* 2013).

Wild edible plants have remained more important in countries in which wild food is important in the traditional

Table 1. Wild edible plants consumed by the inhabitants of the Western Himalaya

Family and plant botanical name	Collector No. assigned	Local name	Gathering season	Part(s) consumed	Use frequency	Consumption form	Consumption mode	Conservation status (Red data Book)
Anacardiaceae								
Mangifera indica	128	Aam	May–June	Fr	Frequent	fru, veg	fr, ck, pi, pp	–
Rhus parviflora	122	Tungla	July–November	Sd	Rare	fru	fr	–
Apocyanaceae								
Carrisa opaca	138	Karunda	March–April	Fr	Frequent	fru, veg	fr, ck	–
Araceae								
Colocasia esculenta	189	Pindalu	November–April	Lf, Rh	Frequent	veg	ck	–
Athyriaceae								
Diplazium esculentum	192	Lingra	Late summer to rainy	Lf	Frequent	veg	ck	Least concern
Berberidaceae								
Berberis asiatica	112	Kingora	June–July	Fr	Frequent	fru	fr	Vulnerable
Bombacaceae								
Bombax ceiba	147	Semal	March–April	Bd	Frequent	veg	ck	Near threatened
Caesalpiniaceae								
Bauhinia variegata .	151	Kweral	March–April	Bd	Frequent	veg	ck	Least concern
Cannabiaceae								
Cannabis sativa	166	Bhang	September–October	Sd	Rare	gr	ro, dr	–
Combrataceae								
Terminalia chebula	149	Haida	October–December	Fr	Occasional	fru	fr	–
Dioscoreaceae								
Dioscorea belophylla	190	Tairu	October–January	Rh	Occasional	veg	ck	–
Dioscorea bulbifera	187	Genthi	September–January	Blb	Rare	veg	ck	–
Ericaceae								
Rhododendron arboreum	175	Burans	March–April	Fl	Frequent	flo	fr, drnk	Vulnerable
Euphorbiaceae								
Phyllanthus emblica	115	Aonla	September–October	Fr	Frequent	fru	fr, pi, pp	–
Juglandaceae								
Juglans regia	107	Akhrot	August–October	Fr	Frequent	ker	dr	–
Linaceae								
Reinwardtia indica	146	Phionly	November–December	Fl	Rare	flo	fr	–

Cont...

Lythraceae								
Woodfordia fruticosa	171	Dhaula	May–July	Ne	Frequent	nec	fr	–
Moraceae								
Ficus palmata	164	Bedu	June–August	Fr	Frequent	fru, veg	fr, ck	Least concern
Ficus roxburghii	156	Timla	June–July	Fr	Frequent	fru, veg	fr, ck	Least concern
Ficus semicordata	191	Khaina	June–October	Fr	Frequent	fru	fr	Least concern
Ficus subincisa	154	Chanchari	March–June	Fr	Rare	fru	fr	–
Morus serrata	141	Shatoot	April–June	Fr	Frequent	fru	ck	Vulnerable
Morchellaceae								
Morchella esculenta	196	Guchii	May–June	Fr	Frequent	veg	ck	–
Myricaceae								
Myrica esculenta	136	Kaphal	April–June	Fr	Frequent	fru	fr, sl	Vulnerable
Myrtaceae								
Syzygium cumini	142	Jamun	March–April	Fr	Frequent	fru	fr	–
Oxalidaceae								
Oxalis corniculata	143	Khatti buti	Throughout year	Lf	Occasional	chtn	fr	–
Pinaceae								
Pinus roxburghii	116	Kulah	March–June	Sd	Occasional	gr	dr	–
Poaceae								
Dendrocalamus hamiltonii	198	Bans	Late rainy season	Rh	Frequent	veg	ck	–
Polygonaceae								
Rumex hastatus	144	Almoda	June–August	Lf	Rare	chtn	fr	–
Rhamnaceae								
Zyziphus mauritiana	120	Ber	November–December	Fr	Frequent	fru	fr	–
Rosaceae								
Fragaria nubicola	193	Ghanyakaphal	June–July	Fr	Occasional	fru	fr	–
Prunus armeniaca	170	Chullu aaru	Late March to early April	Fr	Frequent	fru	fr	–
Pyrus pashia	188	Melu	May–December	Fr	Rare	fru	fr	–
Rubus ellipticus	186	Hisola	Early rainy season	Fr	Frequent	fru	fr, drnk	Near threatened
Rubus nivens	195	Kala hisola	September	Fr	Frequent	fru	fr	Least concern
Rutaceae								
Aegle marmelos	125	Bael	June–July	Fr	Rare	fru	pp	Vulnerable
Murraya koengii	139	Curry patta	June–October*, throughout year	Fr, Lf	Rare	fru, con	fr	–

Cont...

Solanaceae								
Solanum nigrum	194	Ghinway	November–December	Fr	Rare	fru	fr	–
Tiliaceae								
Grewia optiva	165	Bhuial	August–November	Fr	Rare	fru	fr	–
Ulmaceae								
Celtis australis	197	Khadik	September–October	Fr	Rare	fru	fr	–
Urticaceae								
Urtica dioca	183	Kandali	June–August	Lf	Frequent	veg	ck	–

Part(s) consumed: Lf–leaf, Fr–fruit, Sd–seed, Rh–rhizome, Fl–flower, Bd–bud, Ne–nectar, Blb –bulb
Consumption form: veg–vegetable, con–condiment, gra–grain, fru–fruit, ker–kernel, nec–nectar, chtn–chutney, flo–flower
Consumption mode: ck–cooked/boiled, fr–fresh/raw/salad, ro–roasted, pi–pickle, dr–dried, pp–processed products, drnk–drink, sl–sale
*Denotes collection season for fruit of *Murraya koengii*

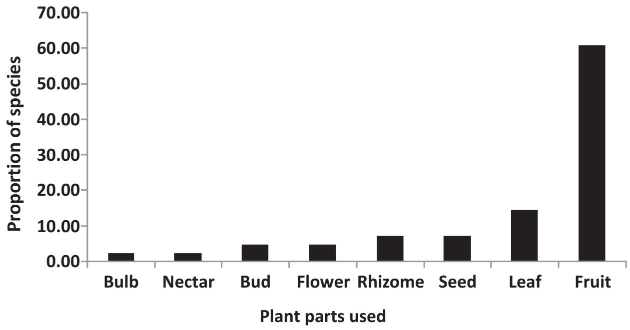

Fig. 1. Proportion of wild edible plant species by parts used

cuisine, as opposed to countries where traditional cuisine is primarily based on agricultural products (Schulp *et al.,* 2014). But even in everyday conditions, wild plants have played an important role in complementing staple foods to provide a balanced diet by supplying trace elements, vitamins and minerals, and can accomplish at the time of crisis too (Tardio *et al.,* 2006). Wild foods are utilized persistently by food–insecure households to supplement nutrition, increase food volume, and stave off starvation (Harris and Mohammed, 2003). Traditional Knowledge plays an important role in WEP harvest and consumption because it is difficult to collect, prepare and consume wild foods without knowledge of their habitat, toxicity, or seasonal availabilty (Shumsky *et al*., 2014). Availability of WEPs motivates their use, with the most popular species being the one growing in the locality (Pardo–De–Santayana *et al.,* 2005). The growing interests in the use of wild food plant resources nowadays may additionally have emerged from efforts to discover substitutes for the industrialization and globalization of farming practices, and to provide food security during adverse periods (Turner *et al.,* 2011).

CONCLUSION

In spite of the significant usage of WEPs in the study area, ethno–botanical information concerning local knowledge of these plants is restricted to the older generation, and the older people tend to know more about the native wild vegetation. In present scenario the younger generation is much less familiar with traditional uses of wild plants may be due to urbanization and societal transformations, which has lead to the lack of traditional knowledge associated with the species and consequently poses danger to rural poor who relied on these relatively easily accessible food plants. Thus the study concluded that traditional knowledge can be important entry point and vital information for further research on and development of wild edibles. The insights of the study was capable to explain that the way of life of gathering and consuming wild edible plants among the inhabitants of

Western Himalaya continues to be alive, and the natural environment of the region has the potential to offer considerable source of wild food plants. The present study provides a realistic instance of use and research on wild edibles which can probably assist policy makers in linking socio‑economic development of rural population with biodiversity conservation regionally and nationally.

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Impact of Climate Change on the Proliferation of Invasive Alien Plant Species in Almora district of Uttarakhand Himalaya

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Abstract: A total of 16 invasive alien species belonging to 9 families have been recorded based on field observations and people perceptions. The maximum invasive alien plant species (IAS) were herbs (87%, 14 taxa) followed by shrubs (6.25%) and trees (6.25%). Most of invasive alien flora were belonged to Asteraceae and was most dominant family with 6 taxa. The highest percentage (43.75%, 7 taxa) of invasive alien flora was found up to altitudinal gradient of 2100 meters. Findings also revealed that climate change have been major impact on range shifting, distribution and proliferation of IAS. Findings revealed that local communities were aware about major invasive alien plants and their impact on forest resource and agriculture productivity in their locality. Some IAS were invaded and proliferated progressively in the study area and respondents observed that these plant species had grown in their locality over past 10‒15 years, having previously been confined to lower altitude, they believed that the invasion of these plants species was due to the anthropogenic activities (deforestation, habitat fragmentation, land degradation, etc.) and changing climatic conditions. Findings also revealed that IAS especially *Ageratum, Lantana, Eupatorium, Parthenium* and *Urena lobata* was major threats to forests resources especially herbaceous flora, agriculture productivity and hence socioeconomic status of local inhabitants. It was found that forest sites with high IAS covers contains little understorey herbaceous vegetation as compared to sites having low IAS.

***Keywords*:** Alien invasive species, Climate change, Proliferation, Almora, Uttrakhand

Climate change has emerged as one of the most serious challenge for 21st century. Temperature projections for the 21st century suggest a significant acceleration of warming over that was observed in the 20th century (Ruosteenoja *et al.,* 2003). In Asia, it is very likely that all areas will warm during this century. Based on regional climate models, it is predicted that the temperature in sub‒continent will rise between 3.5 and 5.5˚C by 2100 (Kumar *et al.,* 2006).Various studies suggest that warming in the Himalayas has been much greater than the global average of 0.74˚C over the last 100 years (IPCC 2007; Du *et al.,*2004). In case of Almora, Uttarakhand average temperature increased by 0.46°C in last 53 years from 1955‒2007 (UCOST, 2012), In view of this, it is likely that the fragile Himalayan ecosystem and its components will be impacted considerably by changing climate. Climate change has been affecting the physiology and biological characteristics of Himalaya modifying their ecosystem structure and functioning. The Himalayan region is facing loss of species diversity, water resources, upward shifting of vegetation line and arrival of new species. Climate change contributes to erratic rainfall, drying up of local springs and streams, adjustment of species distribution, phenology and morphology, shift in agriculture calendar, emergence of invasive species and outbreak of diseases and pests (IPCC, 2007).

Biological invasion is recognized as one of the most serious global threat to natural ecosystem (Pysek and Richardon, 2010) .The effects of invasive plants on species diversity of plant communities showing either a positive or negative relationship, invasive plants primarily had negative effect on plant diversity when they become abundant at a much lower cover level compared with native plants (Qi *et al.,* 2014). It is estimated that biological invasions can have strong effects on structure and function of ecosystems that are responding to a changing climate and climate change is also changing the context in which potential invasive species succeed or fail (Husain and Agnihotri, 2009). Invasive alien species threaten the environment, economies, and human welfare (Lodge *et al.,* 2006). They reduce biodiversity, replace economically important plant species and increase the investment in agriculture and silviculture (Ricchardi *et al.,* 2000). Uttarakhand Himalaya is also experiencing changes in climatic related parameters (Pratap, 2013). A total of 190 invasive alien species under 112 genera, belonging to 47 families have been recorded in the Indian Himalayan region and 163 invasive species in Uttarakhand (Sekar, 2012). Altitudinal shift in vegetation has also been observed by Bhardwaj (2017) in Chail wildlife sanctuary. Data was generated to explore the status of invasive plant species and their impact.

MATERIAL AND METHODS

Almora district of Uttarakhand is located between 29˚37'N to 29˚62'N latitudes and 79˚40'E to 79˚67'E longitudes, with an altitude of 1651 meters. The area is situated on a ridge at the southern edge of the Kumaun hills of the central Himalaya, having an area of 3090 km^2. The climate of Almora is characterized by relatively high temperature and evenly distributed precipitation throughout the year. The main seasons are summer (March –June), Monson season (July –November) and winter (December –February).

For the present study, data was collected by household survey, ecological and by review of available literature. A field visit was made in January – April 2016 and a total of 120 individuals were interviewed during a household questionnaire survey. A total of 120 households were selected randomly from 12 villages of two blocks namely Halbawgh and Lamgarah of Almora district (6 villages from each block and 10 household from each village). For the questionnaire based study household head above the age of 40 were selected. The questionnaire included questions like invasive introduction, causes of introduction, impact of invasive species in forest and agriculture fields.

Ecological assessment by phytosociological methods: Ecological assessment was carried out in 36 different sites at different altitudes (from 1200–2100 meters) and aspect of forests of two Blocks Halbawgh and Lamgarha of Almora district. The Phytosociological data were collected by laying 10x10m quadrate (Misra, 1968). A *vegetation analysis* was carried out for shrub and herb layer in the year July 2014–August 2016 by using Random quadrat sampling method. A total of 36 stands were investigated on the basis of aspect and altitude. Each 10x10 on quadrat were having two 5x5m subqudrats for enumeration shrubs (*Lantana camera*) and four 1x1m for herbs (*Ageratum, Biden, Eupatorium* and *Parthenium*). After collection of vegetation data, the data was assessed for density, frequency (Curtis and McIntosh, 1950).

RESULTS AND DISCUSSION

Status of Invasive alien plant species in study area: A total of 16 taxa belonging to 16 genera and 9 families have been recorded as invasive alien plants in Almora district of Uttarakhand Himalaya based on both field observation and people perception (Table 1). Among these, 87% are herbs, 6.25% and 6.25% shrubs and trees, respectively. Among these about fifty per cent of invasive alien plant species are native to tropical America. The Australia, South America, Mexico, Brazil, Europe, Tropical North, Tropical Africa, Tropical South America sources contributed 6.25% each. Among life forms herbs constituted 87% (14 taxa) viz *Ageratum conyzoides, Biden pilosa Conyza canadensis, Datura stramonium, Euphorbia hirta, Galinsoga parviflora ,Impatiens balsamina, Ipomoea muricata, Mimosa pudica, Oxalis corniculata, Parthenium hysterophorus, Urena lobata and Youngia japonica.* Whereas, trees and shrub were represented by one species each viz Acacia dealbata and Lantana camara, respectively. Most of invasive alien flora belonged to Asteraceae and was most dominant family with 6 taxa; Mimosaceae with 2 taxa; Solanaceae Euphorbiaceae, Balsaminaceae, Convolvulaceae, Verbenaceae, Oxalidaceae and Malvaceae with one species each. The altitudinal analysis of IAS shows that the highest percentage (43.75%) of invasive alien flora was found up to

Table 1. Invasive Alien plant species of Almora district of Uttarakhand, India

Name of species	Family	Nativity	Life form	Altitude (in meters)
Acacia dealbata Link	Mimosaceae	Australia	Tree	Up to 2,100
Ageratum conyzoides L.	Asteraceae	Tropical America	Herb	Up to 1,800
Biden pilosa L.	Asteraceae	Tropical America	Herb	Up to 2,100
Conyza canadensis (L.) Cronquist	Asteraceae	South America	Herb	Up to 2,100
Datura stramonium L.	Solanaceae	Tropical America	Herb	Up to 2,100
Eupatorium adenophorum Spreng.	Asteraceae	Mexico	Herb	Up to 2,100
Euphorbia hirta L.	Euphorbiaceae	Tropical America	Herb	Up to 1,950
Galinsoga parviflora Cav.	Asteraceae	Tropical America	Herb	Up to 1700
Impatiens balsamina L.	Balsaminaceae	Tropical America	Herb	Up to 1,250
Ipomoea muricata (L.) Jacq.	Convolvulaceae	Tropical America	Herb	Up to 1,800
Lantana camara L.	Verbenaceae	Tropical America	Shrub	Up to 1,800
Mimosa pudica L.	Mimosaceae	Brazil	Herb	Up to 2,100
Oxalis corniculata L.	Oxalidaceae	Europe	Herb	Up to 1,950
Parthenium hysterophorus L.	Asteraceae	Tropical North America	Herb	Up to 1350
Urena lobata L.	Malvaceae	Tropical Africa	Herb	Up to 2,100
Youngia japonica (L.). DC.	Asteraceae	Tropical south America	Herb	Up to 1,700

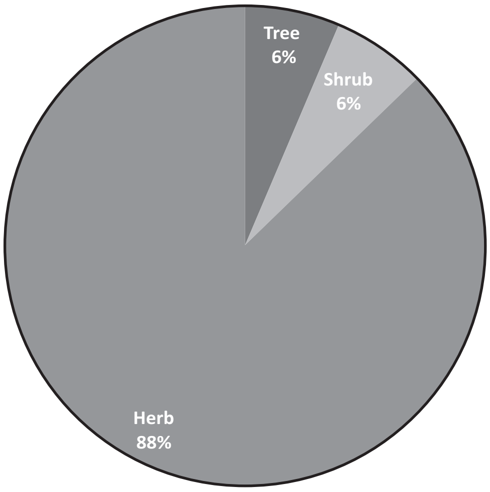

Fig. 1. Life forms of invasive species

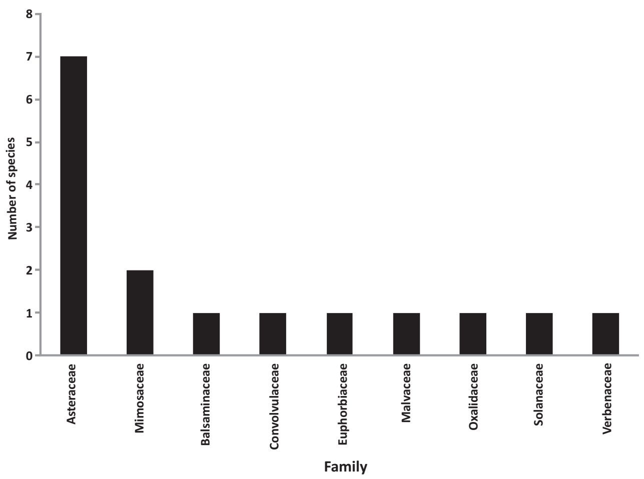

Fig. 2. Nine dominant families of invasive species

altitudinal gradient of 2100 meters with (7 taxa), the altitude up to 1800 and 1950 obtained highest of 30.80% (5 taxa), 12.5% for 1250 meter, whereas, as up to altitudinal gradient of 1700m and 1350m, 6.25% each invasive flora was found.

Distribution and impact of alien invasive plant species on native plants: Climate change appears to be affecting distribution, range shifting and proliferation of IAS. Literature survey revealed that IAS had grown in study area over past few decades, having previously been confined to lower altitude as they prefer warmers conditions (Priyanka and Joshi, 2013). Among the 16 IAS the tropical American species especially *Ageratum conyzoides, Eupatorium adenophorum, Lantana camara* and *Parthenium hysterophorus* were found to be very troublesome that impact negatively to the native plant diversity. It was found that forest sites with high IAS covers contains little herbaceous vegetation as compared to sites having low IAS forest sites. Alien invasive species has impacted negatively on all parameters of plant community viz plant species composition, richness, diversity, abundance and were responsible for decreasing/deteriorating about 15 species. Furthermore, the forests with more diversity was less affected than less diverse forest except *Eupatorium adenophorum,* which was abundant even in highly diverse forests (Fig. 4).

People perceptions about alien invasive plant species (AIPS): Data analysis revealed invasion of new weeds in their locality (agricultural fields, forest areas, roadsides). The respondents were aware about eight most common invasive weeds viz *Eupatorium* (80.55%), Ageratum (47.22%), *Biden pilosa* (88.88%), *Parthenium hysterophorus* (19.44%), *Lantana camera* (19.44%), *Euphorbia hirta* (13.88%) *Urena lobata* (16.66%) and *Conyza canadensis* (38.88%) as these are invaded and proliferated in their locality very rapidly. The Invasive alien species spread aggressively in their locality and were commonly cited as major threat to crop production and forest resources. In agriculture field, IAS replaced native grasses (*Binmosia, Junadia, Chundia*, etc.) and also adversely impacted on agriculture crops such as rice, wheat, pulses, vegetables, etc. IAS replaced valuable fodder

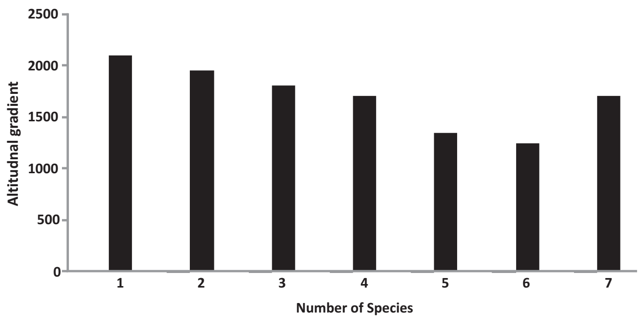

Fig. 3. Altitudinal range of IAS

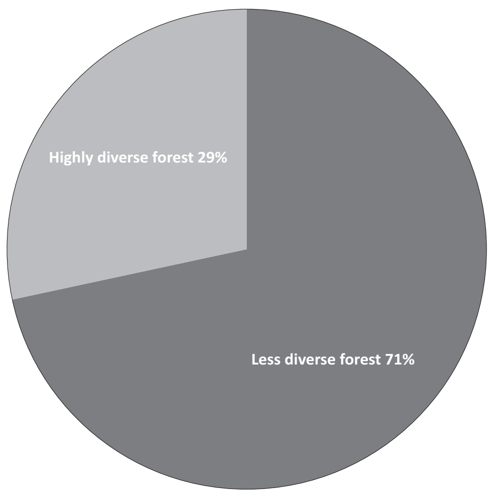

Fig. 4. IAS % in less diverse and highly diverse forests

Table 2. Invasive species impact field, range of impact and their proliferation

Name of invasive species	Impact at	Impact range on agriculture field, forest and roadside areas		Range of density ha^{-1}	Frequency (%)
		Based on people perception	Based on field observations		
Acacia dealbata	Forests	–	Least	10–30	8.33
Ageratum conyzoides	Agriculture fields, forests, roadsides	High	High	2500–56500	47.22
Biden pilosa	Agriculture fields, forests, roadsides	High	Moderate	200–39250	88.88
Conyza canadensis	Forests	–	Least	750–30000	38.88
Datura stramonium	Agriculture fields, forests, roadsides	moderate	Least	1250–2250	5.55
Eupatorium adenophorum	Agriculture fields, forests, roadsides	High	High	1250–41750	80.55
Euphorbia hirta	Forests	–	Least	3250–34500	13.88
Galinsoga parviflora	Agriculture fields, forests, roadsides	Moderate	Least	2250–14250	2.77
Impatiens balsamina	Forests	–	Least	12750	2.77
Ipomoea muricata	Forests	–	Least	1750	2.77
Lantana camara	Agriculture fields, forests, roadsides	High	High	60–720	19.44
Mimosa pudica	Forests	–	Least	1750–8250	8.33
Oxalis corniculata	Forests	–	moderate	750–21000	44.44
Parthenium hysterophorus	Agriculture fields, forests, roadsides	High	High	3750–23500	19.44
Urena lobata	Agriculture fields, forests, roadsides	Moderate	High	1500–11250	16.66
Youngia japonica	Forests	–	Least	1250–4000	5.55

grasses resulting food scarcity in study area. Invasive plants were generally non-edible and poisonous for cattle. IAS impacts humans too when they comes with in to contact with them. Respondents observed that they are becoming host of various diseases viz Malaria, Allergic problems, viral Fever, respiratory problems when they live in and around Alien invasive plants. IAS had grown in their locality over past 10–15 years, having previously been confined to lower altitude. According to people, the main causes of invasion and proliferation of Invasive alien species in their locality were due to anthropogenic activity (forest fire, land degradation, deforestation, fragmentation) and persistent changes in climate viz., increasing temperature and decreasing rainfall. Climate change results invasion of new species were already reported by several studies (Bhausl, 2009).

CONCLUSION

Findings revealed that invasive alien species were invaded and proliferating very aggressively in study area and were threat to native plant species and livelihood. Impact of IAS was observed especially in forest and agriculture land. Most of invasive alien flora belonged to Asteraceae and was most dominant family. Findings revealed impact of climate change on range shifting, distribution and proliferation of IAS. Local communities were aware about major invasive alien plants and these plant species had grown in their locality over past 10–15 years. It was observed that forest sites with high IAS covers had little understorey herbaceous vegetation as compared to sites having low IAS.

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Assessment and Management of the Effects of Illegal Grazing on River Water Quality in Old Oyo National Park, Nigeria

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Abstract: Old Oyo National Park (OONP) is a protected area gazetted to protect and conserve biological diversity while maintaining cultural values of the supporting communities. Nevertheless, there is a conflict of interest between meeting the objectives of the park and the livelihood of the supporting communities. This study aims to analyse river water quality in OONP with respect to grazing activities carried out by local communities in and at the fringes of the park and evaluate the management strategies used by the park management. Questionnaire survey, Key Informant Interview, field survey, laboratory analysis and secondary data obtained from OONP management were used to achieve the objectives of the study. Total coliform ranged from $0.09 \times 10_5$ and $6.4 \times 10_5$ cfu/ml. while coliform count was <2 MPN/100ml. Microorganisms identified were *Aspergillus fumigates, Psedomonas* sp., *Shigella* sp. and *Aspergillus flavus*. Zoning of OONP, law enforcement, conservation education and support zone development projects were identified as the major strategies used to combat illegal grazing. The river water quality in the buffer and core zones were affected by illegal grazing. It is recommended that the park management conduct a periodic assessment of river water quality as a means of monitoring the ecosystem health. Grazing lands should be located far away from the Park and illegal grazers should be prevented from entering the park.

Keywords*:* Grazing, Old Oyo National Park, Water Quality, Nigeria

Old Oyo National Park (OONP) was established by Decree 36 of 1991 with the objectives of biodiversity conservation, preservation of gene pool and protection of wetlands and catchment areas while promoting cultural values through ecotourism. While the local community need wildlife resources for income generation and nutritional requirement, the interest of the park manager is to conserve biodiversity for posterity and sustainability. Wild animal health is majorly impacted by anthropogenic activities. In a situation where air, water or soil is negatively affected, wild animal population and abundance is threatened. There is therefore the need to assess the impacts of human activities on wildlife resources and their habitat. Various researches had focused on the effects of human activities on different species of wild animals, their distribution, abundance, populations, foraging pattern and ecotourism. Akinyemi and Kayode (2010) stated that agricultural practices have resulted into local migration of ungulates to core zones in Old Oyo National Park, Nigeria. However, only few studies have emerged on the effects of illegal grazing on water quality in park.

Runoff from pastoral land generally degrades water quality. Under intensive farming practices where inputs, nutrient recycling rates and stocking densities are high, runoff significantly pollutes surface water. Monaghan *et al.* (2007) and Ajibade *et al.* (2008) found that nutrients, sediment and faecal bacteria from soil to water through runoff are major pollutants from pastoral farming.

Domestic animal species, variations in climatic conditions, drainage pattern, stock density and other anthropogenic interferences are directly or indirectly related to faecal contamination. There is a direct link between meteorological conditions and microbial water quality of a river. Nnane *et al*. (2011) noted that high rainfall and floods are likely to result in greater incidence of pathogen loads in rivers. Grazed watershed is an extreme case for faecal contamination of surface waters (Fisher *et al*., 2000), while irrigated water runoff from dairy farming contribute greatly to water quality degradation in terms of high concentrations of *E. coli*, suspended solids, nitrogen and phosphorus (Monaghan *et al*., 2009). This study aims to assess the effect of illegal grazing on river water quality in Old Oyo National Park, Nigeria and evaluation of the effectiveness of the management strategies currently in place in OONP on river water quality.

MATERIAL AND METHODS

Old Oyo National Park is located in Ifedapo Local Government Area in Oyo State. The park lies between Latitude $8^{\circ}\ 15^{''}$ and $9^{'''}$ North; and Longitude $3^{\circ} 35^{1}$ and $4^{\circ}\ 42^{1}$ East. It covers a total area of 2512km^2 (Adetoro *et al.,* 2011; Ogunjimi *et al*., 2012; Oladeji *et al.,* 2012). Adjacent to the park are several agricultural settlements or villages, which include Igboburo, Yawota, Dogo, Alayin, Ikere, Temidire, Alagunta, Tessi Apata, Lukutu-Kekere, Tessi garuba and Budo-Alhaji. These villages comprise the support zone communities of the Old Oyo National Park. The activities in these villages are more crucial than those of urban dwellers in the conservation and management effort within the park.

The park is drained mainly by River Ogun, and its network of tributaries that cover the entire Southern part of the park. River Tessi is the main source of water for the wild animals in the Northern part of the park. This river is seasonal and dries-off at the peak of dry season. The Southern section of the park is forest/savannah mosaic with dense woodlands and semi deciduous forests. The central and northern sectors consist of mixed leguminuous plants (Oladeji and Agbelusi, 2014). The annual rainfall varies between 1110mm and 1250mm while temperature ranges between 20°C and 33.6°C (Adetoro, 2008).

Data collection: Key informant interviews were conducted for park rangers and cattle rearers. Secondary data from Old Oyo National Park were also collected. Water samples were collected from six rivers namely; Ogun, Tessi, Iweke, Opo, Iwe, and Ayinta. The samples have a wide spread between the Northern and Southern sectors of the park. Rivers Tessi, Iwe and Iweke are located in Oyo-Ile range in the Northern sector of the park while rivers Ogun, Opo and Ayinta are in Marguba and Tede range in the Southern sector of the park.

Water samples (100 ml each) were collected from 8 sites during the rainy season between April and June, 2016. Sample bottles were sterilized before use. The American Public Health Association, APHA (1998) standard method for water quality analysis was used.

RESULTS AND DISCUSSION

Microbial analysis of river water samples in Old Oyo National Park, Nigeria: Many of the cattle rearers had more than 100 cattles and took their herd into the park and its buffer zone for grazing. During the field work, herds were sighted in the park and were considered as the major illegal activity in Old Oyo National (2014). Table 1 shows the result of microbiological analysis of river water samples from Old Oyo National Park (OONP). River Ayinta had a total coliform count of 3.10 $x10^5$ cfu/ml, *Salmonella/Shigella* sp. count of 0.2 $x10^3$ cfu/ml, fungi count of 2.0 $x10^3$ cfu/ml, Coliform count of <2 MPN/100ml, microflora observed were *Aspergillus fumigatus*, *Bacillus* sp., *Salmonella* sp., *Enterobacter* sp.

River Opo had a total coliform count of 0.40 $x10^5$ cfu/ml, *Salmonella/ Shigella* sp. count of 0.7 $x10^3$ cfu/ml, Coliform count of <2 MPN/100ml while the microflora observed were *Bacillus* sp., *Psedomonas* sp. *Salmonella* sp. and *Shigella* sp. River Ogun (Point A) had a total coliform count of 6.40 $x10^5$ cfu/ml, *Salmonella/Shigella* sp. count of 8.2 $x10^3$ cfu/ml, Coliform count of <2 MPN/100ml, and *Bacillus* sp., *Psedomonas* sp. Shigella sp. *Enterobacter* sp.

Table 1. Microbial analysis of river water samples in Old Oyo National Park, Nigeria

Sample ID (Rivers)	Total bacterial count ($x10^5$	Staph. aureus. count ($x10^2$ cfu/ml)	Salm/ Shig. Sp. count ($x10^3$ cfu/ml)	Fungi count ($x10^2$cfu/ml)	Coliform count MPN/100ml	Microflora observed
Ayinta	3.10	Nil	0.2	2.0	<2	*Aspergillus fumigatus, Bacillus* sp., *Salmonella* sp., *Enterobacter* sp.
Opo	0.40	Nil	0.70	NG	<2	*Bacillus* sp., *Psedomonas* sp., *Salmonella* sp., *Shigella* sp.,
Ogun (Point A)	6.40	Nil	8.20	NG	<2	*Bacillus* sp. *Psedomonas* sp., *Shigella* sp. *Enterobacter* sp.
Ogun (Point B)	4.40	Nil	0.60	NG	<2	*Salmonella* sp., *Bacillus* sp., *Psedomonas* sp., *Enterobacter* sp.
Iweke	0.09	Nil	0.05	0.06	<2	*Shigella* sp., *Salmonella* sp., *Bacillus* sp., *Aspergillus fumigatus*
Iwe	0.60	Nil	0.10	0.15	<2	*Actinomycetes* sp., *Bacillus sp.Shigella* sp., *Salmonella* sp., *Aspergillus fumigatus*
Tessi (Point A)	0.27	Nil	0.02	0.30	<2	*Actinomycetes* sp., *Bacillus* sp., *Shigella* sp., *Salmonella* sp., *Aspergillus flavus*
Tessi (Point B)	0.15	Nil	8.0	0.07	<2	*Bacillus* sp. *Shigella* sp., *Salmonella* sp., *Aspergillus fumigatus*

River Ogun (Point B) had a total coliform count of 4.4 x10^5 cfu/ml, *Salmonella/Shigella* sp. count of 0.6 x10^3 cfu/ml and Coliform count of <2 MPN/100ml. The microflora observed were *Salmonella* sp., *Bacillus* sp., *Psedomonas* sp. and *Enterobacter* sp. River Iweke had a total coliform count of 0.09 x10^5 cfu/ml, *Salmonella/ Shigella*. sp. count of 0.05 x10^3 cfu/ml, fungi count of 0.06 x10^3 cfu/ml, Coliform count of <2 MPN/100ml, while the microflora consist of *Shigella* sp. *Salmonella* sp., *Bacillus* sp. and *Aspergillus fumigates.*

River Iwe had a total coliform count of 0.6 x10^5 cfu/ml, *Salmonella/ Shigella*. sp. count of 0.1 x10^3 cfu/ml, fungi count of 0.15 x10^3 cfu/ml, Coliform count of <2 MPN/100ml and microflora consisting of *Actinomycetes* sp., *Bacillus* sp., *Shigella* sp., *Salmonella* sp and *Aspergillus fumigates.* River Tessi (Point A) had a total coliform count of 0.27 x10^5 cfu/ml, *Salmonella/Shigella* sp. count of 0.02 x10^3 cfu/ml, fungi count of 0.3 x10^3 cfu/ml, Coliform count of <2 MPN/100ml and microflora observed were *Actinomycetes* sp., *Bacillus* sp., *Shigella* sp., *Salmonella* sp. and *Aspergillus flavus.* River Tessi (Point B) had a total coliform count of 0.01 x10^5 cfu/ml, *Salmonella/Shigella* sp. count of 8.0 x10^3 cfu/ml, fungi count of 0.07 x10^3 cfu/ml, Coliform count of <2 MPN/100ml and microflora observed were *Bacillus* sp., *Shigella* sp., *Salmonella* sp. and *Aspergillus fumigates.*

Total coliform count ranged between 0.09 × 10^5 cfu/ml to 6.4×10^5cfu/ml. *Salmonella* sp. and *Shigella* sp. count ranged from 0.02×10^3 to 8.2×10^3 cfu/ml, fungi count ranged from nil to 2.0×10^2 cfu/ml. Coliform count was <2 MPN/100ml. Microorganisms identified were *Aspergillus fumigates, Bacillus* sp., *Salmonella* sp., *Enterobacter* sp., *Actinomycetes* sp., *Psedomonas* sp., *Shigella* sp. and *Aspergillus flavus.*

Management strategies for combating anthropogenic activities: Zoning of protected area, law enforcement, conservation education and support zone development projects are the management strategies for combating anthropogenic activities. Litigation unit was established to prosecute offenders who carry out illegal activities in the park while the Park Protection and Conservation Unit is saddled with the responsibility of protecting the park from illegal activities and to educate the communities about wildlife and wildlife resources. The purpose of zoning is to apply different management principles in each zone to attain the best overall management objectives of the park. Old Oyo National Park was zoned into four viz: wilderness (core), tourism development, support (community use) and limited access (research) zones.

Biological research, field surveys and comprehensive inventory of the resources of the park which ideally should precede a zoning plan were inadequate. This could be due to inadequate funding, absence of technical ability, and planning processes difficulty (Sabatini, *et al*., 2007). Park planners and managers subsequently faced the challenge of choosing the most suitable evaluation indicators and framework in dividing reserve area to zones. The National Park Service Act 46 of 1999 is the law that established National Parks in Nigeria but Part VI of the act specified the offences punishable under the law and their penalties (Table 2). The offences include any activity carried out in the park that contradicts the objectives of the park. The litigation officer stated that going through a court case is time consuming but the management through its lawyer has the power to give verdicts without going through court processes.

The Conservation Education unit is responsible for creating wildlife conservation education awareness among the public most especially in the support zone communities. Primary school pupils and secondary school students are usually thought wildlife resources through conservation clubs created in their school. Support zone communities are reached through their traditional leaders (King and Chiefs) and other community leaders.

Table 2. Offences and penalties stated in National Park Service Act 46 of 1999

Offences	Penalties/		
	fines (Individual)	Imprisonment (Individual)	Corporate body
Entry into National Parks, etc	₦20,000	2 years	___________
Hunting, etc, in the national Parks	________	5 years	₦100,000-₦1,000,000
Use of weapons, etc, in the national Parks	₦5,000-₦25,000	6 months-5 years	₦100,000-₦1,000,000
Introduction of wild animals into National Park	₦10,000−₦50,000	5 years	₦100,000-₦1,000,000
Introduction of domestic animals into National Parks		3 months-5 years	₦100,000-₦1,000,000
Introduction of plants into National Parks	₦10,000−₦50,000	5 years	₦100,000-₦1,000,000
Prospecting for genetic materials in National park		6 months – 5 years	₦100,000-₦1,000,000
Aiding and abetting of offences, etc	Offenders penalties	Offenders penalties	₦100,000-₦1,000,000

₦ = Nigerian currency; Source: Adapted from National Park Service Act 46 of 1999

The management of Old Oyo National Park support developmental projects in the support zone communities in order to solicit for their support as regards wildlife conservation. Some of the projects implemented were feeder roads and renovation of classrooms. The absence of *E. coli* confirms that there are no fresh faecal contamination in the water bodies (WHO, 1998). The presence and abundance of total coliform, *Shigella* sp. and *Salmonella* sp. shows that rivers in Old Oyo National Park is not totally free from bacterial contamination which could come from wildlife and or domestic animals. Ajibade *et al.* (2008) isolated *Pseudomonas* spp*., Escherichia coli, Bacillus* spp*., Acetobacter* spp., *Klebsiella* spp*.* and *Maroxalla* spp. from rivers in Kainji Lake National Park, Nigeria with total bacteria count ranging from 20‒290cfu/ml while the coliform counts ranged from 6 to 116cfu/ml.

Rivers Ogun and Ayinta are the most highly faecal polluted while Rivers Tessi, Iwe, Iweke and Opo are less faecal polluted. Rivers in the southern sector of the park are more faecal polluted than rivers in the northern sector of the park. Although both sector experience illegal grazing this being a major threat to water quality, the river flow explains the significant difference in the faecal pollution. In the southern sector, the river flow is perennial, while in the northern sector, the rivers get dried up during the dry season. Thus, there is a direct link between meteorological conditions and microbial water quality of the rivers as earlier noted by Nnane *et al.* (2011) with high rainfall and floods resulting in high pathogen loads.

CONCLUSION

Illegal grazing in the park affected river water quality in the buffer and core zones. *Eschericia coli* were not detected in the rivers of Old Oyo National Park. Rivers in the southern sector of the park were more faecal polluted than rivers in the northern sector of the park. The management strategies used in combating the effects of illegal grazing included: zoning, law enforcement, conservation education and support zone developmental projects. These have been effective by reducing human activities in and around the National Park, which could cause pathogen loads in the rivers. The park management should ensure a periodic assessment of river water quality in the park as a means of monitoring the ecosystem health. Grazing lands should be located far away from the Park and illegal grazers should be prevented from entering into the park. Ecosystem approach should be used to zone protected areas in order to protect sensitive habitats such as aquatic ecosystem, which has cumulative effects on flora and fauna species.

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Regeneration Status and Soil Physico-Chemical Analysis of Dominant Forest Communities of Chail Wildlife Sanctuary in Himachal Pradesh

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Abstract: The per cent regeneration ranged from 30-67.50 in Chail Wildlife Sanctuary. Regeneration was satisfactory in chir (65%) and deodar forest community (67.50%), but deodar + chir (30%), chir + oak (32.50%), mixed (40%), oak (42.50) forest communities had poor regenerated. Chir showed poor establishment of regeneration in association with deodar. Oak showed poor response to established regeneration in mixed forest community. Oak regeneration was also unable to establish in association with chir. *Rhododendron arboretum* and *Pyrus pashia* seems to be under threat as regeneration of these species was almost absent. Mixed and oak dominated forest communities had more humus depth than chir and deodar forest community. Solar influx was higher in chir followed chir + deodar, chir + oak, deodar + oak, deodar, mixed forest, and oak forest community in descending order. Soil pH of Chail wildlife sanctuary ranged from 5.2-6.89. The mixed and oak + deodar dominated communities had rich organic carbon than chir dominated forests. The mixed and oak + deodar dominated communities were rich in available nitrogen, phosphorus and potassium than chir dominated forests.

Keywords: Humus depth, Regeneration, Soil, Solar influx, Wildlife sanctuary

North Western Himalayan States of Himachal Pradesh, Jammu and Kashmir and Uttarkhand occupies about 31% of the total coniferous area, accounting about 49% of the total growing stock in these states. Spruce and silver fir species are usually found associated with deodar, blue pine, chir pine and also with broadleaved species like oaks, walnut, burash, etc. Natural regeneration of these species is however, generally deficient and in many areas conspicuous by their absence. Besides a number of factors considered responsible for the absence of natural regeneration of these species; lack of adequate light on the forest floor in the forest managed under selection system, thick layer of humus accumulation of debris, dense weed growth and continuous grazing (Dhillon, 1961), poor seed production, infrequent seed years and other biotic factors (Chander *et al*., 2015) are the major factors. More litter fall and low decomposition rates (Singh, 1998) have been identified as the hindrances thereby affecting the natural regeneration of these species to a considerable extent. Excessive deposits of needles are inimical to the regeneration of all coniferous trees; complete removal of the sour un-decayed humus would enable seedlings to establish in the forests.

Soils have many ecological roles, including being a medium for plants to grow in, recycling nutrients and waste, providing a habitat for soil organisms, filtering rain water, etc. Forest soils influence the composition of the forest stand and ground cover, rate of tree growth, vigor of natural reproduction and other silvicultural important factors (Bhatnagar, 1956). Physical and chemical properties of soil change considerably as a result of tree planting, however, the effect of tree plantations on soil properties differ with the kind of vegetation (Chapman and Reiss, 1992). Physio-chemical characteristics of forest soils vary in space and time due to variations in topography, climate, physical weathering processes, vegetation cover and microbial activities (Paudel and Sah, 2003; Dengiz *et al.,* 2006). Plant tissues (from above ground litter and below ground root detritus) are the main source of soil organic matter, which influences physio-chemical characteristics of soils such as pH, water holding capacity, texture and nutrient availability (Kumar *et al.,* 2004). The study was conducted with objectives to study regeneration status and physico-chemical properties of soil in different forest communities of Chail wildlife Sanctuary.

MATERIALS AND METHOD

Chail Wildlife Sanctuary lies in Kandaghat Sub-Division of Solan district and part of this also falls under the jurisdiction of Shimla, Sub Division of Shimla District in Himachal Pradesh. It lies between $30^0$53'36” to 31^0 00' 42” N latitude and 77^0 07'20” to 77^0 16' 44” E longitudes. Total area of the sanctuary is 10,853.16 ha comprising of eleven beats. The sanctuary is known to have an exceptional variety of wildlife i.e., barking deer, samber, leopard, black bear, goral, etc. and birds (chir pheasants, chakor, Indian peafowl, red jungle fowl, kaleej pheasants, etc.).

The major forest species that represent the Chail Wildlife Sanctuary are chir (*Pinus roxburghii)*, deodar (*Cedrus deodara),* kail *(Pinus wallichiana),* oak *(Quercus leucotrichophora*), burash (*Rhododendron arboretum)* and kainth (*Pyrus pashia)* distributed along altitudinal gradient from 1400–2000m above mean sea level, which confirms to Group 9–Sub–tropical pine forests and Group 12–Himalayan moist temperate forests (Champion and Seth, 1968). These species occurs either in pure or mixed with other important or associated species. Based on species dominance, seven forest communities were selected viz. chir forest, chir + oak forest, pure deodar forest, deodar + chir forest, deodar + oak forest, pure oak forest and mixed forest for the study.

Ten sub–quadrat of 2 x 2 m (4 sq m) within quadrat of size 10m x 10m each under different forest community types were measured to record regeneration i.e. recruits, un–established and established, and per cent regeneration was calculated following Chacko (1965). For physico–chemical properties of soil, soil samples were collected from seven major forest community and analysed for pH, organic carbon, available nitrogen, phosphorus and potassium through standard common procedure.

RESULTS AND DISCUSSION

In seven forest community types, the recruits ranged from 250 –66000 ha^{-1} with maximum in deodar and minimum in oak forest community (Table 1). High quantity of recruits at deodar forest may be due to adequate number of seed bearers and shade site condition as is evident form solar influx value of 13.76% recorded at the site (Table 2). Whereas, in oak forest lowest number of recruit may be due to high density (1470 ha^{-1}) (Table 1) and thick layer of humus layer (Table 2).

Un–established regeneration was recorded maximum in both oak forest community (2250 ha^{-1}) and chir + oak forest community (chir 500 ha^{-1} and oak 1750 ha^{-1}) as compared to mixed forest (deodar 250 ha^{-1}, oak 1500 ha^{-1} and Kail 250 ha^{-1}), chir forest 1500 ha^{-1}, deodar + chir forest (deodar 250 and chir 750), deodar forest (750 ha^{-1}), deodar + oak forest community 500 ha^{-1} (deodar nil and oak 500 ha^{-1}). The maximum number of un–established in oak forest and chir + oak forest may be attributed to frequent lopping of trees for fodder, fuel and grazing, that cause oak seedling remain un–established, which was also reported by Ammer (1996) for the mixed mountain forests in Bavarian Alps.

Table 2. Humus depth and solar influx (%) under different forest community type

Forest community type	Depth of humus layer (cm)	Solar influx (%)
Chir forest	0.8	27.01
Chir + oak forest	2.7	15.58
Deodar forests	1.2	13.76
Deodar + chir forest	0.9	17.22
Deodar + oak forest	2.9	14.26
Oak forest	3.4	10.98
Mixed forest	3.7	11.76

Per cent regeneration, which is based on un–established and established regeneration ranged between 30–67.50 per cent with maximum in deodar and minimum in deodar + chir forest. The per cent regeneration success found in various forests communities were in the order of deodar + chir (30%) < chir + oak (32.50%) < mixed (40%) < oak (42.50) < chir (65%) < deodar (67.50%) forest community, respectively. Low per cent regeneration success of oak and its association might be due to over exploitation of oak for fodder, fuel and grazing (Turner, 2001). The better regeneration of deodar forest might be attributed to less thickness of organic matter, higher available nitrogen, available potassium and soil pH. The results are supported by the work of Pengshalin *et al.* (2006), who reported that depth of organic matter, had indirect relationship with established stocking per cent. The

Table 1. Regeneration status of different forest community

Major forest community type	Recruits (individual ha^{-1})	Un–established (individual ha^{-1})	Established (individual ha^{-1})	Per cent regeneration
Chir forest community	Chir (1,000)	Chir (500)	Chir (1500)	65
Chir + oak forest community	Chir (1500),	Chir (500), Oak(1750)	Chir (250), Oak (nil)	32.5
Deodar forest community	Deodar (66,000)	Deodar (750)	Deodar (1500)	67.5
Deodar + chir forest	Deodar(12,750),	Deodar (250), Chir (750)	Deodar (250), Chir (250)	30
Deodar+oak forest	Deodar (3000),	Deodar (0), Oak (500)	Deodar(250), Oak(1000)	55
Oak forest community	Oak (250)	Oak (2250)	Oak (500)	42.5
Mixed forest community	Deodar (4,500), Oak (250)	Deodar (250), Oak (1500), Kail (250)	Deodar (250), Oak (250)	40

Table 3. Soil pH, organic carbon, available nitrogen, available phosphorus, available potassium in different forest community type

Forest community type	pH			Organic carbon (%)			Available nitrogen (kg ha^{-1})			Available phosphorus (kg ha^{-1})			Available potassium (kg ha^{-1})		
	D1	D2	D1+D2	D1	D2	D1+D2	D1	D2	D1+D2	D1	D2	D3	D1	D2	D1+D2
Chir forest	6.57	6.74	6.66	2.11	1.76	1.94	383.8	303.7	343.75	25.11	21.73	23.42	239.04	281.34	260.19
Chir + oak forest	5.99	6.2	6.10	3.62	3.57	3.60	489.21	412.33	450.77	29.95	23.99	26.97	390.04	410.87	400.16
Deodar forest	6.49	6.52	6.51	3.59	3.51	3.55	435.65	391.56	413.61	28.76	22.84	25.80	382.98	405.01	394.00
Deodar + chir forest	6.31	6.45	6.38	2.98	2.77	2.88	410.8	383.95	397.38	27.89	22.67	25.28	382.33	392.23	387.28
Deodar + oak forest	5.7	6.00	5.85	3.72	3.67	3.70	505.87	455.38	480.63	32.24	25.05	28.65	398.09	436.91	417.50
Oak forest	5.2	5.99	5.60	3.87	3.74	3.81	516.74	489.32	503.06	36.75	33.01	34.88	421.98	481.64	451.81
Mixed forest	6.71	6.89	6.80	4.01	3.76	3.89	53 1.98	503.44	517.71	37.51	33.5	35.51	497.09	503.21	500.15
CD (p=0.05)	N/S	N/S	0.44	0.42	0.44	0.20	17.55	17.06	40.32	2.63	1.29	2.47	30.55	20.28	33.90

depth of humus layer showed inverse relationship between some major forest communities. Regeneration of 67.5, 65, 55 and 42.50 per cent with the humus depth of 0.8, 1.2, 2.9, 3.4 and 3.7cm in deodar forest, chir forest, deodar + oak forest and oak forest, respectively indicate that humus depth of had influence on the regeneration.

Soil physico-chemical property: The depth of humus layer ranges from 0.8 to 3.7 cm in which mixed forests having maximum depth of humus layer (3.7 cm) followed by oak (3.4cm), deodar + oak (2.9cm), chir + oak (2.7cm), deodar (1.2cm), deodar + chir (0.9cm) and chir (0.8cm) forest community (Table 2). More humus depth was recorded in mixed and oak forest as compare to other forest communities. Higher depth may be due to a great potential of oak in conserving soil and water. The green foliage forming the irregular to regular spherical crown has immense power to enrich the thickness of humus layer over the soil. In chir forest community, common fires incidence and fast decomposition of leaves may be responsible for the low depth of humus layer. The range of solar influx in major forest community types varied from 10.08 % to 27.01% (Table 2). It was maximum in chir forest (27.01%) followed by deodar + chir forest (17.22%), chir + oak forest (15.58%) + oak forest (14.26%), deodar forest (13.76%), mixed forest (11.76%) and oak forest (10.98%). The variation in solar influx might be due to the differences in crop composition and crown density.

Soil pH did not show any significance variation among forest community types in 0–15cm and 15–30cm soil depth (Table 3). However, soil were more or less acidic in deodar + oak and pure oak forest community and slightly alkaline in rest of the forest communities. The acidic nature of soil has also been reported in oak dominated and oak–pine mixed forests of Garhwal Himalaya (Bhandari *et al.,* 2000; Dhanai *et al.,* 2000).

The per cent organic carbon ranged from 1.76 % to 4.01 showing higher carbon in mixed followed by oak forest, deodar + oak, chir + oak, deodar, deodar + chir and chir forest community. The higher SOC in oak forest and oak mixed forest could be due to closed canopied forest, resulting in higher inputs of litter, which enriches SOC (high density and thick humus layer). The lower SOC in pine forest is good indicator of wide spacing of trees which provide low inputs of leaf litter to the soil (Table 3). The ranges of nitrogen in different major forest were 303.7 kg ha^{-1} to 531.98 kg ha^{-1}. Whereas, range of phosphorus was 21.73 kg ha^{-1} to 37.51 kg ha^{-1} and potassium was 239.04 kg ha^{-1} to 503.21 kg ha^{-1} in different major forest communities. The values of phosphorus and potassium was higher in this study as compared to the range reported by Bhandari *et al.*

(2000) as 14.40 to 21.60 kg ha^{-1} and Kumar *et al*. (2004) as 9.3 to 18.2 kg ha^{-1} for phosphorus in oak and pine forests of Garhwal. Bhandari *et al*. (2000) also reported potassium range of 170.8 to 295.4 kg ha^{-1} for Garhwal Himalayan oak forests. Kumar *et al.* (2006) studied soil on different aspects and reported range values of SOC (0.47 to 0.68 %), phosphorus (9.67 to 10.67 kg ha^{-1}) and potassium (141.87 to 172.48 kg ha^{-1}). Available nitrogen, phosphorus and potassium were higher in mixed forests followed by oak forest, deodar + oak, chir + oak, deodar forest, deodar + chir forest and chir forest. Oak and oak mixed forest community soils were found rich in available nitrogen, phosphorus and potassium over other forest communities (Table 3).

CONCLUSION

Regeneration in Chail wildlife sanctuary ranged from 30−67.5 per cent. It was good in chir and deodar forest community but deodar + chir (30%), chir + oak (32.50%), mixed (40%), oak (42.50) forest communities had poor regeneration. Chir showed poor establishment of regeneration in association with deodar. Kail failed completely, though oak showed poor response to establish regeneration in mixed forest community. Oak regeneration did not establish when it was in association with chir pine. *Rhododendron arboreaum* and *Pyrus pashia* seems to be under threat as regeneration of these species was absent.

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Abundance, Species Diversity and Spatial Distribution of Rotifer Community of Dal Lake, Kashmir, India

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***Abstract*:** During the study period 44 taxa of Rotifera belonging to 3 orders, viz, Ploima, Flosculariacea and Bdelloidea were recorded. Family Brachionidae was dominant in the lake. Most of the species recorded by earlier authors are still present in the lake but some have been disappeared completely. Hazaratbal basin depicted the highest species diversity, viz, *Brachionus bidentata, B. calyciflorus, B. plicatalis, B. quadridentata, Euchlanis dilatata, Keratella cochlearis, K. stipitata, K.quadrata, K.valga, Notholca acuminata, Platiyas patulus, P. quadricornis, Mytilina mucronata, Trichocerca tetractris. T.longiseta,Cephalodella auriculata, C.exigua, C. gibba, Monostyla bulla, M. quadridentata, M. closterocera, M.lunaris, Lecane luna, Gastropus stylifer, Polyarthra vulgaris, Filinia longiseta and Asplanchna priodonta* but with low population density. Brarinumbal basin recorded low species diversity of Rotifera but their population was high. High rotifer density seems to be a characteristic of eutrophic lakes.

***Keywords*:** Density, Diversity, Rotifers, Eutrophication, Temperature

The eutrophication of lakes often leads to change in species composition due to different nutrient demands. Both biotic and abiotic parameters play an important role in the seasonal succession of Zooplankton (Wolfinbarger, 1999). Growth and distribution of Zooplankton depend on the suitability of abiotic (e.g., transparency, temperature, conductivity, dissolved oxygen and nutrients, etc.) and biotic (e.g., food availability, competition, predation, etc.) parameters. For understanding the level of trophic progression of water body it is important to know the abundance, species diversity and spatial distribution of the Zooplankton community in it. Rotifers play an important role in fresh water environment, particularly in waters of higher trophic stage. Their life cycles are influenced by temperature, food and photoperiod and they quickly increase in population under favourable environmental conditions (Dhanapathi, 2000). In Kashmir, water bodies rotifer studies were initiated by Edmondson and Hutchinson (1934); Kaul and Zutshi (1967); Yousuf and Qadri (1981a,b); Pandit and Yousuf (2002, 2003); Wanganeo *et al.* (2007). The main contributors towards the pollution or eutrophication of the aquatic habitats of the valley are degradation of the catchment areas, surface runoff from the catchment areas loaded with domestic sewage and fertilizers applied to agricultural fields.

MATERIAL AND METHODS

For qualitative analysis collection of the plankton was carried out by hauling plankton net fitted with nylobolt net cloth no. 140T (Nylobolt Co., Mumbai) through water in vertical and horizontal directions. The contents collected in the tube attached to the lower end of the net were transferred to separate marked polythene tubes and preserved in 4 per cent formalin. Detailed qualitative investigations were made under binocular microscope at 40X and 100X. Identification of Zooplankton was done with the help of standard taxonomic keys like Edmondson (1959) and Pennak (1978). For quantitative enumeration plankton samples were collected by sieving 10 litres of water obtained separately from different depths with the help of 2 litre Ruttner type sampler and preserved in 4 per cent formalin. At the time of counting, the preserved sample was shaken and 1 ml of it was withdrawn with a wide mouthed glass pipette into Sedgwick rafter cell (1 ml capacity) and observed under a binocular microscope. For accuracy counting of the sub-samples was in triplicate and mean value was taken for calculating the number of organisms per cubic meter of the water by the formula given in APHA (1998). The results were expressed in indi m^{-3}.

The data for two years from (December, 2011 – November, 2013) was pooled and analyzed for monthly variation. To study the relative effect of some environmental factors Pearson correlation between Rotifera and important physico-chemical parameters was calculated.

Study area: Dal lake is a, shallow urban water body situated at an altitude of 1583 m (Above sea level) within the geographic coordinates of North latitude 34˚ 05' 0N–34˚ 09' 04N and East longitude 74˚ 49' 55N–74˚ 52' 55N at a distance of about 12km to the North east of the Srinagar city. It has a total area of 11.5km^2, with the maximum depth of 1.5m. The lake is open drainage type and receives water from Telbal Nallah (Dachigam Nallah) and Botkol. Some other tributaries, like

Meerak Shah stream and Pishpav stream also contribute water to the lake on the east. The lake is divisible into five basins, Gagribal basin in the South –east, Lokut – Dal in the East with a small island called Rupa-Lank in the middle, Hazaratbal basin in the North with a small island called Sona –Lank in the middle. This basin receives Telbal stream on its north side and is connected by a narrow channel at Ashaibagh with the 4th basin of the lake, the Nageen basin. On the western side the Gagribal basin is connected with the 5th basin called Brarinumbal basin through the Nowpora channel. The excess water from the Dal is drained into River Jhelum through Tsunti Kol which leaves the Gagribal basin at Dalgate. Part of the water also flows out through Nallah Amir Khan which connects the Nageen basin with Khushal Sar lake. Hazarabal basin is the largest while Brarinumbal basin is the smallest basin of the lake. A large portion of the lake extending between Hazaratbal and Gagribal is covered by floating gardens. The lake is infested with many macrophytes *like Myriophyllum spicatum, Ceratophyllum demersum, Potamogeton lucens* and *Nelumbo nucifera* for the most part of its basin. Four study sites were selected in this lake, which represented various microhabitats available in it.

D1:−In the north–west of the lake at 34˚ 08' 41″N and 74˚ 50' 38″E, adjacent to the place where Telbal Nallah enters the lake.

D2:−In Hazaratbal basin, adjacent to Sona Lank Island at 34˚ 07' 28″N and 74˚ 51' 04″ E and is characterized by submerged vegetation, especially *Ceratophyllum demersum*.

D3:−In Lokut Dal, at 34˚ 05' 37″N and 74˚ 52' 15″E. Centaur Hotel is situated on its eastern bank from which heavy amount of waste finds its way into the lake.

D4:−In Brarinumbal basin at 34˚ 05' 18.6″N and 74˚ 49' 58″E. It is located close to human habitation therefore highly eutrophic as raw sewage are discharched into it.

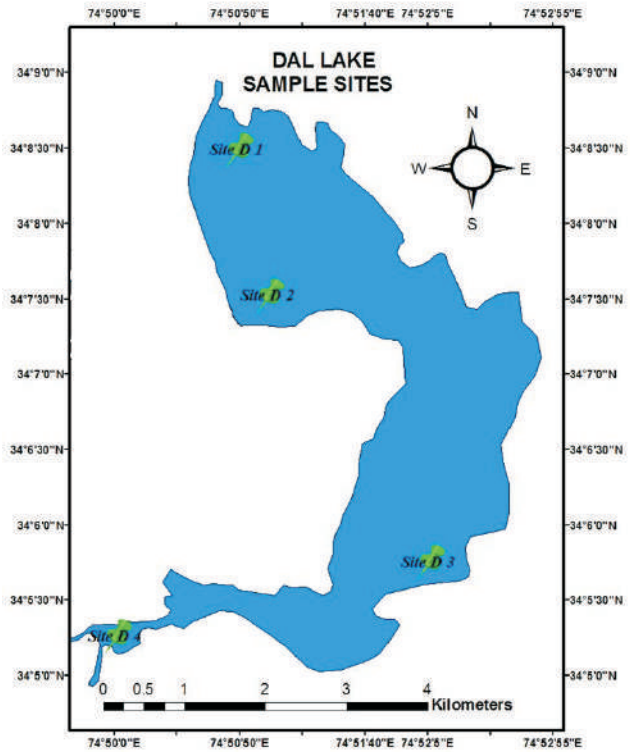

Fig. 1. Map of the Dal lake

RESULTS AND DISCUSSION

During the present investigation forty four taxa of Rotifera were recorded from 4 sites of Dal Lake, which belonged to 3 orders, viz. Ploima, Flosculariacea and Bdelloidea. Order Ploima was represented by nine families, viz, Brachionidae, Lecanidae, Lepadellidae, Notommatidae, Trichocercidae, Asplanchnidae, Gastropidae, Proalidae and Synchaetidae. Family Brachionidae was the most diverse being represented by 17 taxa. In the past, several studies have been conducted on Rotifera from the Dal lake (Akhtar, 1972; Parveen, 1989; Jeelani and Kour, 2014).

In the present study family Brachionidae was dominant in the lake representing eight genera. Among the various genera of Rotifera, Brachionus was the most diverse genus represented by five species, namely *Brachionus angularis, B. calyciflorus, B. bidentata, B. plicatilis* and *B. quadridentata*.Yousuf and Qadri (1981b) also reported Brachionidae family as dominant in terms of genera. All the five species are characteristic of eutrophic, alkaline waters and are cosmopolitan and show a wide variation (Jyoti and Sehgal, 1979; Sharma, 1987, 1992; Dadhick and Saxena, 1999). Radwan and Maemets (1983) reported them as indicators of water quality and were found almost in all seasons of the year. *Brachionus bidentata*, a typical eutrophic species (Jarnefelt, 1952), was recorded in Dal lake during winter through summer season. During the present study *Brachionus calyciflorus* appeared to be eurythermal only in the Brarinambal basin of Dal Lake. In the Hazratbal basin of Dal Lake, it formed an aestival species, being present from spring to autumn. Gannon and Stemberger (1978) reported *Brachionus quadridentata* in mesotrophic, meso-eutrophic and hyper-eutrophic water bodies. The species was recorded during the present study at different times of the year. However, maximum density was recorded during warmer period of the year. The genus Keratella was represented by five species, namely *Keratella. cochlearis, K. hiemalis, K. stipitata, K. quadrata* and *K. valga*. The data revealed an overall dominance of *K. cochlearis* in the Keratella group with high population in Brarinumbal basin of

Table 1. Current versus earlier status of Rotifers in Dal lake

Present study (2011–13	Site D1	Site D2	Site D3	Site D4	Akhtar (1972)	Parveen (1988)	Jeelani and Kaur (2004)
1. Order :−Ploima	*Brachionus plicatalis*	*Brachionus bidentata,*	*Brachionus*	*Brachionus*	*Ascomorpha*	*Anuraeopsis fissa -*	*Anuraeopsis fissa-*
A. Family:− Brachionidae	*B.quadridentata*	*B.calyciflorus*	*calyciflorus*	*angularis*	*eucaudis –*	*Brachionus angularis +*	*Asplanchna sp.+*
Brachionus angularis Gosse, 1851	*Keratella cochlearis*	*B. plicatalis*	*B.quadridentata*	*B. bidentata*	*Ascomorpha*	*B. calyciflorus+*	*Brachionus angularis+*
B. bidentata Anderson, 1989	*K. quadrata*	*B.quadridentata*	*Keratella cochlearis*	*B.calyciflorus*	*brightwelli -*	*B. quadridentata+*	*B. calycifloris+*
B.calyciflorus Pallas1766		*Euchlanis dilatata*	*Kellicotia longispina*	*B. plicatilis*	*Asplanchna*	*Epiphanes-*	*B.quadridentata+*
B. plicatilis Muller,1786	*Platiyas*	*Keratella cochlearis*	*Mytilina ventralis*	*B. quadridentata*	*priodonta+*	*Euchlanis dilatata+*	*Cephalodella sp.+*
B. quadridentata Hermann, 1783	*quadricornis*	*K. stipitata*	*Lepadella patella*	*Keratella*	*B. quadridentata+*	*Keratella cochlearis+*	*Colurella adriatica-*
Keratella cochlearis Gosse, 1851	*Mytilina mucronata*	*K.quadrata*	*L. ovalis*	*cochlearis Mytilina*	*E. dilatata+*	*K. valga+*	*Epiphanes sp.-*
K. quadrata Muller, 1786	*Trichocerca longiseta*	*K.valga*	*Squatinella mutica*	*mucronata*	*K. cochlearis+*	*K. quadrata +*	*Euchlanis dilatata +*
K. stipitata Ehrenberg, 1834	*Colurella obtusa*	*Notholca acuminata*	*Monostyla lunaris*	*Trichocerca*	*K. quadrata+*	*Mytilina* sp.+	*Filinia longiseta+*
K. valga Ehrenberg, 1834	*Lepadella ovalis*	*Platiyas patulus*	*Polyarthra*	*longiseta*	*Platiyas dalensis -*	*Notholca acuminata +*	*Gastropus sp.+*
Mytilina mucronata Muller, 1773	*Squatinella mutica*	*P. quadricornis*	*dolichoptera*	*T.cylindrica*	*Trichotria*	*Platiyas quadridentata+*	*Keratella cochlearis+*
M. ventralis Ehrenberg, 1832	*Monostyla bulla*	*Mytilina mucronata*	*Filina longiseta*	*T.porcellus,*	*tetractris+ Colurella*	*Trichotria tetractis +*	*Keratella quadrata+*
Platiyas patulus Muller, 1786		*Trichocerca tetractris*	*Cephalodella*	*Lepadella ovalis*	*bicuspidate-*	*Colurella adriatica-*	*Keratella valga+*
P.quadricornis Ehrenberg, 1832		*T.longiseta,*	*auriculata,*	*Colurella obtusa*	*Lecane luna+*	*Lepadella ovalis +*	*Lecane luna+*
Trichotria tetractris Ehrenberg, 1832		*Cephalodella*	*C.exigua*	*Monostyla bulla*	*Monostyla*	*Squatinella mutica +*	*Lecane ohiensis-*
Euchlanis dilatata Ehrenberg, 1832		*auriculata,*	*C. gibba,*	*M.quadridentata,*	*quadridenta+*	*Lecane luna+*	*Lepadella ovalis+*
Notholca acuminata Gosse, 1887		*C.exigua*		*Cephalodella gibba*	*Polyarthra*	*Lecane ohiensis -*	*Monostyla bulla+*
Kelicotia longispina Ahlostrom, 1838		*C. gibba,*		*Polyarthra vulgaris*	*vulgaris+*	*Lecane depressa -*	*Mytilina* sp.+
B. Family : Lepadellidae		*Monostyla bulla*		*P. dolichoptera*	*Polyarthra*	*Lecane elasma-*	*Philodina* sp+.
Lepadella ovalis Muller,1773		*M. quadridentata,*		*Testudinella* spp	*euryptera-*	*Monostyla bulla+*	*Polyarthra vulgaris+*
L. patella Muller, 1786		*M.closterocera*		*Filinia longiseta*	*Polyarthra*	*M. quadridentata+*	*Pompholyx sulcata-*
Colurella obtusa Ehrenberg, 1833		*M.lunaris*		*Philodina roseola*	*quadricornis-*	*M. closterocerca+*	*Squantinella mutica+*
Squatinella mutica Ehrenberg, 1832		*Lecane luna*		*Rotaria citrinus,*	*Synchaeta oblonga*	*M. lunris+*	*Synchaeta* sp.-
C. Family :−Lecanidae		*Gastropus stylifer*		*Dissotrocha* spp	-	*Proalinopsis-*	*Trichocerca longiseta+*
Monostyla bulla Gosse, 1886		*Polyarthra vulgaris*		*Proales.*	*Synchaeta*	*Cephalodella+*	*Trichocerca* sp. *Trichotria*
M. closterocerca Schmarda, 1859		*Filinia longiseta*			*pectinata-*	*Notomata-*	*tetractis+*
M. lunaris Ehrenberg, 1832		*Asplanchna*			*Filinia longiseta+*	*Ascomorphella*	
M. quadridentata Ehrenberg, 1834		*priodonta.*			*Pompolyx* sp−	*Trichocerca longiseta+*	
Lecane luna Muller, 1776					*Floscularia*	*T. cylindrica+ T. similis*	
D. Family : Notommatidae					*ringens- Floscularia*	*T. porcellus+*	
Cephalodella auriculata Ehrenberg, 1938					*conifer- Conchilus-*	*Ascomorpha* sp+	
C. exigua Ehrenberg, 1838						*Asplanchna priodonta +*	
C. gibba Ehrenberg, 1838						*Gastropus- Pleosoma-*	
E. Family : Trichocercidae						*Polyarthra vulgaris+*	
Trichocerca cylindrica Imhof, 1891						*Synchaeta- Filinia*	
T. longiseta Shrank, 1812						*longiseta +*	
T. porcellus Gosse, 1886						*Testudinella* sp +	
Ascomorphella sp. Wiszneiewski, 1856						*Hexarthra* sp−	
F. Family : Gastropidae						*Conochilus-*	
Ascomorpha saltans Bartsch, 1886						*Philodina+*	
Gastropus stylifer Imhof, 1891						*Un - identified*	
G. Family :−Asplanchnidae						*Bdelloids-*	
Asplanchna priodonta Gosse, 1850							
H. Family :−Proalides							
Proales Myers, 1933							
I. Family : Synchaetidae							
Polyarthra dolicohoptera Idelson, 1925							
P. vulgaris Carlin, 19432.							
2. Order :−Flosculariacea							
Family :−Testudinellidae							
Filinia longiseta Ehrenberg, 1834							
Testudinella sp. Bory 1851							
3. Order : Bdelloidea							
Family : Philodinidae							
Rotaria citrinus Scopoli, 1832							
Philodina roseola Ehrenberg, 1832							
Dissotrocha Bryee, 1848							

Dal lake. Keratella has been reported to comprise pollution tolerant species, which indicate accumulation of organic matter in water body and act as an index of eutrophic water (Ruttner-Kolisko, 1974). Pandit and Yousuf (2003); Maier and Buchholz (1998); Wanganeo *et al*. (2006) reported *Keratella cochlearis, K. quadrata, K. tropica* and *K. valga* in meso and hypereutrophic water bodies. Genus Trichotria was represented by *T. tetractris* in Hazratbal basin of during spring-summer. Yousuf (1979) reported it to be a perennial form in Manasbal lake, while Yousuf *et al.* (1984) found it during winter and spring in Mirgund wetland. The absence of this genus from Brarinumbal basin, may be due to very low dissolved oxygen in these waters. Primicerio and Klemetsen (1998), Yousuf and Qadri (1981b), Qadri and Yousuf (1982) and Balkhi *et al.* (1984) reported *Kellicotia longispina* and *Notholca acuminata* as cold stenothermal species. *Kellicotia longispina* and *Notholca acuminata* were absent in Brarinumbal which may be attributed to their avoidance to eutrophy. Pandit and Yousuf (2003) reported *Lepadella ovalis, L. patella* and *Colourella obtusa* in meso-eutrophic, to hypereutrophic water bodies. *Squatinella mutica* was recorded during spring/summer with increase of water temperature. Balkhi *et al.* (1984) reported it as a warm stenothermal species. *Polyarthra vulgaris* was recorded mainly during warm period in Dal. Hutchinson (1967) and Yousuf (1979) have designated some species of Trichocerca as warm water forms. *Trichocerca longiseta* was recorded during summer with the highest density in Brarinumbal basin, indicating its ability to withstand anoxic conditions. *Monostyla bulla* has been regarded as a good biological indicator of eutrophication (Rajagopal *et al.,* 2010). The present data are in complete conformity with this view as the species recorded high density. *Filinia longiseta* was present in good numbers and is known to be a valuable indicator of eutrophy (Maemets, 1983). Pandit and Yousuf (2002) reported *Philodinia roseola, Rotaria citrinus* and *Dissotrochas* in meso-hypertrophic water bodies and thereby acting as eutrophic indicator.

Dal lake depicted the highest counts of rotifers at Hazaratbal basin, viz, *Brachionus bidentata, B. calyciflorus, B. plicatalis, B. quadridentata, Euchlanis dilatata, Keratella cochlearis, K. stipitata, K.quadrata, K.valga, Notholca acuminata, Platiyas patulus, P. quadricornis, Mytilina mucronata, Trichocerca tetractris. T.longiseta,Cephalodella auriculata, C.exigua, C. gibba, Monostyla bulla, M. quadridentata, M.closterocera, M.lunaris, Lecane luna, Gastropus stylifer, Polyarthra vulgaris, Filinia longiseta* and *Asplanchna priodonta*. As stated by Wetzel (1983), the abundance of rotifers is hard to generalize in a particular area. Hazaratbal basin is the largest basin of the Dal lake and supports extensive vegetation, which provided varied micro habitat for the rotifers and accordingly this site recorded the highest species diversity. Since rotifers are more sensitive to alterations in the quality of water (Gannon and Stemburger, 1978), they respond to environmental changes faster. High density of Rotifers in Hazaratbal basin indicates the influence of phosphorus supported by positive correlation, r = 0.713 (Table 2). Kabayashi *et al*. (1998) also reported positive correlation between total phosphorus and rotifer abundance. A positive correlation seems when phosphorus consumption by primary producers increases the phytoplankton population, the latter triggers an increase in Zooplankton mainly rotifers (Buzkurt and Guven, 2009; Esler *et al.,* 2001). Against this scenario, the hypereutrophic Brarinumbal basin, which receives large quantities of domestic sewage, has high population density but relatively lower species diversity viz, *Brachionus angularis, B. bidentata, B. calyciflorus, B. plicatilis, B. quadridentata, Keratella cochlearis, Mytilina mucronata, Trichocerca longiseta, T. cylindrica, T.porcellus, Lepadella ovalis, Colurella obtusa, Monostyla bulla, M.quadridentata, Cephalodella gibba, Polyarthra vulgaris, P. dolichoptera, Testudinella* spp, *Filinia longiseta, Philodina roseola, Rotaria citrinus, Dissotrocha* spp and *Proales*. Decomposition of organic matter at Brarinumbal basin takes place throughout the year, resulting in anoxic conditions. Most of rotifers recorded during the entire study period have flourished well and depicted highest population densities. It is evident that with eutrophication some tolerant species flourish well assuming nuisance populations (Jeffries and Mills, 1990). High rotifer density has been reported to be a characteristic of eutrophic lakes (Sendacz, 1984).

The seasonal fluctuation is greatly influenced by the variations in temperature along with many other factors. During the study period bimodal trend was also recorded in Dal lake, with first peak in the July with a population density of 715,000 indi m^{-3} (Fig. 2), which was contributed mainly by *Brachionus calyciflorus, B. quadridentata, B. plicatilis, Mytilina mucronata, Keratella cochlearis, Trichocerca longiseta, Filinia longiseta, Philodina roseola* and *Rotaria citrinus*, while the second peak in the September with a population density of 502,000 indib m^{-3}, which was dominated by *Brachionus bidentata, B. quadridentata, B. plicatilis, Mytilina mucronata, Colurella obtuse, Keratella cochlearis, Cephalodella gibba, Trichocerca longiceta* and *Rotaria citrinus*. A positive correlation was found between rotifer density and temperature, the values of co-efficient of correlation (r) between the two being 0.999 (Table 2). The minimum population density was recorded during winter months. During the extreme environmental conditions of winters, the rotifer assemblage was composed of only a few

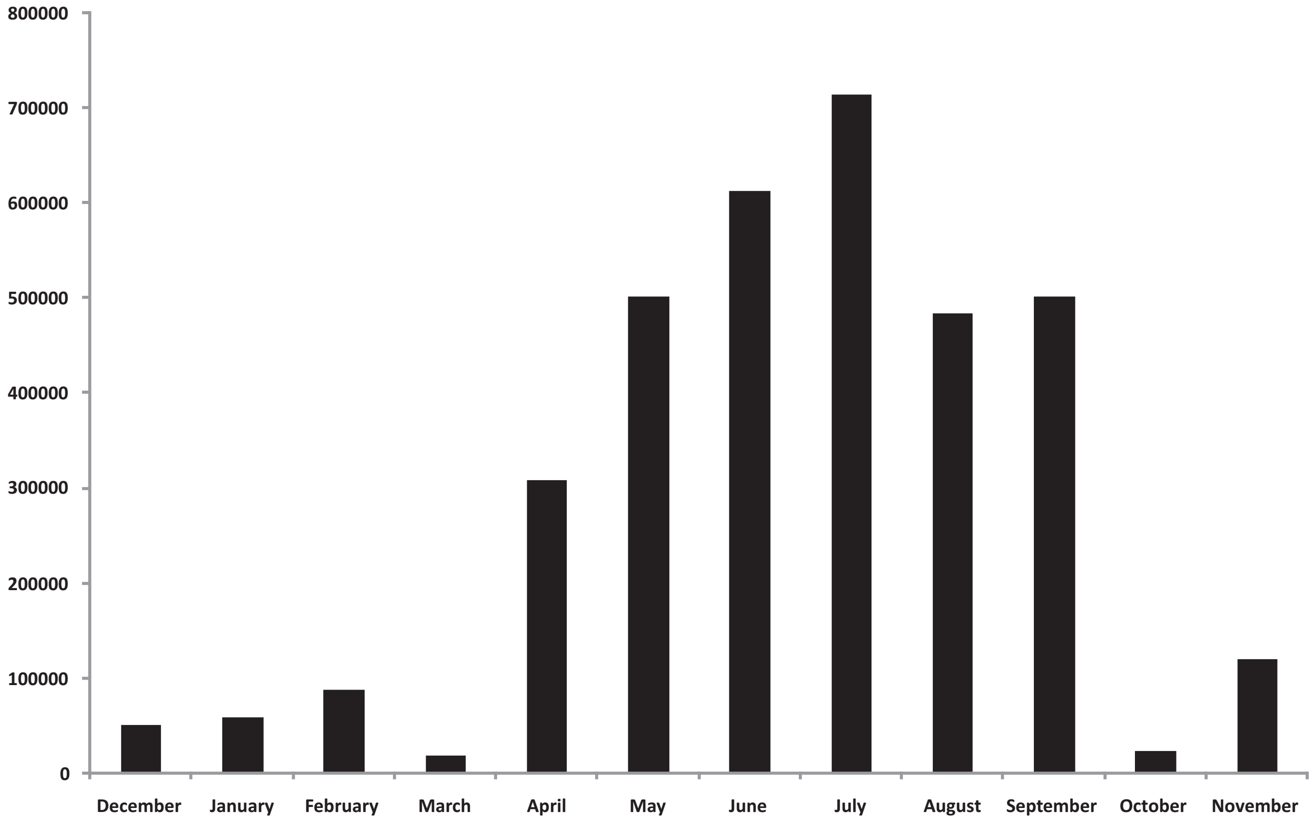

Fig. 2. Monthly fluctuations of Rotifera in Dal Lake

Table 2. Correlation coefficient of Rotifer abundance with physico-chemical parameters of Dal lake

Rotifer density	Temperature	pH	Conductivity	Oxygen	Carbon dioxide	Phosphorus
	0.999***	0.846***	0.999***	0.099	-0.828***	0.713

well adapted species, viz., *Notholca acuminata, Keratella hiemalis, K. valga, K. cochlearis, Kellicotia longispina* and *Trichocerca longiseta.* Temperature has been considered to be the main factor to cause fluctuations in the abundance of Rotifera in fresh water (Mecombie, 1953; Saler and Sen, 2002). The minimum population density was recorded during winter months, when the water temperature records the minimum values. During the extreme environmental conditions of winters (6.9˚C–10.5˚C) the rotifer assemblage was composed of only a few well adapted species, viz., *Kellicotia longispina, Notholca acuminata, Keratella hiemalis, K. valga, K. cochlearis, Trichocerca longiseta* (Virro *et al.,* 2009). With the onset of spring, rotifer population started to increase with the re-appearance of several species (Erdugan and Guher, 2005). It seems increasing temperature stimulates the growth of phytoplankton population, resulting in the increase of population density of rotifera due to hastening of the growth rate (Taylor, 1974). Rotifers have been reported to prefer alkaline waters (Byars, 1960) and the same appears true for the Rotifer density in the present lakes as it showed positive correlation with pH.

A comparative checklist of rotifer species recorded during the present study and past studies reveals that in the Dal lake most of the species, viz, *Brachionus bidentata, B. plicatilis, Cephalodella auriculata, C. exigua, C. gibba, Colurella obtusa, Dissotrocha, Keratella stipitata, Kellicotia longispina, Lepadella patella, Mytilina ventralis, M. mucronata, Platiyas patulus, P. quadricornis, Proales, Polyarthra dolicoptera, Philodina roseola, Rotaria citrinus, Trichocerca porcellus,* were not recorded before in the lake however, some of the species have disappeared completely and got replaced by other allied ones. The change in the trophic status of the investigated water body during the last three – four decades seems to have led to the change in the species composition of the water concerned.

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Agroforestry Impacts on SOC and Aggregate Stability in Different Textured Soils in Shiwalik Regions of Northwest India

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Abstract: Soil aggregates profoundly influence soil fertility and soil erosion. A large number of studies have showed that soil aggregate loss was mainly affected by raindrop impact however, few attempts have been made to investigate its impact in this region. Single raindrop simulator was used to study the impact of raindrops on the aggregate stability under different textured soil and cropping systems. The stability index was highest in agroforestry system under fine textured soil (0.223 J kg^{-1}) and lowest in maize-wheat system under coarse textured soils (0.086 J kg^{-1}) in surface soils. The cropping system and soil particle fractions significantly influenced the aggregate stability.

Keywords: Agroforestry, Maize-wheat rotation, Soil aggregate, Soil texture

The increase in population at alarming rate in the Shiwalik region of northwest India is a principal factor for change in land use pattern that is conversion of natural forest into intensive agricultural lands for the food security. This adverse change in land use pattern has deteriorated the physical environment of soil (Poeplau *et al.,* 2011; Saha *et al.,* 2011) resulting in soil erosion, depletion of soil organic carbon (SOC) and poor aggregate stability (Kukal *et al.,* 1991).Aggregate stability is a prerequisite for fertile soil as it determines nutrient and water uptake by the plant (Saha and Kukal*,* 2014). The distribution and stability of aggregates, and of the pores within and between them, affect soil properties and the composition and activity of soil biotic communities (Tisdall, 1994; Mikha and Rice, 2004). At the same time, aggregate formation and stabilization are affected by various factors, including climate conditions, mineral composition, types and amount of soil organic carbon (SOC) (Denef and Six, 2005). Aggregates resulting from physico-chemical and biological interaction in soil promote SOC sequestration by protecting it in inter-aggregate spaces from microbial activity. The SOC budget is a function of carbon input as plant litter and its turnover rate being higher in agroforestry than in sole agricultural crop (Gupta *et al.,* 2009). It is widely known that SOC depletes with conversion from native forest to croplands (Mikhailova *et al.,* 2000; Murty *et al.,*2002) and under any given environmental conditions its amount increases as soil texture becomes finer (Anderson *et al.,* 1981; Tisdall and Oades, 1982). The protection of SOC through the formation of clay humus complex is a direct effect of soil texture, apart from its encapsulation by clay particles to form domain (Giller *et al.,* 1997), which further forms micro and macro-aggregates. Hence soil texture, the indigenous characteristic of the soil plays a crucial role in SOC sequestration and in the aggregation process.

The changing land use practices influences the soil physical, chemical, and biological environment (Bushchbacher *et al.,* 1988; Solomon *et al.,* 2000). By managing land use strategies one can improve SOC status and contributes to good soil health and quality (Lal *et al.,* 2004). The build up of SOC in its ecosystem can be acquired by appropriate selection of crop species, which produce high biomass, application of organic matters, residue restoration, shifting to perennial crops, and inclusion of crop rotation and adoption of agroforestry (Nieder and Benbi, 2008). Agroforestry is the practice of growing multipurpose tree species along with crops, improves soil quality and productivity (Shift *et al.,* 2006; Noble *et al.,* 1998) sequester the above-and below ground carbon into soils (Gupta *et al.,* 2009). It also serves the objective for income in drought conditions, which is common in the lower Shiwalik area. The characterization of carbon in the agroforestry is well understood but the study of agroforestry in relation to texture and SOC dynamics in soil aggregation is poorly understood under different cropping system.

MATERIAL AND METHODS

The study was conducted in a mixed watershed situated in the foothills of lower Shiwalik in northwest India at an altitude of 336 m above the mean sea level, having hot and semi-arid type of climate and lies at 31º31´46.53´´ N latitude and 75º55´12´´E longitude. The study was conducted in watershed comprising of three different textures viz. loamy sand, sandy loam and clay loam under two cropping systems maize–wheat and agroforestry. The maize (*Zea mays*) was grown during summer season (June–October) and wheat (*Triticum aestivum*) during winter season (November–April). The agroforestry system comprised of poplar (*Populus deltoides*) trees intercropped with sorghum fodder (*Sorghum bicolor*) during summer and wheat during winter season.

Soil and aggregate sampling: The bulk soil samples were collected from three sites for each texture. At each site, the sample were randomly collected from four places and mixed to prepare a composite sample. The samples were ground and passed through 2 mm sieve after air drying for further analysis. The natural undisturbed soil aggregates were collected from three sites for each texture under the maize–wheat and agroforestry cropping systems. The clods of about 40–50 cm diameter were collected separately with the help of a spade from 0–15 and 15–30 cm soil layers. The samples were collected after clearing the land surface of the accumulated leaf litter under agroforestry and for maize–wheat system; the sampling was done when the area was without any crop cover. The clods of soil collected from different sites were transported carefully to laboratory so as to avoid breakage due to force handling. The clods were let to fall freely from a height of 90–100 cm on the grassy ground so as to get the aggregates formed naturally by breaking at natural cleavage points. The particle size distribution of soils was determined in terms of sand (2–0.02mm), silt (0.02–0.002mm) and clay (<0.002mm) as per ISSS classification, using an International pipette method (Day, 1965) (Table 1).

Physico-chemical properties: The soil pH and electrical conductivity were determined in a 1:2 soil–water suspension by using an ELICO glass electrode pH metre (Jackson, 1967) and a conductivity bridge, respectively. The SOC was determined by Walkley and Black rapid titration method as detailed by Piper (1950). The SOC stock was calculated by multiplying the SOC concentration with the bulk density of corresponding depth with the depth of soil. The aggregates so obtained were passed through 6 mm sieve and those retained on 4 mm sieve were used for aggregate size analysis. The stability of aggregates was studied in terms of kinetic energy (KE) of the rain drops used for the complete disruption of aggregates. A raindrop simulator designed to produce single raindrop from a height of 3 m was used as described by Kukal *et al.* (2008) was used (Fig. 1). The stability index of aggregates was calculated in terms of KE of all the raindrops used for their complete disruption. The total kinetic energy of raindrops used for complete dispersion of the aggregate was expressed on g basis to calculate stability index as $SI_{SRT} = N\,(1/2mv^2)$

Where, SI_{SRT} is the stability index based on single rain drop technique, N is the number of drops used to completely disperse an aggregate per gram of soil, m is the mass of rain drop of size (r = 0.5 mm) and v is the terminal velocity of the raindrop calculated on the assumption that 95 per cent of terminal velocity of the raindrop was achieved from a fall height of 3 m (Bryan, 1974).

Micro–morphological studies of soil aggregates from 0–15 cm soil layer with three different textures under two cropping systems were observed under stereo–microscope in order to obtain the micrographs of the aggregates.

Statistical analysis: The data so obtained for SOC and SI under different texture and cropping system was compared using least square difference (LSD) at 5% level of significance calculated from analysis of variance (ANOVA) in

Table 1. Basic physico–chemical properties of surface (0–15 cm) in different soil texture

Properties	Cropping system					
	Agroforestry			Maize–wheat		
	Coarse	Medium	Fine	Coarse	Medium	Fine
Sand (%)	78.11	62.03	45.95	80.87	64.9	43.8
Silt (%)	8.07	16.23	21.89	11.83	14.44	23.6
Clay (%)	13.82	21.70	32.15	7.3	20.66	32.6
pH (1:2)	8.42	8.2	8.06	8.46	8.25	8.1
EC (dSm^{-1})	0.29	0.31	0.32	0.196	0.3	0.33

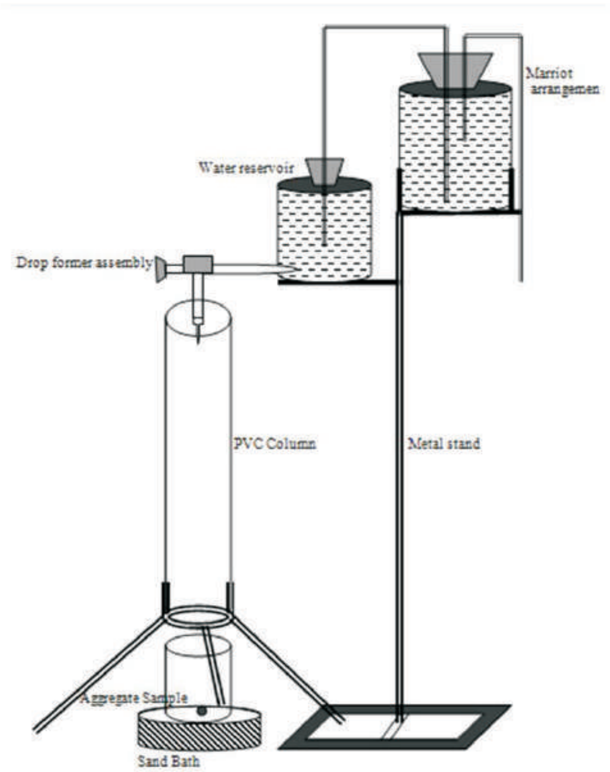


Fig. 1. Schematic diagram of single raindrop simulator

completely randomized factorial design using software SAS 9.3.

RESULTS AND DISCUSSION

The SOC and stock: The SOC concentration as affected by soil texture and cropping system is presented in Table 2. The mean SOC content was significantly higher (0.69%) in fine textured soils followed by medium (0.63%) and was lowest (0.42%) in coarse textured soils. It is commonly accepted that SOC concentration is proportional to the increase in clay plus silt content and decreases with increase in sand content (Zinn *et al.,* 2005; Gami *et al.,* 2009). The clay particles are being charged form organo-mineral complexes with humus (McLaren and Cameron, 1996) and clay skin is formed around the humus thereby resulting in protection of SOC from easy decomposition. Snelder (2001) observed that SOC was highest in clayey soils due to stable clay-humus complexes. It has been demonstrated that the organic C (fresh or labile) derived from crop residues is incorporated into the coarse sand fraction during the initial decomposition period and subsequently accumulates and becomes stable in silt or clay soils (Six *et al.,*2000).

Consequently, it is possible that higher fresh SOC contents could first accumulate in larger fractions, particularly in soils receiving large amounts of crop residues through leaf fall (Chen *et al.,* 2014). The C:N ratio indicates the degradation of fresh plant residues, which is important in the process of C sequestration (Potter *et al.,*1998). Gupta *et al.* (2009) observed that increase in SOC due to agroforestry was higher in loamy sand than in sandy clay soil. Among the cropping system, agroforestry system (0.73%) has higher SOC concentration compared to maize-wheat system (0.43%). This could be due to high input of C through leaf litter fall and greater root biomass of tree species compared to sole crops. Poplar trees add about 2.9–3.3 t ha^{-1} of litter fall every year (Ralhan *et al.,* 1996) and supply 2.3 t C ha^{-1} y^{-1} through roots and leaves (Chauhan *et al.,*2011), which adds to increased SOC concentration. This may be due to addition of crop residues through leaf fall coupled with less disturbance of soil where residues could be stabilized in the form of organic matter in soil (Lorenz *et al.,*2005). In subsurface (15-30 cm) soil layer, the cropping system and soil texture had significant interaction. The coarse textured soils under maize-wheat could store lower soil organic carbon (14.5 Mg ha-1) compared to 23.3 Mg ha^{-1} in soils under agroforestry system (Fig. 2). The medium and fine textured soils under maize-wheat stored higher SOC than the coarse textured soils. However, the SOC stock in different textured soils under agroforestry was almost similar. This could be due to the addition of enormous amount of litter fall in agroforestry soils, which might have nullified the effect of soil texture (Young 1989; Ralhan *et al.,* 1996; Singh and Tripathi 1998).

Table 2. Soil organic carbon concentration (%) in relation to soil texture and cropping system

Soil texture	Cropping system		
	Maize-wheat	Agroforestry	Mean
0-15 cm soil layer			
Coarse	0.26	0.58	0.42
Medium	0.48	0.78	0.63
Fine	0.55	0.83	0.69
Mean	0.43	0.73	
LSD (0.05)	Cropping system (CS) = 0.054; Soil texture (ST) = 0.067; CS× ST = NS		
15-30 cm soil layer			
Coarse	0.31	0.38	0.34
Medium	0.42	0.45	0.43
Fine	0.50	0.52	0.51
Mean	0.41	0.45	
LSD (0.05)	Cropping system (CS) = NS; Soil texture (ST) = NS; CS× ST =0.08		

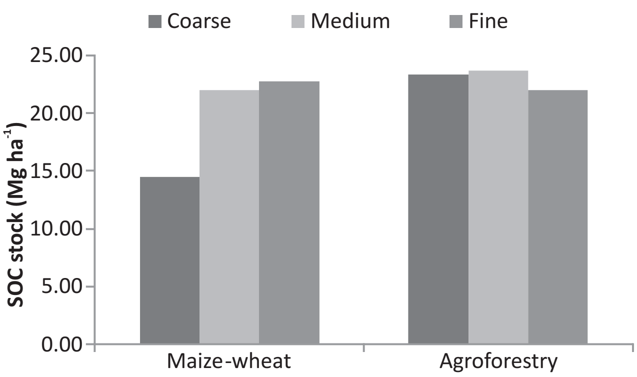


Fig. 2. Soil organic carbon stock in 0-30 cm soil layer in relation to soil texture and cropping system

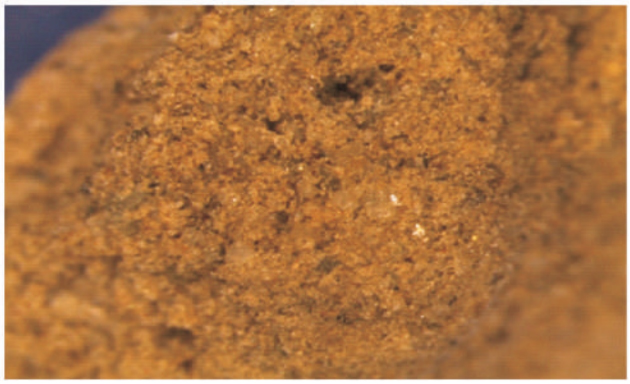
Stability index: The stability index (SI) of aggregates as obtained by single raindrop technique and expressed as J kg^{-1} is illustrated in Table 3. This technique has been used to measure the aggregate stability under laboratory conditions as it simulates the actual process of detachment of soil aggregates under rainfall conditions. Soil texture affected SI significantly. The mean SI was highest (0.186 J kg^{-1}) in fine textured soils followed by medium (0.139 J kg^{-1}) textured soils and was lowest in coarse textured soils (0.115 J kg^{-1}). The SI decreased by 25.3 per cent and 38.2 per cent in medium and coarse textured soils from that in fine textured soils. The increase in SI of aggregates with increase in fineness of soil is due to the binding effect of clay particles apart from the higher SOC associated with fine textured soils than in coarse

Table 3. Stability index (J kg^{-1}) of aggregates in relation to soil texture and cropping system

Soil texture	Cropping system		
	Maize-wheat	Agroforestry	Mean
0–15 cm soil layer			
Coarse	0.086	0.144	0.115
Medium	0.116	0.162	0.139
Fine	0.148	0.223	0.186
Mean	0.117	0.176	
LSD (0.05)	Cropping system (CS) = 0.022; Soil texture (ST) = 0.027; CS × ST= NS		
15–30 cm soil layer			
Coarse	0.074	0.126	0.099
Medium	0.091	0.133	0.112
Fine	0.131	0.177	0.154
Mean	0.099	0.145	
LSD (0.05)	Cropping system (CS) = 0.01; Soil texture (ST) = 0.013; CS × ST = NS		

textured soils. The higher stability index of agroforestry system (0.176 J kg^{-1}) than in maize-wheat system (0.117 J kg^{-1}) may be due to higher organic matter content as SOC is the major determinant of stability of aggregates and hence soil erodibility (Haynes, 2000). Humberto *et al.* (2007) related decreased aggregate stability from grass to cultivated treatments to the loss of organic matter upon cultivation. In subsurface (15–30 cm) soil layer, the SI followed the similar trend as in the surface layer except that the magnitude of the values was low. The mean SI was significantly higher (0.145 J kg^{-1}) in agroforestry than in soils under maize wheat (0.099 J kg^{-1}). Similar trend was observed with respect to soil texture as in 0–15 cm soil layer.

Stereo-microscopy: The stereo-micrographs of the surface (0–15 cm) soil aggregates from different soil textures and under maize-wheat and agroforestry are depicted in Figs. 3-5. The aggregates from fine textured soils seemed to be darker in colour in comparison to medium textured soil and were light in coarse textured soils. This dark colour of the aggregate may be due to higher content of organic carbon, as colour of humus is dark brown. This indicates that the fine textured soils have highest organic carbon content followed by medium and in coarse textured soils. This is in accordance with the quantitative amounts as analysed in the laboratory using Walkley and Black method (Table 2). The black spots in coarse textured aggregates under agroforestry are confined to isolated places but in fine textured aggregates these seems to be uniformly distributed at many places throughout the aggregate. The dark brown colour of the aggregates from fine textured soil could be due to higher organic carbon, which might be present inside the aggregate in more protected form by forming complexes with the clay known as clay-humic complexes. The cracks were more prominent in the aggregates from medium textured soils. Further the comparison of aggregates under agro-forestry and maize-wheat indicates that the aggregates from agroforestry seem to be comparatively dark in colour then the aggregates from maize-wheat. Perhaps, it could be due to higher amount of organic deposits in the form of leaf litter or mineral coated with organic carbon. The carbon deposits are shown by encircled areas (dark brown to black colour deposits). The aggregates from agroforestry show minute pores, which could probably be due to larger number of penetrating root hairs.



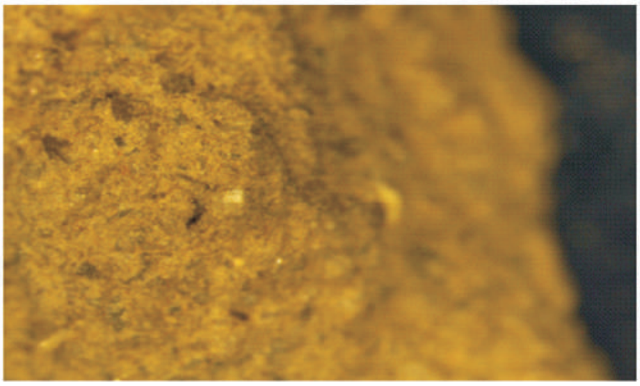
(a)

(b)

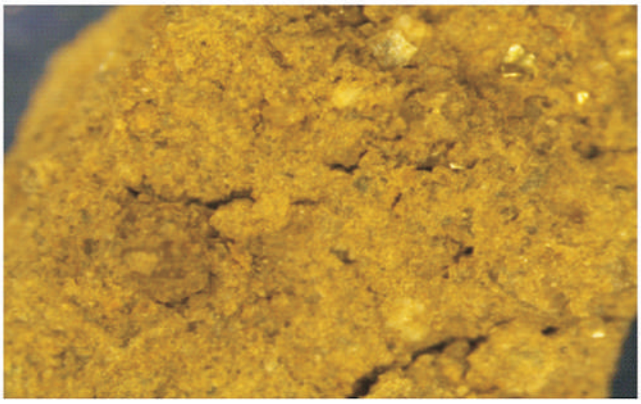
Fig. 3. Stereo-zoom of aggregate from (a) maize-wheat and (b) agroforestry under coarse textured soils at 19.4x

CONCLUSION

Soil particle-size fractions and cropping systems individually and interactively impacted soil carbon and aggregate stability in the Shiwalik region of northwest India. The highest SOC and aggregate stability existed in fine textured soils. The fine size fractions held higher soil carbon and better soil conditions for aggregates stability than coarse size. Thus, we recommend soil fractionation as a promising

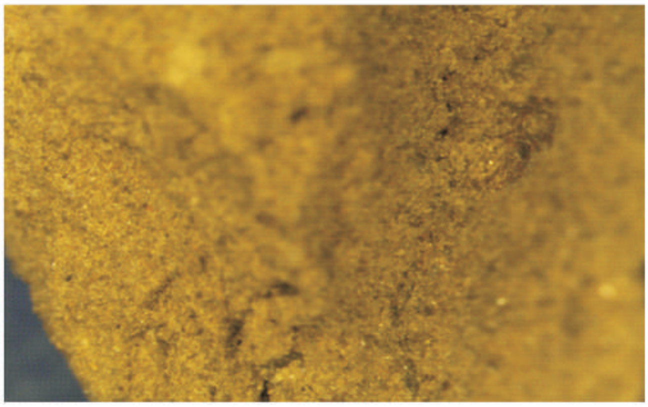


(a)

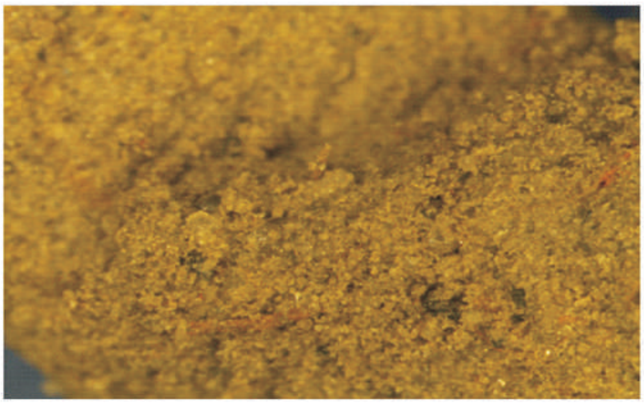


(b)

Fig. 4. Stereo-zoom of aggregate from (a) maize-wheat and (b) agroforestry under medium textured soils 19.4x



(a)



(b)

Fig. 5. Stereo-zoom of aggregate from (a) maize-wheat and (b) agroforestry under fine textured soils 19.4x

approach that offers potential in analyzing the relationship between soil carbon and aggregate stability, which can be correlated with soil erosions under different land use systems in the region.

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Effect of Vermicompost on Growth and Yield of *Stevia rebaudiana* Bert. Under Plum Based Agroforestry System in Mid hill Zone of Himachal Pradesh

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Abstract: An experimental trial comprising of seven treatments and a control i.e., plum + *Stevia rebaudiana* + recommended dose of NPK and FYM, Plum + *Stevia rebaudiana* + 75% recommended dose and 25% vermicompost, Plum + *Stevia rebaudiana* + 60% recommended dose and 40% vermicompost, Plum + *Stevia rebaudiana* + 45% recommended dose and 55% vermicompost, Plum + *Stevia rebaudiana* + 30% recommended dose and 70% vermicompost, Plum + *Stevia rebaudiana* + 100% FYM only, Plum + *Stevia rebaudiana* +100% vermicompost only and control; *Stevia rebaudiana* + recommended dose of NPK and FYM was carried out to study its effect on growth and yield parameters of *Stevia rebaudiana* Bert., soil physio-chemical properties and bio-economical appraisal of the system. *Stevia rebaudiana* achieved higher values for most of the growth and yield parameters viz., plant height (20.97 cm), number of leaves plant^{-1} (70.37), LAI (2.24), total fresh weight (61.57 q ha^{-1}) values under plum + *Stevia rebaudiana* + 75% recommended dose and 25% vermicompost. Plum tree had a positive effect on growth and yield performance of *Stevia rebaudiana* Bert., which were found healthier and better thriving underneath plum canopy than in open conditions. Soil pH, bulk density, organic carbon, available N, P and K in the surface as well as subsurface soils were found to be significantly effected by different doses of organic manures and chemical fertilizers. The bio-economics of this system revealed that the total net return was higher in agroforestry than sole cropping. From the present investigation, it can be concluded that *Stevia rebaudiana* can be grown under plum based agroforestry system successfully for better economic returns.

Keywords: Vermicompost, *Stevia rebaudiana,* FYM

Agroforestry is receiving long overdue attention as a resource efficient, environmentally positive, and profitable method of farming. Agroforestry land use systems have been designated as the multifaceted, viable and profitable option which is able to address the multifarious needs of rural peasants and industries too. Incorporating MAPs in farming along with multipurpose tree species (MPTS) or fruit trees is an old practice in India and other parts of South and South East Asia. The continuous production from these systems, and the flexibility of having several options for management make agroforestry systems of immediate and potential value. Apart from grains and pulses, MAPs are destined to play an important role in socio-economic transformation of marginal land holders into more productive agrarian economy. These plants, as intercroped in agroforestry will open new vistas for research and development.

Most of the Indian agricultural lands are deprived of some of the essential nutrients for growth and development of crop plants. Chemical fertilizers supplement the nutrient supply. But such chemical fertilizers pose serious health hazards and microbial population problem in soil besides being quite expensive and making the cost of production high. In such a situation the organic manures play an important role.

Stevia rebaudiana Bert.is a herbaceous plant native to South America (Paraguay and Brazil) but recently domesticated in India. The glycoside obtained from *Stevia* is considered to be the best alternative source of sugar for diabetes. Stevia has garnered attention with the rise in demand for low-carbohydrate, low-sugar food alternatives. Medical research has also shown possible benefits of *Stevia* in treating obesity and high blood pressure. As the drug industry requires large quantities of raw material for extraction of the active compounds, there is a need to enhance the biomass of cultivated MAPs through proper cultural techniques and integrated nutrient management. Hence, the present study aimed to study the effect of different doses of vermi-compost on growth and yield of *Stevia rebaudiana* Bert. Inter-cropped under plum based agroforestry system, soil physio-chemical properties and its bio-economical appraisal.

MATERIAL AND METHODS

The present investigation was carried out at experimental field of the Department of Silviculture & Agroforestry, Dr Y.S. Parmar University of Horticulture and Forestry, Nauni, Solan, H.P. during the year 2010 - 2011. The experimental site falls in the mid-hill zone of Himachal

Pradesh at 30°51'N latitude and 76° 11' E longitude, with an elevation of 1200 m amsl. The climate of the area is transition between sub-tropical to sub temperate. In general, May and June are the hottest months and, December and January are the coldest ones. The annual rainfall varies from 1000–1400 mm, about 75 per cent of it is received during monsoon period (mid-June to mid-September). The soils of the area belong to Typic Eutrochrept at subgroup level according to Soil Taxonomy of USDA. The important chemical properties of the experimental sites for 0–15 cm and 15–30 cm depth are: pH (1:2): 6.75 and 6.90; organic carbon (%): 0.84 and 0.58; available nitrogen (kg ha^{-1}): 344.81 and 327.63; available phosphorus (kg ha^{-1}): 29.78 and 26.10; available potassium (kg ha^{-1}): 143.21 and 142.46 and bulk density (g/cm^3): 1.25 and 1.27 respectively.

Experimental methodology: The experiment was laid out in randomized block design with three replications comprising of seven treatments and a control (T_1; *Prunus domestica L.* + *Stevia rebaudiana* Bert. + Recommended dose of NPK and FYM, T_2 ; *Prunus domestica L.* + *Stevia rebaudiana* Bert. + 75% Recommended dose and 25% Vermicompost, T_3; *Prunus domestica L.* + *Stevia rebaudiana* Bert. + 60% Recommended dose and 40% Vermicompost, T_4; *Prunus domestica L.* + *Stevia rebaudiana* Bert. + 45% Recommended dose and 55% Vermicompost, T_5; *Prunus domestica L.* + *Stevia rebaudiana* Bert. + 30% Recommended dose and 70% Vermicompost; T_6 ; *Prunus domestica L.* + *Stevia rebaudiana* Bert. + 100% FYM only, T_7; *Prunus domestica L.* + *Stevia rebaudiana Bert.* + 100% Vermicompost only and Control; *Stevia rebaudiana Bert.* + Recommended dose of NPK and FYM of plum). Twenty three years old plum plants have an average height of 5.33m, basal diameter of 30.58cm and crown spread area of 2,31m^2 planted in East to West direction at a distance of 6m x 6m were used for the experiment. The plot size was 2m x 1m and spacing of 40cm x 20cm was maintained for *Stevia rebaudiana*. Seedlings were transplanted in the month of July 2010. Light irrigations were given after transplanting to facilitate the establishment of seedlings. Hand weeding was done after one and two months of transplanting and hoeing was done after each weeding. The experimental plots were maintained properly and kept free of weeds. Half of the calculated doses of N and full doses of P and K and organic manures like Vermicompost and Farm Yard Manure were applied in the individual plots at the time of transplanting of seedlings. In control, recommended doses of NPK and FYM were given. Remaining dose of N was given after a month. Hand weeding was done from time to time to keep the beds free from weeds. Hoeing and irrigations were given as per crop requirement. Harvesting of *Stevia rebaudiana was done* during the month of November.

Estimation of growth and yield parameters and physiochemical properties of soil: Plant height of *Stevia rebaudiana* was determined in centimeters with the help of a scaled ruler from the ground level to the top of the highest shoot of the plant for all treatments. Plant height was measured 90 days after transplanting. Each value is the mean of three replications, ten plants per replication. The number of leaves $plant^{-1}$ of *Stevia rebaudiana* was recorded for each treatment before harvesting. Each value is the mean of three replications within each treatment. The total numbers of branches arising from main stem of ten randomly selected plants were counted and mean number of branches per plant was worked out. The leaf Area Index (LAI) of *Stevia rebaudiana* was measured with the help of pre-calibrated programmed LAI 2000 Plant Canopy Analyser (LI-COR, USA). Each value was computed on the basis of one open and four beneath the canopy readings. The open reading was taken away from the canopy by holding the sensor of the canopy analyser above the canopy of medicinal plants. Thereafter, the sensor was held underneath the medicinal plants canopy near the base of the crops, 3-5 cm above the ground level to take 4 below canopy readings. Each value of the LAI is the mean of three replications and has been expressed as unit less quantity. The yield of economic parts of *Stevia rebaudiana* refers to the fresh weight of leaves. The yield of the economic parts was expressed in q ha^{-1}.

For soil analysis, viz., pH, organic carbon, available N, P, K and Bulk density, composite soil samples were collected from 0–20cm and 20-40cm depth from each plot, before transplanting and after harvesting of crops, air dried and sieved to pass a 2mm screen. The pH of soil were determined using 1:2.5 soil : water suspension (Jackson, 1973). Organic carbon, available nitrogen, available phosphorus and available potassium were determined by using rapid titration method (Walkley and Black, 1934); alkaline potassium permanganate method (Subbiah and Asija, 1956); neutral 1N ammonium acetate method (Merwin and Peech, 1951), respectively. Whereas, Bulk density (g cm-3) was estimated by the specific gravity method (Singh, 1980). Bio-economics of system was analyzed by calculating the cost of cultivation, gross and net returns per hectare. All these parameters were calculated on the basis of market price prevailing at the time of termination of experiment. The data thus recorded for different parameters were subjected to appropriate statistical analysis as per the standard procedure (Gomez & Gomez, 1984).

RESULTS AND DISCUSSION

Growth and yield parameters: The plum had a positive effect on growth and yield performance of *Stevia rebaudiana* and were found healthier and more thriving underneath plum than in open conditions. The results in general indicate that organic manures are found to improve the growth and performance of medicinal plants. The growth and yield parameters like plant height, no. of leaves per plant, no. of branches per plant, leaf area index and fresh weight yield of plants were significantly influenced by different doses of organic manures (Table 1). Results showed that *Stevia rebaudiana* achieved higher values of growth and yield parameters viz., plant height (20.97 cm), number of leaves plant^{-1} (70.37), LAI (2.24), total fresh weight (61.57 q ha^{-1}) values under T_2, where plants under plum were supplied with 75% recommended dose of fertilizers + 25% vermicompost. Further, combined application of 45% recommended dose of fertilizers + 55% vermicompost gave significant higher value for number of branches plant^{-1} (12.21). Further, minimum values of number of leaves plant^{-1} (54.00), number of branches plant^{-1} (10.90) and total fresh weight (50.00 q ha^{-1}) of *Stevia rebaudiana* were recorded under T_6 (100% FYM). Whereas, minimum plant height (16.73) was recorded under control and minimum lai under T_7 (100% vermicompost only). It was observed that out of three combinations tried i. e. simple recommended dose of NPK and FYM, fractions of recommended dose replaced with nitrogen equivalent proportions of vermicompost and the pure organic manures (vermicompost and FYM), effectiveness of second combination was much more than the others. The reason may be the nutrient enrichment of soil due to the use of vermicompost and chemical fertilizers in combination. These results are in line with that of Scheffer *et al*. (1993), Paturde *et al*. (2002) and Zohra *et al*. (2005). Also, the low nutrient present in organic manures in comparison with inorganic fertilizers might have been balanced by the combined application of both. The results are in agreement with the findings of Singh *et al.* (2002). A closer look of the results reveal that the plants receiving vermicompost and fertilizers had better yield as compared to FYM. This can be ascribed to the better residual build up of organic carbon and available NPK in soil by vermicompost application or may be due to the easy and fast availability of nutrients in fertilizers and vermicompost as compared to combinations where the fraction of FYM or vermicompost was more. The data indicate that the combined use of vermicompost with chemical fertilizer was found most effective in enhancing number of leaves per plant, number of branches per plant and LAI in both the species under investigation.

The increment in growth performance is attributed to the organic carbon and nitrogen provided by the organic manures and fertilizers and this improvement at micro level in soil physicochemical properties further contribute to the better growth of plants. For example, increased leaf area intercepts more photosynthetically active solar radiation and provides more photosynthetic surface in plants. These results are in conformity with Sehgal (2007), who reported improved growth of medicinal and aromatic plants namely *Ocimum sanctum* and *Tagetes minuta* by the use of organic manures under agroforestry condition. Maheswarappa *et al*. (1998) and George and Pillai (2000) also reported that vermicompost stimulated the growth of intercrop grown under coconut trees. The possibility that the herbal crops can be benefited from the microclimate of trees was somewhat apparent as growth and yield parameters of the species were found to have higher values inside the plum orchard than the outside without trees (control).

Soil pH and bulk density: The application of different doses of organic manures found to have significant influence on soil pH, bulk density, organic carbon, available N, P and K in the

Table 1. Effect of different doses of vermicompost on growth and yield characteristics of *Stevia rebaudiana* under plum based agroforestry system

Treatments	Height (cm)	No. of leaves plant^{-1}	No. of branches plant^{-1}	LAI	Fresh Weight (q ha^{-1})			
					Shoot (Stem + Leaves)	Leaves	Root	Total
T_1	18.80	62.00	11.25	2.09	49.00	46.80	4.47	53.47
T_2	20.97	70.37	11.34	2.24	56.67	52.10	4.90	61.57
T_3	19.90	67.47	12.17	2.16	55.67	51.43	5.17	60.84
T_4	19.43	63.50	12.21	2.23	52.00	48.53	4.70	56.7
T_5	18.13	55.90	11.55	2.12	50.33	46.77	4.64	54.97
T_6	17.10	54.00	10.90	2.03	45.77	41.00	4.23	50.77
T_7	17.76	59.13	11.67	2.00	48.97	44.50	4.43	53.4
Control	16.73	61.47	10.91	2.06	49.07	45.79	4.42	53.49
CD (p=0.05)	0.84	9.01	.91	0.05	6.31	6.36	0.52	6.33

surface as well as subsurface soils (Table 2). pH of soil ranged from 6.38 (T_6) to 6.74 (T_2) at 0-20cm and 6.53 (T_6) to 6.90 (T_2) at 20-40cm depth which means that it is normal and no treatment is required. The slight decline in the soil pH under organic manure treatment can be attributed to the production of organic acids formed during decomposition of organic stuff. The results are in accordance with the findings of Srikanth *et al.* (2000) and Jayabhaskaran *et al.* (2001), who also reported a decline in the soil pH with application of poultry manure and vermicompost. The values for BD ranged from 1.21 gcm^3 (T_7) −1.32 gcm^3 (T_2) at 0-20cm and 1.24 gcm^3 (T_7) −1.36 gcm^3 (T_2) at 20−40cm depth. The bulk density values also can be explained in light of the results reported by Kadalli *et al.* (2000). They attributed the decline in the bulk density to the better soil aggregation and aeration brought about by organic amendments through the addition of humic fractions. However, Lanjewar *et al.* (1992) ascribed a decrease in the decline in the bulk density, with the addition of organic materials to improve soil structure. Ghuman and Gur (2006) reported that increase in organic carbon content in the manured plots caused the reduction in bulk density. In the present investigation also an increase in organic carbon content (Table 2) was noted where bulk density values were low. Increased microbial and enzymatic activity due to addition of organic manure might have led to lower bulk density. Mukherjee *et al*. (2000) and Srikanth *et al*. (2000) also reported a decrease in bulk density with the addition of different organic amendments. A critical appraisal of data reveal that subsurface soil registered higher pH values compared to surface soils. The lower pH of the surface soil can be attributed to their higher organic matter content and their more weathered conditions. A trend similar to this has also been reported by Raina and Goswami (1988).

Soil organic carbon: The data pertaining to organic carbon (Table 2) reveal that application of organic manures significantly influenced organic carbon at both depths of soil. In the depth 0-20cm, the highest value (1.32%) of organic carbon was found under treatment T_6 where plants were supplied with 100% FYM followed by (1.24%) in T_7 where plants were supplied with 100% vermicompost only and the least was 0.86% in control. In the depth 20-40cm, the maximum (0.88%) organic carbon was found to be in treatment T_6 where plants were supplied with 100% FYM followed by T_7 (0.84%) where plants were supplied with 100% vermicompost only and the least value observed was 0.62% in control. These results are in line with the findings of Mukherjee *et al*. (1999) and Tolanur and Badanur (2003). They reported a progressive increase in OC content of soils with the addition of different organic amendments. Marimuthu *et al.* (2001) also reported that application of organic sources (FYM or farm residue) along with inorganic fertilizers increased the OC content of soils compared to those which received sole applications of chemical fertilizers only.

Available N, P and K: The different combinations of organic and chemical fertilizers significantly influenced the amount of available N, P and K in surface and sub surface soils. The maximum available N (363 kg ha^{-1}) (342.80 kg ha^{-1}) at 0-20cm and 20-40 cm depth, respectively were recorded under T_7 where plants were supplied with 100% vermicompost only. Whereas minimum value of available N to the tune of 350 kg ha^{-1}and 332.29 kg ha^{-1}at 0-20cm and 20-40 cm depth respectively were recorded under T_4, where plants were supplied with 45% recommended dose + 55% Vermicompost. In the surface (0-20cm) and subsurface (20−40cm) soil the maximum available P (36.41 kg ha^{-1}) and (32.03kg ha^{-1}), respectively were recorded for the treatment T_1 where plants were supplied with recommended dose of

Table 2. Effect of different doses of Vermicompost on soil physico-chemical characteristics

Treatments	pH		BD (gcm^{-3})		OC (%)		Available nutrient content (Kg ha^{-1})					
	D_1	D_2	D_1	D_2	D_1	D_2	N		P		K	
							D_1	D_2	D_1	D_2	D_1	D_2
T_1	6.56	6.67	1.24	1.27	0.90	0.64	357.11	341.30	36.41	32.03	162.23	158.48
T_2	6.74	6.90	1.32	1.36	0.97	0.66	360.68	340.26	35.14	31.75	160.51	157.14
T_3	6.68	6.83	1.26	1.28	1.01	0.75	353.42	334.38	32.37	30.35	158.65	156.67
T_4	6.64	6.78	1.26	1.26	1.10	0.76	350.17	332.29	31.11	28.28	158.14	155.59
T_5	6.62	6.73	1.24	1.29	1.16	0.72	351.87	335.00	31.33	28.67	155.37	155.23
T_6	6.38	6.53	1.24	1.25	1.32	0.88	355.00	334.67	34.63	30.66	160.37	154.88
T_7	6.49	6.60	1.21	1.24	1.24	0.84	363.00	342.80	30.61	27.30	154.81	157.27
Control	6.55	6.57	1.24	1.26	0.86	0.62	358.00	337.82	35.64	32.00	161.67	158.43
CD (p=0.05)	0.04	0.03	0.01	0.03	0.02	0.01	1.15	1.02	0.53	0.36	0.26	0.44

D_1= 0-20cm; D_2=20-40cm

Table 3. Economic appraisal of plum based agroforestry system intercropped with *Stevia rebaudiana*

Treatments	Gross returns (Rs ha^{-1})	Cost of cultivation (Rs ha^{-1})	Net returns from intercrop (Rs ha^{-1})	Net returns from trees (Rs ha^{-1})	Total net returns from the system (Rs ha^{-1})
T_1	61,230	25600	35630	74,790	110420
T_2	64,550	26440	38110	74,790	112900
T_3	63,780	26700	37080	74,790	111870
T_4	61,500	27,350	34150	74,790	108940
T_5	59,790	27,900	31890	74,790	106680
T_6	57,670	22700	34970	74,790	109760
T_7	58,320	28,990	29330	74,790	104120
Control	59,580	24650	34930	–	34930
Mean	60803	26291.25	34511,25	74,790	99952.5

NPK and FYM. The least value for available P to the tune of 30.61kg/ha at 0–20cm depth and 27.30 kg ha^{-1} at 20–40cm were observed in treatment T_7 i.*e.* plants supplied with 100% FYM. Maximum available K in the surface soil (0–20cm) to the tune of 162.23 kg ha^{-1} was recorded for the treatment T_1 where plants were supplied with recommended dose of NPK and FYM, whereas, in the same depth the least value for available K, 154.88 ha^{-1} was observed in treatment T6 i.*e.* plants supplied with 100% FYM. However, in subsurface soil (20–40cm), the maximum available K (158.48kg ha^{-1}) was recorded for the treatment T_1 where plants supplied with recommended dose of NPK and FYM , whereas, the least value for available K157.27Kg ha^{-1} was observed in treatment T_7 i.*e.* plants supplied with 100% FYM. Addition of organic manures with lower C: N ratio(less than 20:1) might have increased the microbial activity, thereby, accelerating the rate of mineralization. This might have lead to more release of N from native organic sources, ultimately, resulting in higher N content in soils. Raina and Goswami (1988) have also reported that the addition of organic material accelerates the decomposition of native soil organic matter (a positive priming effect), thus, leading to higher mineralization and release of nutrient elements. Other workers (Marimuthu *et al*., 2001; Sreenivas *et al*., 2000; Singh *et al*., 2002) have also reported that the inclusion of organic amendments and inorganic fertilizers at variable rates increased the soil N, P and K content. Prakash *et al*. (2002) in their study on comparative efficacy of organic manures and inorganic fertilizers in relation to nutrient availability, reported higher availability of all major nutrient elements in treatments supplemented with organic nutrient sources compared to chemical fertilizers alone.

Bioeconomics of the system: The economics of the plum based agroforestry system intercropped with Stevia rebaudiana revealed that the cost of cultivation was maximum incurred in the practice, where plants were grown with Plum and supplied with 100% vermicompost while minimum cost of cultivation to the tune of Rs. 24,650 ha^{-1} was obtained under control (Table 3). Intercropping of Stevia rebaudiana with plum and supplemented with the 75% Recommended dose and 25% Vermicompost (T_2) gave higher total net return i.e., (Rs. 112900 ha^{-1}) than other treatments. Comparing the economics of agroforestry and open cropping systems of the medicinal plant, agroforestry intervention was found to be more remunerative than open cropping system. This is because of its higher biomass production and market price. Open cropping systems found to have lowest gross returns. The cost of FYM was very less as compared to vermicompost and chemical fertilizers, which affects the net return of the system. Comparatively more returns were obtained from agroforestry systems than in sole cropping. It is due to the additional income procured from the plum trees. The results are in line with the findings of Yadava and Singh (1996), Chauhan (2000) and Dutt and Thakur (2004).

CONCLUSION

The results obtained from the present investigation indicated that the medicnal plant species *Stevia rebaudiana* Bert. thrive well under plum based agroforestry system. Growth and yield attributes as well as soil physio chemical properties were positively affected by application of different doses of organic manures. The use of organic manure + chemical fertilizers has been found to be more efficient than organic manures alone. The treatment where plants were supplied with 75% recommended doses + 25% vermicompost was found to have higher values for most of the growth and yield attributes. Also, the production potential and economic returns were higher inside the agro forestry system than open cropping. Therefore, it can be suggested that growing of *Stevia rebaudiana* under plum based agroforestry system is economically more profitable and the use of combinations of organic manures and inorganic fertilizers further improves the growth and helps in enhancing the yield of this herb. Hence, it can be concluded that *Stevia rebaudiana* can be grown successfully under plum based agroforestry systems and this diversification practice can be a viable option for boosting the economy of farming community.

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Growth and Performance of Trees and Green Gram (*Vigna radiata* L. Wilczek) in Agri-silvicultural System in the Dryland Conditions of Jammu Region

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Abstract: A field experiment was conducted to study the influence of three tree species viz., *Albizia lebbeck*, *Grewia optiva* and *Leucaena leucocephala* on the growth and yield of green gram (*Vigna radiata* L. Wilczek) under rainfed conditions. Association of tree species in agri-silviculture system reduced the growth parameters, yield attributes and grain yield of green gram as compared to control (sole green gram). The yield reduction was maximum under *Leucaena leucocephala*, minimum with *Albizia lebbeck* and moderate under *Grewia optiva*. The yield of green gram got reduced to the tune of 16.72, 24.23 and 33.69 per cent under *Albizia lebbeck*, *Grewia optiva* and *Leucaena leucocephala*, respectively. The reduction in Incidental Solar Radiation (ISR) under the canopy of tree species also followed the similar trend.

Keywords: Agroforestry, Agri-silviculture, Green gram, Drylands

Agroforestry is an old-age practice of growing multipurpose tree species in association with crops on the same unit of land. It meets on-farm needs of the farmers by providing fuel wood, fodder, timber, etc. and act as insurance against aberrant weather condition in addition to several indirect benefits especially enriching the soils and carbon sequestration. The competition for light, water and nutrients between trees and food crops is perhaps the most important interaction in agroforestry systems.

Poor productivity in dryland regions is characterized by low and erratic rainfall, intense solar radiation, high wind velocity, low organic matter and nutrient status. Sparse vegetation does not provide security of food, fodder and fuel wood. Integrating trees enhances the overall productivity and income by ameliorating harsh environment of the area. That's why the farmers maintain growing sparse trees of *Prosopis cineraria*, *Tecomella undulata*, and *Ziziphus nummularia*, on their cultivated fields. These trees sustain the farming during the crop failure by producing food, fodder and timber but density of such trees is very low and variable (Tewari *et al*., 2007). Dryland areas in the foot hills of Jammu Shivaliks of Jammu and Kashmir are also subjected to such limitations vis-a-viz low productivity and frequent crop failures. Thus, agri-silvicultural system involving pulse crops under tree species such as *Albizia lebbeck*, *Grewia optiva* and *Leucaena leucocephala* can be a viable option for farmers of drylands. Pulses by virtue of their soil ameliorative properties and nitrogen fixing ability play an important role in sustaining soil health. Green gram (*Vigna radiata* L. Wilczek) is the third important pulse crop of the country after chickpea and pigeonpea. Green gram, however, holds its own uniqueness in the sense that no other pulse crop matures in 60-70 days and this feature enables it to fit in most of the cropping systems. Keeping in view these considerations, the present study was undertaken to study the effect of trees on growth and yield of green gram as an understorey crop in agri-silvicultural system.

MATERIAL AND METHODS

The present investigation was carried out at the Experimental Farm of the Dryland Research Sub-station, Dhiansar, Sher-e-Kashmir University of Agricultural Sciences and Technology of Jammu (SKUAST-J). It is located at 32° 39' N latitude and 74° 53' E longitude, 332 meters above mean sea level in the Shivalik foothills of North-Western Himalayas. The average annual rainfall of the experimental site is about 1100 mm, which is mostly received from south-west monsoons during the rainy season i.e. July to September. The maximum temperature rises upto 39.4°C during June and minimum falls to 5.7°C during January. The soil of the experimental site is sandy loam in texture, slightly acidic in reaction, low in organic carbon and available nitrogen but medium in available phosphorus and potassium.

The agri-silvicultural system comprised of three tree species viz., *Albizia lebbeck*, *Grewia optiva* and *Leucaena leucucephala* planted at 6×2 m spacing during 1996. The green gram (*Vigna radiata* L. Wilczek), var. SML-818 was sown as inter-crop as per the recommended agronomic practices during 2014 in the space between the hedgerows of tree species as well as in the open conditions (control).

The data on growth parameters (plant height, number of branches plant^{-1} and dry matter accumulation plant^{-1}), yield contributing characters (number of pods plant^{-1}, number of grains pod^{-1} and 1000 grain weight) and grain yield of green gram was recorded during the course of investigation. Observations on tree height, collar diameter, crown diameter, leaf biomass, branch + twig biomass, stem biomass and total above ground biomass of trees were also recorded in order to describe the status of these trees species under agroforestry system. The incidental solar radiation (ISR) was measured at 12:00 noon at crop canopy level using a luxmeter (Yoshida *et al*., 1972). Measurements were recorded at a distance of one meter from the tree rows along with one reading in the plot without trees (control). It was worked out using the following formula:

$$\text{ISR (\%)} = \frac{\text{Light intensity under tree canopy over test crop}}{\text{Light intensity over test crop without trees}} \times 100$$

The statistical analysis for each character was carried out on mean values. The data was subjected to analysis of randomized block design as suggested by Gomez and Gomez (1984).

RESULTS AND DISCUSSION

Growth and above ground biomass of tree species: Significant differences were observed among the tree species for growth parameters and above ground biomass except crown diameter (Fig.1). Among the three tree species, maximum height was observed in *Leucaena leucocephala* (6.52 m) followed by *Albizia lebbeck* (5.30 m) while maximum collar diameter observed in *Leucaena leucocephala* (18.83 cm) but statistically alike to collar diameter in *Albizia lebbeck* (18.30 cm). Minimum plant height of 4.19 m and collar diameter of 13.51 cm was recorded in *Grewia optiva.* The leaf biomass was maximum (4.88 kg tree^{-1}) in *Albizia lebbeck* closely followed by *Leucaena leucocephala* (4.10 kg tree^{-1}) while branch + twig biomass and stem biomass were found maximum in *Leucaena leucocephala* (11.52 kg tree^{-1} and 33.86 kg tree^{-1}, respectively) followed by *Albizia lebbeck*. So far as total above ground biomass is concerned, it was recorded highest in *Leucaena leucocephala* (49.49 kg tree^{-1}) followed by *Albizia lebbeck* (40.31 kg tree^{-1}) and lowest in *Grewia optiva* (22.30 kg tree^{-1}). The variation in growth characteristics and biomass might be due to different genetic make-up and their variable growth potential as the environmental conditions were similar for all the tree species in the study (Singh and Sharma, 2012; Singh *et al.,* 2016).

Growth performance of green gram: The presence of the tree species viz., *Albizia lebbeck*, *Grewia optiva* and *Leucaena leucocephala* in agri-silviculture system significantly affected growth parameters of green gram (Table 1). Maximum plant height (57.02 cm) was recorded in control (sole green gram) which was statistically at par with that recorded under *Albizia lebbeck* (55.39 cm) and *Grewia optiva* (53.46 cm). Minimum plant height of 46.75 cm was recorded under *Leucaena leucocephala*. Reduction in plant height of the crops grown under the tree species has also been reported by Thaware *et al*. (2004) in rice, (Pandey *et al.* (2011) in gram (*Cicer arietinum*), Palsaniya *et al*. (2012) in barley, Kumar *et al*. (2013) in wheat and mustard and Singh *et al.* (2016) in turmeric.

Maximum number of branches plant^{-1} (5.72) obtained in control was statistically alike with the number of branches recorded under *Albizia lebbeck* (4.52), while minimum number of branches plant^{-1} (3.76) was recorded under *Leucaena leucocephala.* Numerous earlier reports described

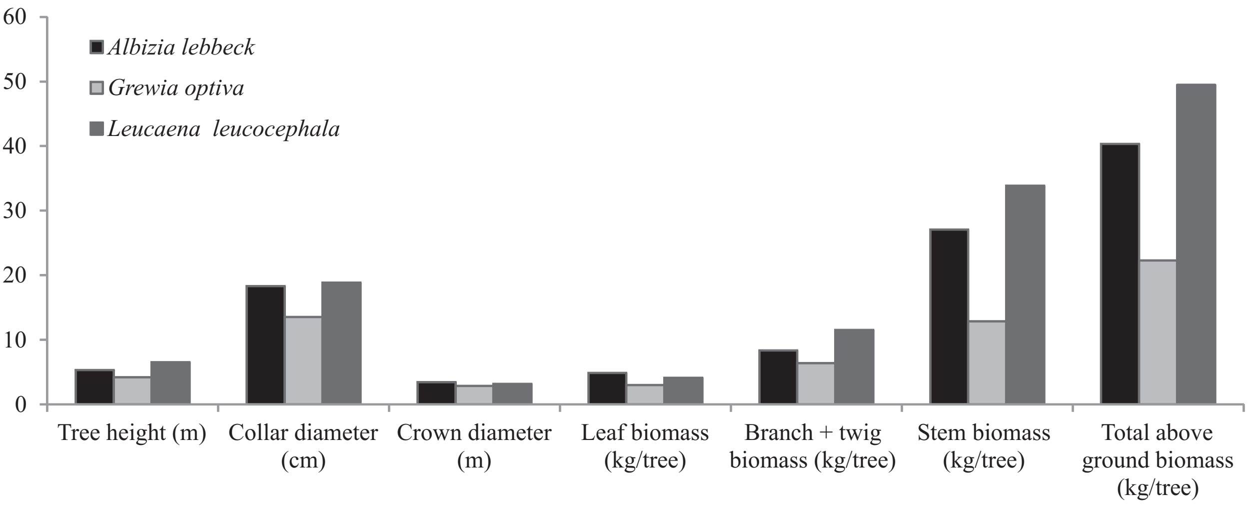

Fig.1. Tree growth and above ground biomass production by different tree species under agri-silviculture system

Table 1. Effect of different tree species on growth and yield of green gram (*Vigna radiata* L. Wilczek)

Treatments	Plant height (cm)	Number of branches plant^{-1}	Number of pods plant^{-1}	Number of grains pod^{-1}	1000 grain weight (g)	Grain yield (kg ha^{-1})	Dry matter accumulation (g plant^{-1})	ISR (%)
Albizia lebbeck + green gram	55.39	4.52	11.72	11.12	34.15	719.63	9.28	64.78
Grewia optiva + green gram	53.46	4.20	10.48	10.64	32.68	654.75	7.98	58.43
Leucaena leucocephala + green gram	46.75	3.76	8.80	10.04	30.93	572.96	7.05	54.16
Control (sole green gram)	57.02	5.72	15.20	12.08	38.56	864.10	10.87	100
SE m±	1.58	0.39	1.14	0.48	0.89	36.48	0.55	1.22
CD (p=0.05)	4.92	1.21	3.56	N.S.	2.77	113.65	1.71	3.81

the negative effect of trees on associated crops in terms of number of branches plant^{-1} and the findings of the present investigation are in accordance with the study of Kumar and Nandal (2004) in mustard and lentil, Pandey *et al.* (2011) in gram (*Cicer arietinum*), Kumar *et al*. (2013) in mustard, Yadav *et al*. (2005) and Sarvade *et al*. (2014) in wheat.

Maximum dry matter accumulation of 10.87 g plant^{-1} was recorded in sole crop (control) which was statistically similar with that observed under *Albizia lebbeck* (9.28 g plant^{-1}). Minimum dry matter accumulation (7.05 g plant^{-1}) was observed under *Leucaena leucocephala* but was statistically at par with that observed under *Grewia optiva* (7.98 g plant^{-1}). Suresh and Rao (1999) also found higher dry matter accumulation in sole sorghum as compared to intercrop grown under *Faidherbia albida*, *Acacia ferruginea* and *Albizia lebbeck.* Reduction in growth parameters while growing green gram in association with the tree species as compared to sole crop (control) is probably attributed to the intense competition for resources like water, nutrients, light, etc., especially at tree-crop interface. The tree species being the stronger and dominant component of the system certainly has greater and easy access to the available resources. This deprives the associated crop of their share resulting in resource crunch at the tree-crop interface.

Yield attributes and grain yield of green gram: The effect of trees on yield attributes (except number of grains pod^{-1}) of green gram was significant (Table 1). Maximum number of pods plant^{-1} (15.20), number of grains pod^{-1} (12.08) and 1000 grain weight (38.56 g) was recorded in control (sole green gram) followed by the value under *Albizia lebbeck* and *Grewia optiva*, while minimum number of pods plant^{-1} (8.80), number of grains pod^{-1} (10.04) and 1000 grain weight (30.93 g) was recorded under *Leucaena leucocephala*. Reduction in yield parameters of crop grown under the tree species has also been reported by Korwar *et al*. (2006) in green gram, Pandey *et al.* (2010) in black gram.

Similarly, grain yield (kg ha^{-1}) of green gram decreased significantly under tree species as compared to sole cropping (864.10 kg ha^{-1}). Among the tree species, maximum grain yield (719.63 kg ha^{-1}) recorded under *Albizia lebbeck* was at par with the grain yield of 654.75 kg ha^{-1} observed under *Grewia optiva.* Minimum grain yield of green gram (572.96 kg ha^{-1}) was obtained under *Leucaena leucocephala*. The reduction in grain yield was mainly due to poor sink development (number of pods plant^{-1}, number of grains pod^{-1} and 1000 grain weight). Incidental solar radiation was significantly low under different tree species compared to open situation (100%) due to light interception by the tree canopy. ISR value on the surface of intercrop was maximum (64.78%) under *Albizia lebbeck* followed by *Grewia optiva* (58.43%) and *Luecaena leucocephala* (54.16%).

The green gram mean yield (per unit area) in the agri-silviculture was generally lower as compared to sole crop which may be due to the higher plant population in the sole crop than the inter-crop and partially due to the inter and intra specific competition for sunlight and other resources. Growth, yield and yield contributing parameters of green gram though were lower under trees compared to sole crop. These parameters recorded maximum values under *Albizia lebbeck,* followed by *Grewia optiva* and then *Luecaena leucocephala*. It may be attributed to the variable canopy. *Luecaena leucocephala* has deep shade compared to other two and hence the light requirement of the intercrop is not fulfilled. The competition among the woody and non-woody components is believed to be responsible for decline in crop yields in agri-silviculture systems. It reflects the resource sharing pattern of the associated crops and trees and thus, controls productivity. The intercropping of green gram with tree species is less productive than sole crop but the farmers surely have additive advantage of trees in the production system. However, the results from the present study cannot be generalized and need to be verified at different locations in the dryland conditions of Jammu region of J&K to assess the productivity of agri-silvicultural system.

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Leaf Decomposition and Nutrient Release of Poplar Plantations in Moist Plain Area of Central Himalaya, Uttarakhand

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Abstract: Present study deals with the decomposition of leaf litter and nutrient release pattern in high density (666 tree ha^{-1}) poplar (*Populus deltoides* Marsh, 1-4 yrs age) plantations. The studied plantations were located in Tarai region (a low-lying land with high water table and nutrients) of central Himalaya. The decomposition study was carried out by using litterbag technique to examine the weight loss patterns and nutrient dynamics placed in each age plantation. Analysis of variance indicated significant differences in weight loss between age and time. The most rapid weight loss occurred at 1-yr age stand and decreased with plantation age. The weight loss ranged from 93-96 per cent. The temperature, rainfall and humidity had a significant effect on leaf litter decomposition of poplar in each stand. The rate of decomposition was higher than the natural forest adjacent to the central Himalaya. The rates of decomposition were significantly correlated with initial nutrient concentration.

Keywords: *Populus deltoides*, Leaf decomposition, Nutrients, Moist plain area

The rate and release of nutrients from the leaf litter influences the nutrient and biochemical properties of soil sub-system, which depends on decomposition pattern of litter and nutrient status of leaf litter. Thus, the knowledge of decomposition process of litter is vital for the study of ecosystem functioning. In plantations, the release of nutrients from forest floor through natural decomposition process is recognized as being a very important part of the nutrient cycle, whereby essential mineral elements tied-up in the plant biomass are made available for further plant growth. The rate of litter decomposition is influenced by a number of factors, including moisture, temperature and nature of micro-organisms, and soil fauna active in decomposition process. Nutrient changes in decomposition litter have been reported for natural forests and exotic plantations in central Himalayan Mountains by Lodhiyal and Lodhiyal (2003). The major objectives of this study were to examine the pattern of weight loss, nutrient release and effects of age from decomposing leaf litter of poplar plantations, and to compare present decomposition study with tree species of adjacent region and other parts of the world.

MATERIAL AND METHODS

The 90 ha plantation site for present study was located between $29^0 3$-$29^0 12$ N latitude and $79^0 20$-$79^0 23$ E longitude at 300m altitude in the Tarai belt, a low lying land with high water and nutrients of Central Himalaya. The detail of meteorological data, of study sites were already published by Lodhiyal *et al.* (1995). Geology of Tarai is characterized by tertiary sediments consisting of lower sand stones of old Tarai deposits washed from the Himalayan Mountains. The soil is deep, fertile and moist alluvial loamy, conspicuously free from boulders and gravels. During the last two to three decades, foresters/farmers have been raising poplar (*Populus deltoides* Marsh) plantations replacing natural sal-mixed broad-leaved forests (Lodhiyal and Lodhiyal, 1997).

The mature leaves, nearly senesced (on the basis of colour) but attached poplar leaves were collected in September from the middle canopy of trees from each poplar plantation. The litter bag technique was followed for quantifying the rate of decomposition. The nylon litter bags (1 mm mesh and 10 x 10 cm size) containing 5 g air dried leaf litter were placed on the forest floor of each plantation in September. Proper care was taken not to disturb forest floor vegetation. A mesh size of 1 mm was sufficient to permit movement of micro-arthropods, which are the predominant litter feeders (Sharma *et al.,* 1984).

One hundred sixty two litterbags were placed at the forest floor soil interface on each plantation site in a representative $100m^2$ sample plot. Five litterbags from each age plantation were recovered randomly at monthly intervals for one-year period. In some plantations of present study, the litter did not disappear entirely from the bag in one year. In such cases the bags were lift in place and recovered periodically until the litter had disappeared completely. Immediately after recovery, the litterbags were placed in individual polythene bags and transported to laboratory. The recovered materials were carefully separated from soil particles, oven dried at 70°C to constant weight. The weighted and ground (<1 mm) in a Wiley Mill. Samples of initial as well as exposed materials were analyzed for N by micro-Kjeldahl (Piper, 1944), after dissolving the ash in acid, P was analyzed by colorimeter (Jackson, 1958) and K by Flame photometer (Jackson, 1958).

RESULTS AND DISCUSSION

The basal area and litter fall was 0.83-22.22 m^2 ha^{-1} and 1.99-4.77 t $ha^{-1}yr^{-1}$, respectively. The bulk density ranged from 1.05-1.15 g cm^{-3}, whereas, soil pH was 7.0 to 7.2 (Table 1).

Table 1. Stand structure and soil characteristics of poplar plantations at different ages

Parameter	Age of plantation (Years)			
	1	2	3	4
Altitude (m)	300	300	300	300
Plantation area (ha)	20	27	19	24
Density (tree ha^{-1})	666	666	666	666
Basal area (m^2ha^{-1})	0.8	5.5	12.7	22.2
Litter fall (t ha^{-1} yr^{-1})	2.0	2.9	3.8	4.8
Bulk density (g cm^{-3})	1.05	1.09	1.11	1.15
Texture				
(i) Sand (%)	29.0	27.0	26.0	25.0
(ii) Silt (%)	40.0	44.0	47.0	50.0
(iii) Clay (%)	31.0	29.0	27.0	25.0
Water holding capacity (%)	87.1	86.9	85.5	85.2
Soil pH.	7.2	7.1	7.0	7.0

The soil bulk density increased with the increase in age of plantation while reversed for soil pH. This indicates that as the age of tree increases the soil compactness and soil acidity increases. These findings also support to the previous observations made in different forests and plantations of the region. Present decomposition rate in poplar plantations was higher as compared to the adjacent natural forests of the region (Upadhyay *et al.,* 1989). However, it was somewhat similar to that of eucalypt and sal forest (Bargali *et al.,* 1993). Even though these vegetation found at different ecological soil conditions. The moisture conditions are less favorable to plant growth of foothill sal forest sites than Tarai region (moist plain area site), which was more favorable for eucalypt and poplar plantations (Lodhiyal *et al.,* 1995).

Decomposition Dynamics

Color change of litter: There were marked physical changes in leaf litter of poplar plantation. As decomposition progressed colour changed from yellow to dark brown, which was concomitant with progressing fragmentation of leaf litter.

Weight loss of litter: The weight loss of litter during the decomposition progress was continuous in 1 to 4 year old poplar plantations upto 61 days of decomposition. The percentage of weight loss was 93-96% during one-year period (Fig. 1). In general, across all poplar plantations, the rate of decomposition (% day^{-1}) was markedly rapid 0.38 and 0.32% day^{-1}, respectively in 4 and 1-yr-plantation during the initial period of 61 days (September and October) and it declined up to 181 days. At the end of annual cycle (365 days), it ranged 0.25-0.26 day^{-1} (Table 2).

To study the temporal pattern of weight loss, the natural logarithm of present weight remaining was regressed against the time (days). The regression developed for between various parameters for plantations were significant at P<0.01and P<0.05 (Table 3). The correlation coefficient ranged from -0.989 to -0.992. The intercept values ranged from 96.236 to 101.282 indicating that the regression equations were statistically significant. Among plantations, the most rapid losses were observed at the 1-yr-age followed by 2, 3 and 4-yr age plantations. In the studied poplar plantations, leaf litter disappeared nearly 93-96% within 365 days. The rate of leaf litter weight loss in the plantations was on lower side in the 4-year-plantation than 1-year plantation. The leaf litter material decomposed slowly in 4-yr than 1-yr-age plantation. Maximum weight loss (93 in 1yr-96% in 4yr) occurred within one-year interval (Fig.1). The maximum weight loss during the first 61 days appears mostly due to physical changes, leaching of soluble nutrients and microorganisms of the sites. According to Singh *et al.* (1990), the abundance of decomposer microbes depends partly on the native leaf litter through its influence on soil properties. The litter mass loss was 63-94% reported for intensively managed agroforestry poplar plantations in 285 days and controlled by the presence of soil nutrient level (Sharma *et al.*, 2013).

Table 2. Rate of leaf litter decomposition (day^{-1}) of poplar plantations at different ages

Period after placement of bags (days)	Age of plantation (Years)			
	1	2	3	4
61	0.32	0.35	0.35	0.38
122	0.23	0.25	0.24	0.25
181	0.22	0.22	0.21	0.23
242	0.25	0.25	0.24	0.26
303	0.26	0.25	0.25	0.25
365	0.26	0.26	0.26	0.25

The sal mixed broad leaved natural forests, which were replaced by poplar plantations, might have been higher in decomposers and their influence may have continued for some time after the planting of poplar trees. Moreover, there is a constant fractional weight loss from the litter kept in the

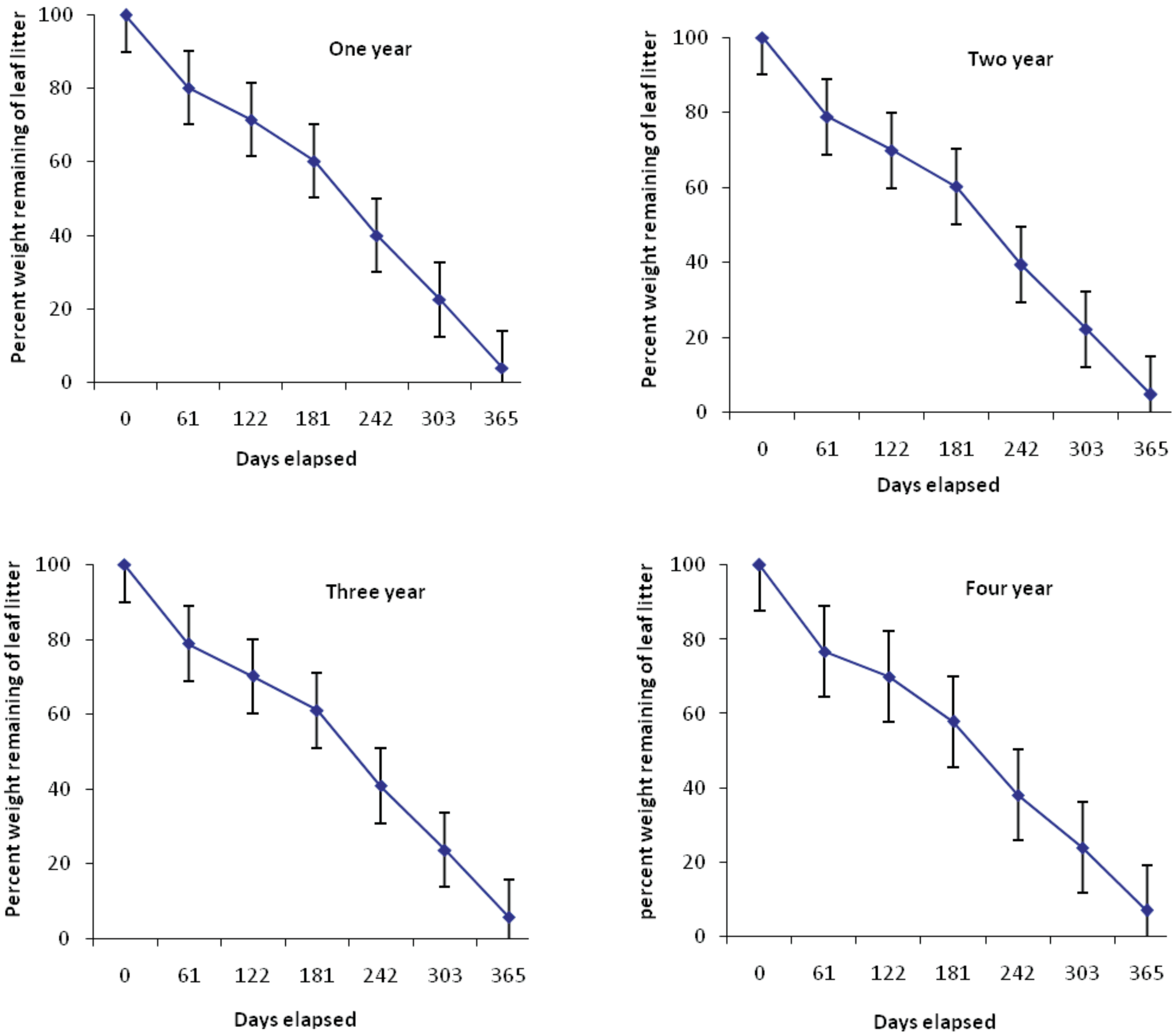

Fig.1. Per cent weight remaining for leaf litter during days elapsed of *Populus deltoides* Marsh plantations at the age 1-4 years

nylon mess bags (size 10x10 cm with 1x1 m net size). Further, the continuous changes in weight loss in leaf litter of poplar plantations was due to more leachable substances with time and greater microbial influences on the litter. Pande and Sharma (1993) also gave similar conclusion. Thus, it was concluded that rate and pattern of leaf litter decomposition of poplar was greatly influenced by the substrate quality of the site, micro-climate, temperature, rainfall and microorganisms (fauna) present in the soil of poplar plantations. However, the high rate of litter decomposition was firstly because sites were located in Tarai having moist and warm climate, which contains higher amount of temperature, moisture and humidity; and secondly sites were accompanied by greater microbial populations. Several attempts have now been made to produce simple general model of litter weight loss, which include the duel effect of biotic and litter quality variables (Upadhyay *et al.*, 1989). The rate of decomposition decreased with increase in plantation age because of higher canopy cover of trees. The regression equations produced in our study are directly comparable to several earlier attempts of the researchers. A significant relationship was recorded with the rate of decomposition according to the following regression equations.

RD = 64.500 –150.00 Sm (r = -0.948, P<0.01)

RD = 0.200 + 5.00 Bd (r = 0.980, P<0.01)

RD = 78.750 – 200.00 Slt(r = -0.956, P<0.01)

RD = 84.750 +500.00 Cly (r = 0.956, P<0.01)

RD = 160.00 – 300.00 Cly (r = 0.948, P<0.01)

RD = 110.875 – 95.00 WHC (r = -0.805, P<0.01)

Where, RD = rate of decomposition (% day^{-1}) Sm = soil moisture (%), Bd = bulk density (gm-3), Slt = silt, Cly = clay, WHC = water holding capacity (%).

Present study showed that the leaf litter placed on 1-yr plantation decomposed at faster rates than 4-yr-age plantation. The rate of leaf litter decomposition decreased significantly with increase in plantation age.

Y= 0.245+0.006x(r=0.948, P<0.01), Where, Y=rate of decomposition (% day^{-1}) and X=age of plantation (year).

Change in Nutrient

Nutrient concentration: There was a continuous increase in nitrogen concentration of the residual litter throughout the decomposition cycle of 365 days. At the end of decomposition cycle, the nitrogen concentration was 1.96–2.06 times greater of initial level for all plantations of poplar (Fig. 2).

The phosphorus concentration continuously increased in residual litter throughout the decomposition cycle. At the end of annual cycle, the phosphorus concentration was 1.6-2.1 times as much as the initial value (Fig. 3). However, a decrease in potassium concentration of leaf litter decomposition was observed during one-year period for the poplar plantations. The changes in potassium concentration declined with time (Fig. 4). In younger age poplar plantation (1-yr-age), the nutrients (NPK) in leaf litter were more because of higher organic matter and also the nutrients in the soils as well as the greater herbaceous ground cover. It was also evident that the high temperature and humidity due to sparse tree canopy had played a significant role to enhance the decomposition rate of litter. Thus, it was concluded that all these above factors may combine to favor the faster rate of leaf litter decomposition.

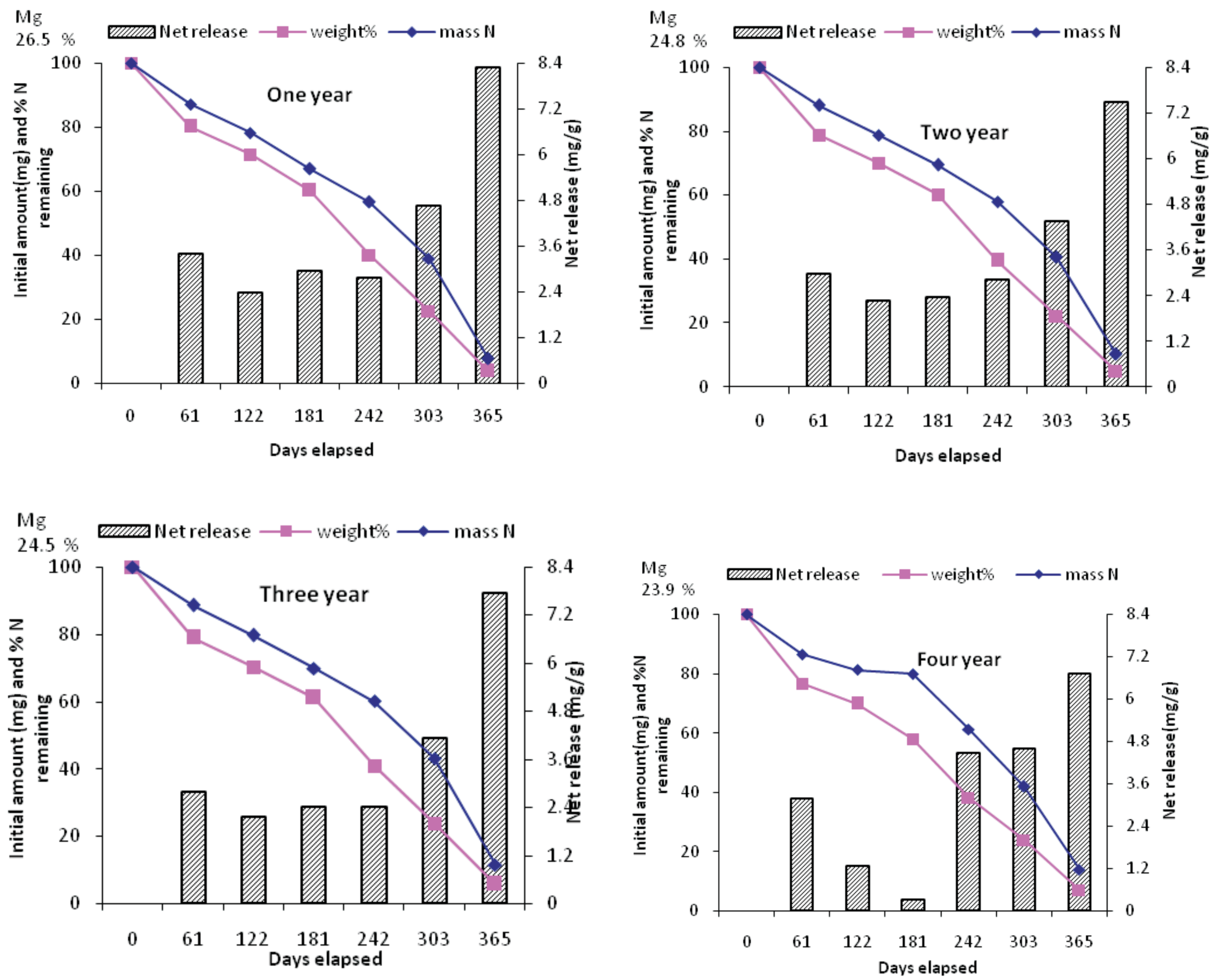

Fig. 2. Changes in absolute amount of nitrogen (solid line curves) in litter mass enclosed in litter bags placed at each age poplar plantation. The initial mass of N in the bag is given on the left side of Y-axis. The columns indicate the net change between the measurements (right Y-axis). The broken line curves just below of the solid lines indicate the percentage weight remaining of the enclosed litter

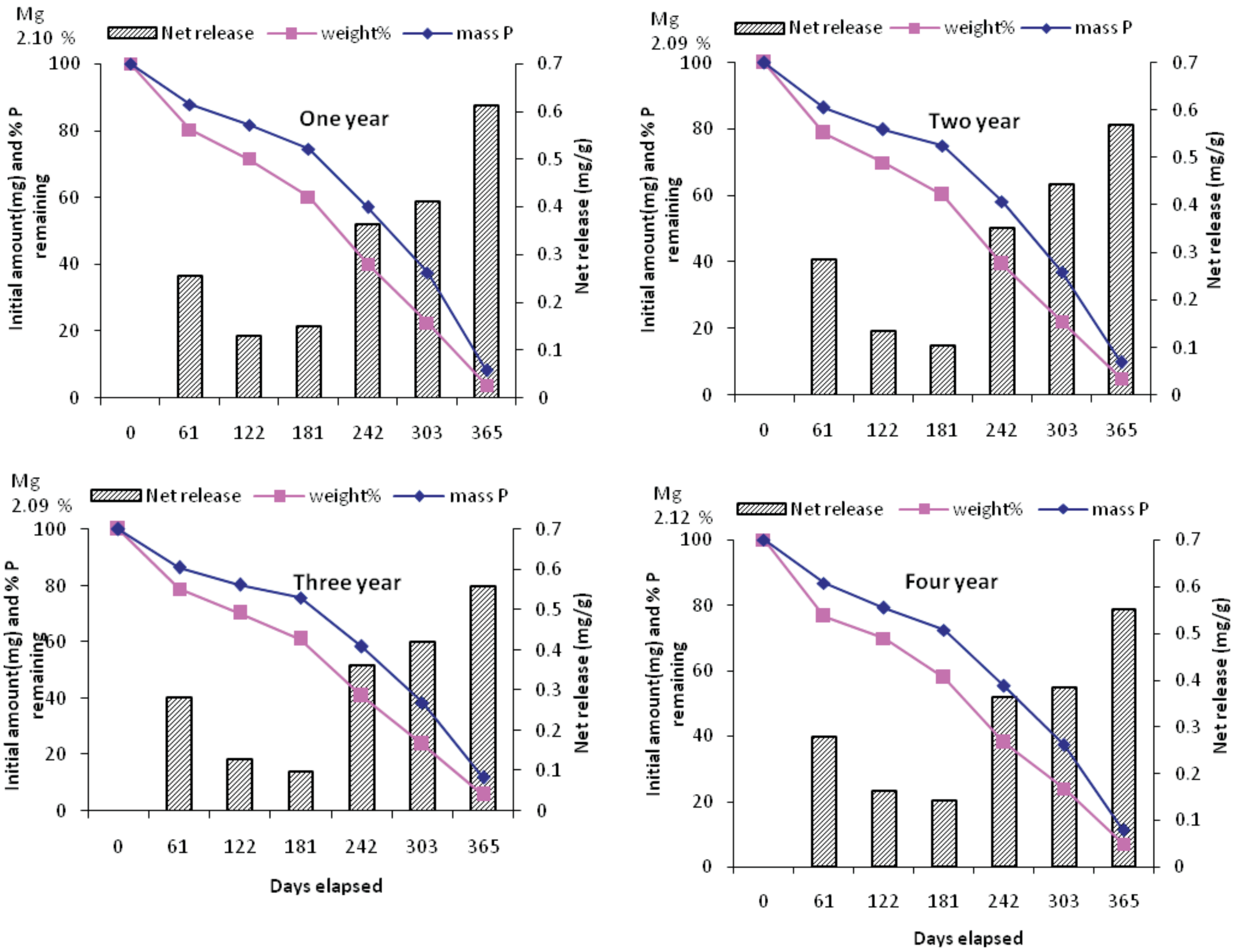

Fig. 3. Changes in absolute amount of Phosphorus (solid line curves) in litter mass enclosed in litterbags placed at each age poplar plantation. The initial mass of P in the bag is given on the left side of Y-axis. The columns indicate the net change between the measurements (right Y-axis). The broken line curves just below of the solid lines indicate the percentage weight remaining of the enclosed litter

The study had shown that the labile fractions of litter provide a readily available source of energy for decomposers. Moreover, the nutrients are easily leached out. Hence, the nutrient composition of litter should therefore be most influential in determining the rate of decomposition in the initial stages. However, according to Upadhyay *et al.* (1989), the refractory fractions of lignin content of litter also changed the decomposition rate. Berg and Staff (1980) found that in litter, with high initial lignin concentrations, the decay phase controlled by nitrogen trends to be shortened. The initial nitrogen, phosphorus and potassium concentrations were significantly correlated with weight loss rates. It was thus found that the initial N to be moderately well correlated with weight loss. Apparently when weight loss occurs very rapidly, the nutrient controlled phase was quickly passed, and then the slowly degrading materials dominate. The nutrient concentration and moisture content in the soil decreased with age of plantations (Lodhiyal *et al.,* 1994; Lodhiyal and Lodhiyal, 1997).

The rate of decomposition was significantly correlated with the initial nutrient concentrations (Table 4). This is consistent with the finding of several studies on leaf decomposition carried out in the Central Himalayan region and elsewhere.

Nutrient release pattern: The total nitrogen release was about 86.1-92.3%. The total net release of nitrogen mass per litter bag over annual cycle was 20.5-24.4 mg yr^{-1}(Fig 2). 99.76 mg/litter bag in 4yr to 117.32mg/litter in 1yr plantation in one year interval. The per day N mass release ranged from 0.273mg in 4yr to 0.321mg/litter bag in 1-yr age plantation. The maximum N mass release occurred in rainy season and minimum in winter season. The pattern of phosphorus release was almost similar to nitrogen. About 82–88% phosphorous was released in the annual cycle. The total phosphorous release was 1.5–1.6 mg yr^{-1} (Fig. 3). The potassium release was in continuous pattern. Release of K was about 94–97% over the annual cycle. The periodic changes in K release after litter incubation reflected almost similar pattern as visualized by percent observed in 365 days was 7.9–9.9 mg yr^{-1} (Fig. 4). The initial and critical (at net N–release) C:N ratio in litter increased with the increase in plantation age and ranged from 55.5 to 58.6 for initial and 25.2 to 27.8 for critical phase. In this study, the higher C: N ratio showed slower nutrient release from the litter and was not consistent with findings of Pandey and Singh (1982) and Upadhyay *et al.* (1989).

The decrease in rate of leaf litter decomposition with increasing age of poplar plantation suggests that pure plantation may lead to soil degradation as they were harvested at short rotation period. The decomposition rate of organic matter on soil surface and within soil had been enhanced by the short harvest cycle of poplar, thus rendering the system vulnerable to leakage of nutrients from the soil sub–system. The decomposition rate assessed for present study plantation was on lower side than natural forests of the region and could produce nutrient limitations for primary producers by the accumulation of a large nutrient stock at the soil surface. It also suggests that the harvesting poplar plantation (at 4–yr age) was too short for restoration of plantation soil that may be brought through the biological

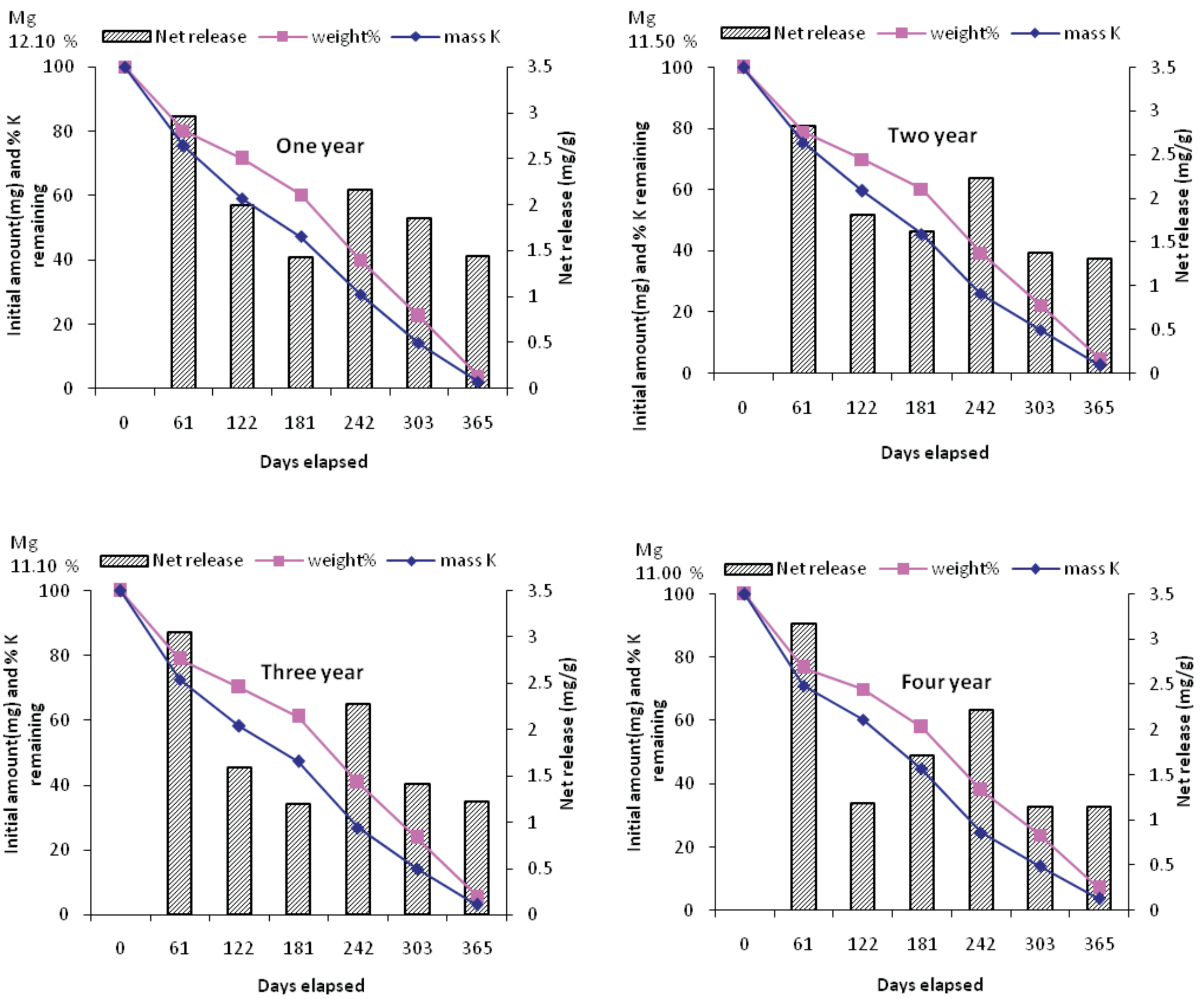

Fig. 4. Changes in absolute amount of potassium (solid line curves) in litter mass enclosed in litterbags placed at each age poplar plantation. The initial mass of K in the bag is given on the left side of Y–axis. The columns indicate the net change between the measurements (right Y–axis). The broken line curves just below of the solid lines indicate the percentage weight remaining of enclosed litter

Table 3. Allometric relationship between weight loss (WL) and rainfall (R) and temperature (T) between weight remaining of leaf litter (WR) and day elapsed (DP) at different ages

X vs Y	Plantation age (yr)	Intercept (a)	Slope (b)	Correlation coefficient (r^2)
WL vs T	1	35.112	-0.085	0.708*
	2	40.570	-0.076	0.708*
	3	41.117	-0.069	0.655**
	4	42.289	-0.068	0.668
WL vs T	1	-15.770	2.882	0.780*
	2	-10.228	2.607	0.777*
	3	-11.956	2.780	0.807*
	4	-7.028	2.607	0.781*
WRLL vs DE	1	101.282	-0.258	-0.991*
	2	99.251	-0.251	-0.990*
	3	99.307	-0.247	-0.989
	4	96.236	-0.238	-0.992

Values are significant at *P<0.01 and **P<0.05

Table 4. Relationship between nutrient (NPK) concentration (%) and weight loss (%) of leaf at different ages

Nutrients	Age of plantation (Years)			
	1	2	3	4
Nitrogen				
Intercept (a)	-61.936	-50.696	-50.691	-56.774
Slope (b)	32.470	30.534	30.966	33.263
Correlation coefficient (r)	-0.934	-0.942	-0.931	-0.918
Phosphorous				
Intercept (a)	-63.227	-64.339	-71.875	-106.727
Slope (b)	401.51	410.974	446.391	561.045
Correlation coefficient (r)	-0.940	-0.967	-0.960	-0.989
Potassium				
Intercept (a)	113.02	-85.837	-85.658	-89.019
Slope (b)	167.35	150.363	157.623	162.778
Correlation coefficient (r)	-0.983	-0.978	-0.986	-0.999

Values are significant at P<0.01

processes. Moreover, such land use practice has changed in the region by the introducing exotic tree species, which has also affected the soil structure and microbial activities. The introduction of such tree species in the region also added the ecto-mycorrhizae, which are also responsible for the change of soil organic matter, composition and its property because of specific crop. The soil properties have been impacted and changed by density and age of trees because of fast growth and higher uptake of soil nutrient by poplar plantations (Lodhiyal and Lodhiyal, 2014). They also suggested that poplar plantation can be managed only if leaf litter is utilized judiciously along with certain inputs of inorganic fertilizer and farmyard manures. The soil nutrient availability influences the productivity of forest plantations and is also related to pattern and rates of nutrient cycling.

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Character Association for Fruit Yield and Yield traits in *Holostemma ada-kodien* Schult. - A Vulnerable Medicinal Plant

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Abstract: An experiment was undertaken to study the correlation and path analysis in thirteen *Holostemma ada-kodien* accessions at ICAR-Indian Institute of Horticultural Research, Bangalore during 2015-16. Correlation study revealed that number of fruits plant^{-1} had significant positive correlation with fruit yield plant^{-1}. According to path analysis, thickness of pericarp and number of fruits plant^{-1} recorded positive and high direct effect on yield plant^{-1}. Thickness of mesocarp, leaf width, leaf length, petiole length and fruit length had high negative direct effects on yield. Thus based on correlation and path analysis, the traits viz.,number of fruits plant^{-1}, thickness pericarp and mesocarp, leaf width, leaf length, petiole length and fruit length can be considered as selection indices for high yield.

Keywords: *Holostemma ada-kodien*, Correlation, Path analysis, Fruit yield

Holostemma ada-kodien a species indigenous to India and popularly known as Jivanti or Jivani is a twiny, laticiferous perennial medicinal shrub belongs to the family Asclepiadaceae (Martin, 2003). The species is widely distributed in the tropical rain forests of the world including India, West peninsula, Srilanka and China. In India, maximum distribution is seen in the forests of Andhra Pradesh, Tamil Nadu and Western Ghats of Karnataka and Kerala. The species has got medicinal importance and traditionally the plant is used as an alternative, astringent to the bowels (Irimpan *et al*., 2011); cures ulcers, diseases of the blood, itching, leukoderma gonorrhea, (Warries *et al*., 1995) and it has ability to maintain vigour, strength and vitality. Though distributed widely throughout Southern India, the population in wild is gradually reducing due to the destructive and ruthless collection of root tubers for ayurvedic drug preparations and fruit set is a major problem in multiplying the species in wild, which has led to the species being listed as vulnerable medicinal plant in FRLHT red list (Pushparajan and Surendran, 2014).

As this is a vulnerable plant species, improvement in this species is very less, crop improvement programme initiated through selection has helped to further breeding programme and the improvement of this species is through selection, which in turn depends on the interrelationship of the number of component characters. In our present study, an attempt was made to evaluate the direct and indirect association among the various variables of thirteen accessions of *H. ada-kodien* through correlation and path analysis.

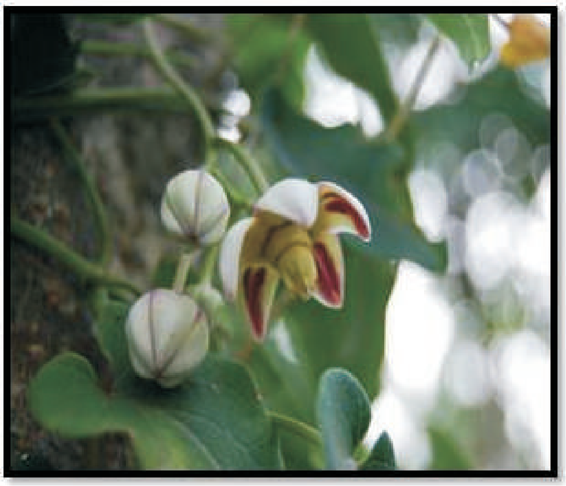
MATERIAL AND METHODS

The experiment was conducted at the ICAR-Indian Institute of Horticultural Research (IIHR), Bengaluru. The thirteen *H. ada-kodien* accessions *viz.,* KAR RET-1,KAR RET-2, KAR RET-3, KAR RET-4, KAR RET-5, KAR RET-6, KAR RET-7, KAR RET-8, KAR RET-56, KERRET-5, KERRET-19, KERRET-28, KERRET-60 were collected from different places from wild and maintained in Field Gene Bank. Recommended cultural practices were followed for proper growth of the plants (Kurian and Sankara, 2007). Observations were recorded for eleven characters from all the replications, belonging to the different accessions. The recorded data were analyzed for correlation coefficient analysis and for path coefficient analysis as coated by (Al-jibouri *et al.,* 1958; Dewey and Lu, 1959).

RESULTS AND DISCUSSION

The correlation study reveals the degree of interrelationship of plant characters for improvement of yield as well as important quality parameters in any breeding programme and a complex association exists among plant characters. Fruit yield was highly significant and negatively correlated with the vegetative characters *viz*., plant height, leaf length, leaf width and petiole length (Table 1). It may be due to the distribution of photosynthates to vegetative growth rather than the reproductive growth.

(a)



(b)

(c)

(d)

Plate 1. Jeevanti (*Holostemma ada-kodien*) a. young plant b.flowers c.fruit d. seeds

Since the crop medicinal property is present in the root tuber, a portion of photosynthates will diverged to tuber development also. Size of the reproductive part namely thickness of mesocarp and pericarp is negatively affecting the yield. A significant positive correlation was recorded between fruit yield and number of fruits per plant. Hence, selection should be only based on number of fruits but not on size of fruits. Above mentioned characters are linear relationships with fruit yield plant^{-1} suggest that selection method of crop improvement should mainly be focused over these characteristics. The path analysis shows that the association of the independent character with dependent variable is due to their direct effect on it. If the correlation between dependent variable and independent character is due to direct effects of the character, it reflects a true relationship between them and hence selection can be made for such character to improve dependent variable. But, if the association is mainly through indirect effect of the character *i.e.,* through another component character, the breeder has to select for the later through which the direct effect is exerted. In the present experiment, path analysis was done for fruit yield plant^{-1} (Table 2). Among the ten yield components, thickness of pericarp and number of fruits plant^{-1} recorded positive and high direct effect on yield plant^{-1}. The characters *viz*., thickness of mesocarp, leaf width, leaf length, petiole length and fruit length showed negative and high direct effect towards yield plant^{-1}. The importance of leaf length, leaf width, number of fruits plant^{-1} has been highlighted in *Jatropa curcus* by Mohapatra and Panda (2010). In our present experiment, the path analysis revealed that number of fruits plant^{-1} and thickness of pericarp were contributing to fruit yield. These two characters are contributing towards yield indirectly by lower vegetative growth.

Table 1. Simple correlation co-efficient among important quantitative character in *Holostemma ada-kodien* accessions

	Plant height	Leaf length	Leaf width	Petiol	Pedice	Fruit length	Fruit diameter	Thickness of pericarp	Thickness of mesocarp	Number of fruits plant^{-1}	Fruit yield
Plant height	1	0.97**	0.80**	0.79**	0.26	-0.01	0.30*	0.36*	0.14	-0.89**	-0.89**
Leaf length		1	0.84**	0.79**	0.30*	-0.08	0.15	0.48**	0.24	-0.92**	-0.92**
Leaf width			1	0.84**	0.15	-0.36*	-0.15	0.27*	0.17	-0.76**	-0.80**
Petiole length				1	0.13	-0.12	0.1	0.11	-0.04	-0.72**	-0.89**
Pedicel					1	0.25	0.32*	0.31*	0.08	-0.28*	-0.30*
Fruit length						1	0.77**	-0.28*	-0.55**	0.01	0.02
Fruit diameter							1	-0.31*	-0.56**	-0.28*	-0.26
Thickness of pericarp								1	0.86**	-0.43**	-0.30*
Thickness of mesocarp									1	-0.2	-0.04
Number of fruits plant^{-1}										1	0.91**
Fruit yield											1

* Significant at 5 % probability level; ** Significant at 1 % probability level

Table 2. Path coefficient of biometrical traits on fruit yield

	Plant height	Leaf length	Leaf width	Petiole length	Pedicel length	Fruit length	Fruit diameter	Thickness of pericarp	Thickness of mesocarp	Number of fruits plant^{-1}	Fruit yield
Plant height	0.007	1.060	-0.779	-0.665	-0.030	0.006	-0.075	0.266	-0.198	-0.683	-0.89**
Leaf length	0.007	-0.726	0.816	0.666	-0.036	0.047	-0.036	-0.266	-0.198	-0.683	-0.92**
Leaf width	0.006	0.952	-0.920	-0.699	-0.018	0.238	0.038	0.197	-0.179	-0.603	-0.80**
Petiole length	0.006	0.873	-0.786	-0.818	-0.017	0.080	-0.025	0.072	0.048	-0.548	-0.89**
Pedicel length	0.002	0.333	-0.142	-0.116	-0.117	-0.164	-0.082	0.205	-0.081	-0.215	-0.30*
Fruit length	-0.000	-0.079	0.341	0.103	-0.030	-0.642	-0.195	-0.179	0.701	0.001	0.02
Fruit diameter	0.002	0.158	0.141	-0.083	-0.039	-0.509	-0.245	-0.191	0.713	-0.211	-0.26
Thickness of pericarp	0.003	0.595	-0.309	-0.101	-0.041	0.195	0.080	0.588	-1.285	-0.356	-0.30*
Thickness of mesocarp	0.001	0.300	-0.143	0.034	-0.008	0.390	0.151	0.656	-1.153	-0.176	-0.04
Number of fruits plant^{-1}	-0.006	-1.022	0.737	0.596	0.034	-0.001	0.069	-0.279	0.270	0.752	0.91**

Diagonal elements (in bold) indicates direct effect. See Table 1 for characters details

The yield was negatively affected by leaf length and width, petiole length, fruit length, fruit diameter and thickness of mesocarp. The vegetative growth is not contributing to the reproductive development, the photosynthates produced can be routed more to root tuber development and vegetative growth itself. The yield of the plant is not affected by the size of the fruits, but only through the number of fruits. Similar observation was made through correlation studies also. Hence, selection for fruit yield should be based on number of fruits rather than the size of the fruits.

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Genetic Divergence for Growth, Leaf Nutrient and Biochemical Traits in Open Pollinated Families of *Dalbergia sissoo*

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Abstract: *Dalbergia sissoo* Roxb. is important timber species of India. The nature and magnitude of genetic divergence was assessed among 59 open pollinated families using non-hierarchical Euclidean cluster analysis. All the open pollinated families were grouped in to nine different clusters. Genotypes clustered irrespective of their origin indicated that non-parallelism between geographic and genetic diversity. The highest inter-cluster distance was found between cluster II and cluster V. Seedling height gave the highest contribution to divergence

Keywords: *Dalbergia. sissoo*, Shisham/talhi, Genetic divergence, Cluster analysis

Dalbergia sissoo Roxb. is an important good quality timber-yielding legume tree species of India. Its wood is used for making furniture, cabinets, musical instruments, ornamental veneers and high-quality commercial plywood owing to great strength, durability and elasticity. Sissoo is naturally distributed in the foothills of the Himalayas from eastern Afghanistan through Pakistan to India and Nepal (Ashraf *et al.,* 2010; Sagta and Nautiyal, 2001). It also produces fibers, alkaloids, tannins, and resins. Due to its economic value, the species is not only widely planted throughout its natural distribution, but also planted worldwide as an exotic species (Wang *et al.,* 2011).

First stage of any improvement programme is assessment of its existing variability in natural population. Precise information on the nature and degree of genetic divergence is also important for selecting parents for hybridization. In a breeding programme, progenies derived from diverse crosses are expected to show a broad spectrum of genetic variability, providing a greater scope for isolating transgressive segregates in the advance generations. Multivariate analysis, which is based on several characters, is one of the powerful tools to assess the relative contribution of different component traits to the total diversity to quantify the degree of divergence between population to understand the trend of evolution and choose genetically diverse parents for obtaining desirable recombination. Seedling growth and leaf nutrient are important character for early establishment and nutrient cycling in plantation. However, leaf phenol and sugar concentration has role in plant defense ability to biotic and abiotic stress. The objective of the study was to evaluate genetic divergence in plus tree progenies of *D. sissoo* for growth, leaf nutrient and biochemical traits. The information on the nature and degree of genetic divergence present may help in further improvement through hybridization in *D. sissoo*.

MATERIAL AND METHODS

The experimental site is located at 32°18N latitude and 15°55E longitude with an altitude of 428m above mean sea level. The study area falls in the sub-tropical zone representing low hills and valley areas of Himachal Pradesh. The average annual rainfall is about 1500 mm, a major portion of which is received during June-August (Monsoon period). The annual range of mean monthly temperature is 12.2 to 31.1°C with mean winter and summer temperature of 13.6 and 29.3°C, respectively. The seed of 59 plus trees (Table1) of *D. sissoo* was sown in the nursery, where the seedlings retained for one year. Then they were transplanted in the field in a randomized complete block design with 3 x 3 m spacing and replicated thrice. There was 25 plants per family per replication. Observations have been taken on 9 plant of each family viz. 3 per replication for seedling height and collar diameter. The leaves were collected and kept in oven at 55°C till the leaves attained a constant weight and dry weight of leaves recorded by electronic balance. Leaf nitrogen content was estimated by micro-kjeldahl method, phosphorus content by spectrophotometer and potassium content was determined using flame photometer (AOAC, 1980). Total sugars in dried samples were estimated by the phenol sulphuric acid method of Dubois *et al.* (1951) and total phenols were estimated by Folin phenol reagent method of Bray and Thorpe (1954). The entire data were analyzed statistically for the assessment of analysis of variance. Analysis of data was done in the Randomized Complete Block Design. Genetic divergence was calculated by using non-hierarchical Euclidean cluster analysis (Beale, 1969; Sparks,1973).

RESULTS AND DISCUSSION

All trait under study showed immense variation and the maximum variation was attributed due to family effect (Table 2). Hence, all the families were subjected to non-hierarchical cluster analysis to classify them in to close groups. Seedling height contributed to the highest extent (24.99%) for divergence followed by collar diameter (13.81%), dry weight of leaves (12.88%) and leaf area (12.13%). The least contribution was for total phenol content (4.01%). The 59 open pollinated families were grouped into nine clusters. Cluster IV exhibited the highest number of families (10) and included families 9, 10, 14, 17, 23, 24, 28, 30, 47 and 51. Cluster V included only one half-sib family. Cluster VII included nine families (4, 31, 38, 40, 48, 49, 50, 52, 55), cluster VIII eight families (12, 16, 25, 29, 36, 41, 43, 44), whereas clusters III and IV included seven each. Cluster II included 5 families (11, 18, 19, 26, 27) while cluster I and IX included six families each (Table 3). The distribution of families in different clusters indicated that, even though the genotypes were selected from different ecogeographic areas, the genetic make-up along with breeding system, heterogeneity, natural and unidirectional selection pressure must be the cause of such genetic diversity among different families, besides

Table 3. Composition of euclidean clusters in *Dalbergia sissoo* families

Cluster	Number of family	Family
I	6	1, 2, 5, 6, 7, 22
II	5	11, 18, 19, 26, 27
II	7	15, 32, 37, 53, 54, 57, 59
IV	7	8, 33, 34, 35, 39, 42, 45
V	1	58
VI	10	9, 10, 14, 17, 23, 24, 28, 30, 47, 51
VII	9	4, 31, 38, 40, 48, 49, 50, 52, 55
VIII	8	12, 16, 25, 29, 36, 41, 43, 44
IX	6	3, 13, 20, 21, 46, 56

Table 1. Description of 59 open pollinated families of *Dalbergia sissoo* selected for study from different districts of Himachal Pradesh and Jammu & Kashmir

District and state (India)	Name and number of families*
Solan , Himachal Pradesh	Nalagarh-1(1), Nalagarh-2(2), Nalagarh-3(3), Nalagarh-4(4), Nalagarh-5 (5), Nalagarh-6 (6), Nalagarh-7 (7), Nalagarh-8 (8), Nalagarh-9 (9), Nalagarh-10 (10), Nalagarh-11 (11)
Bilaspur , Himachal Pradesh	Rishikesh (12), Bharari (13) , Dhar Tatoh-1 (14), Dhar Tatoh-1 (14), Dhar Tatoh-2 (15), Dhar Tatoh-3 (16), Dhar Tatoh-4 (17), Dhar Tatoh-5 (18), Dhar Tatoh-6 (19), Dhar Tatoh-7 (20), Dhar Tatoh-8 (21)
Kangra , Himachal Pradesh	Balu (22), Khajjian (23), Baranda (24), Jassur (25), Pakka Tiala (26), Lodhwan (27), Channi (28), Khaber (29)
Una , Himachal Pradesh	Nakroh (30), Barsali (31), Dhuk (32), Gagret (33), Khurian (34)
Hamirpur , Himachal Pradesh	Nadaun (35), Pakhral (36)
Kathua , J & K	Jagian-1 (37), Jagian-2 (38), Jagian-3 (39), Jagian-4 (40), Jagian-5 (41), Bijouta (42)
Jammu , J & K	Daboh-1 (43), Daboh-2 (44), Devak Bella-1 (45), Devak Bella-2 (46), Devak Bella-3 (47), 17 Mile Depot-1 (48), 17 Mile Depot-2 (49)
Sirmour , Himachal Pradesh	Dudhla (50), Puruwala (51), Bata Mandi (52), Behral (53), Jammukhela (54), Matakmajri (55), Dhaulakuan (56), Dardanwala (57), Uttamwala (58), Teeb (59)

*Figures in parenthese indicate family number

Table 2. ANOVA for different characters and percent contribution of characters to divergence for 59 open pollinated families of *Dalbergia sissoo*

Character	Replication (df=2)	Family (df=58)	Family x Replication (df=116)	Plants within plot (df=354)	Per cent contributions to divergence
Seedling height	201.2189	966.6810**	119.4230	469.6680	24.99
Collar diameter	0.0381	0.4695**	0.0305	0.2540	13.81
Dry weight of leaf	0.0124	0.0763**	0.0216	0.0358	12.88
Leaf area	139.0565	724.1992**	104.0697	356.9527	12.13
Nitrogen	0.0568	0.4588**	0.0481	0.2650	10.16
Phosphorus	0.0092*	0.0041**	0.0027**	0.0010	9.02
Potassium	0.0198	0.0707**	0.0150	0.0493	7.21
Total phenols	2.4894	46.2153**	5.5705	22.5046	5.79
Total sugars	30.3599	107.8299**	41.9805**	41.2989	4.01

*=Significant at 5 per cent level of significance; **=Significant at 1 per cent level of significance , df=degree of freedom

Table 4. Estimates of inter and intra-cluster distances

	I	II	III	IV	V	VI	VII	VIII	IX
I	1.819								
II	3.940	1.644							
III	3.001	4.301	2.242						
IV	3.626	3.104	3.697	1.953					
V	3.599	6.327	4.683	4.516	0.000				
VI	2.810	3.153	2.941	2.563	4.049	2.287			
VII	3.085	4.114	2.529	3.850	4.710	2.413	2.115		
VIII	3.050	2.571	3.743	2.378	5.139	2.441	2.590	2.203	
IX	2.601	3.057	2.869	3.098	4.298	2.507	2.763	2.759	1.968

Underlined figures are intra cluster distances

Table 5. Cluster mean values for different traits among *D. sissoo* families

Traits	I	II	III	IV	V	VI	VII	VIII	IX
Seedling height (cm)	100.21	104.06	83.82	104.56	105.49	100.50	90.26	103.13	97.02
Collar diameter (cm)	0.86	1.28	0.79	0.97	0.68	1.13	0.90	1.07	0.76
Dry wt. of leaves (g)	0.80	0.87	0.71	0.86	0.86	0.74	0.71	0.83	0.86
Leaf area (cm^2)	59.30	81.82	64.70	68.64	33.50	59.46	61.15	69.29	64.72
Nitrogen (%)	2.66	2.85	2.60	2.70	2.50	2.64	2.71	2.93	2.76
Phosphorus (%)	0.20	0.18	0.19	0.22	0.21	0.19	0.18	0.19	0.17
Potassium (%)	1.11	1.25	1.30	1.33	1.22	1.28	1.30	1.33	1.24
Total sugars ($mg\ g^{-1}$)	24.11	27.70	23.09	29.76	26.71	29.32	26.88	28.67	27.97
Total phenols ($mg\ g^{-1}$)	12.97	11.47	11.49	11.39	11.96	12.11	15.83	14.94	11.61

geographic to same extent. The cluster pattern proved that geographical diversity need not necessarily be related to genetic diversity. Therefore, selection of genotype for hybridization should also be based on genetic diversity rather than geographic diversity. Many authors have found similar phenomena in different species where they reported geographical diversity was not related to genetic diversity (Sehgal *et al.,* 1995; Sharma and Sharma, 2001; Kaushik *et al.,* 2007; Meena *et al.,* 2014; Mohamed *et al.,* 2015).

The generalized inter-cluster distance was found to be the highest between cluster II and cluster V (6.327), which were followed by cluster V and cluster VIII (5.139) and cluster III and V (4.683). The minimum inter-cluster distance was observed between cluster IV and cluster VIII (2.378). It is evident from the above results that all the half-sib families within a cluster were genetically closer since these have low intra-cluster distance (<2.287). On the contrary, inter cluster distance was as high as 6.327 (between II and V) indicated presence of higher order of divergence among families (Table 4). Intra-cluster distance for single family (cluster V) was zero. Occurrence of low intra-cluster distances indicated that the chances of getting good segregates by crossing the genotype of the same cluster is remote. Therefore, intra-cluster distances must duly be considered to avoid monoclonal plantation as the risk of failure and inbreeding depression is more under such cases. The highest inter cluster distance was found between cluster II and cluster V (6.327) suggesting that, maximum hybrid vigour and eventually desirable segregates could be obtained if individuals of families of these two clusters are hybridized. Among the 9 clusters formed, cluster II had the maximum cluster mean value for all the morphological traits and cluster IV for nutritional attributes (Table 5). Handa *et al.* (1998) also recorded similar inter and intra-cluster variation in natural population of *Alnus nitida*.

The present study indicated remarkable diversity among the 59 families of *Dalbergia sissoo*. The present investigation suggests the preponderance of genetic diversity than that of geographic diversity of the families. Among the 9 clusters formed by non-hierarchical cluster analysis, families from cluster II should be selected for better growth, however families from cluster IV should be selected for nutritional attributes. Higher Inter-cluster distances show that hybridization between families in cluster II and cluster V would be the better option for getting high hybrid vigour.

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Growth and Quality Indices of Different Nitrogen Fixing Tree Nursery Plants

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Abstract: Successful establishment of seedlings is dependent on their quality, which should be capable of establishing on adverse field conditions. There is strong relationship of field establishment with root parameters. A nursery study was conducted to compute different seedling quality indices for different nitrogen fixing tree species. Seedling parameters in nitrogen fixing tree species were found better than the two non-nitrogen fixing tree species. The indices involving root parameters showed more consistency in nitrogen fixing tree species than sturdiness quotient. Dickson quality index values were more consistent than other indices, which includes biomass and growth parameters to explain the seedling quality.

Keywords: Nitrogen fixing trees, Root behaviour, Seedling growth and biomass, Seedling quality indices

Good planting stock is the foundation on which a plantation is established for higher productivity and good quality. The success of plantation is closely dependent on the choice of species and quality of planted seedlings, which should be capable of adjusting in prevailing adverse field conditions. Domestic and industrial wood demand – supply gap is increasing sharply and it has to be bridged from outside forests, which requires large scale plantations of proven quality planting stock of desired species for target areas of plantation. The good quality planting stock is often in short supply, therefore plantations are raised regardless of stock quality. The poor quality stock performance could be known after only few years when the plantations turn out to be of poor quality and yield less than the desired one. Plantations should be supported with high quality planting stock for good results so that the adopter may not have to face losses due to poor quality nursery stock. Nursery stock root system is of central importance as it regulates the success of plant establishment. Thus, selection of suitable species must take into consideration the root morphology to support the shoot after field planting.

There are evidences that root distribution can be manipulated in the soil and influence of below ground environmental factors is more than genetics architecture (Schroth, 1996). Present study was conducted under same environment with identical conditions in the rhizosphere to know the species root behavior which can be used accordingly to the prevailing plantations conditions. Root studies have very little been attempted in the tree species, and it needs much more scientific studies for their appropriate belowground interactions more specifically in agroforestry interventions and conditions harsh for species establishment. The root distribution not only governs the potential establishment but the subsequent growth through soil, water and nutrient uptake.

It is important to be able to identify characteristics or indices which can anticipate seedling quality for good performance in the field. Usually nursery stocks are used on the basis of their age or seedling height (Wendling *et al.,* 2005; Chauhan and Sharma, 1997) and lack of an appropriate definition to explain seedling standards ultimately leads to poor establishment and growth. Several parameters are used to evaluate seedling quality, including shoot height, collar diameter, root configuration, shoot:root weight ratio, height : diameter ratio, etc. (Paiva and Gomes, 1993; Chauhan *et al*., 1997). Gomes *et al.* (2002) established a positive correlation between seedling height: shoot dry matter weight ratio to their good relative contribution toward the seedling quality and emphasized that the seedling with lower ratio of height to shoot dry weight are more lignified and have potential for the greater field adaptability. However, Fonseca *et al.* (2002) emphasized not to select individual parameter for seedling quality i.e., selecting tall seedling but weak or discarding smaller but sturdier ones. Therefore, present study was conducted to assess the seedling growth (above and below ground) behavior of nitrogen fixing species (leguminous as well as non-leguminous) in comparison to non-nitrogen fixing tree species to analyze the data for quality indices comparison. The nitrogen fixing species were selected for the study due to their suitability for nutritionally poor and degraded soils.

MATERIAL AND METHODS

One year old seedling of seven leguminous *Acacia nilotica* L. (an); *Acacia auriculiformis* A. Cunn. ex Benth. (aa); *Albizia lebbeck* (L.) Benth. (al); *Albizia procera* (Roxb.) Benth; *Leucaena leucocephala* (Lam.) de Wit (ll); *Prosopis juliflora* (Sw.) DC (pj), two non-leguminous (Family Casuarinaceae) but nitrogen fixing; *Casuarina equisetifolia* L. (ce); *Casuarina junghuhniana* L. (cj), and one species each leguminous (Caesalpiniaceae) but non nitrogen fixing, *Acrocarpus fraxinifolius* Wt. & Arn. (af) and non-nitrogen fixing (family Simaroubaceae) fast growing but low water requiring species, *Ailanthus excelsa* Roxb. (ae), raised in the nursery area of Department of Forestry and Natural Resources, Punjab Agricultural University, Ludhiana were selected for making comparison for growth and their rooting behavior. Experiment was raised in a randomized block design with three replications of twenty five plants in each replication. Five plants per replication were randomly selected for take observations on different shoot (plant height and diameter) and root morphological (root depth) and biomass parameters. Roots were cautiously removed, washed and dried with blotting paper to record fresh weight and then dried in oven at 70°C for dry biomass. From the data on individual morphological and biomass parameters, different indices were calculated i.e., height: diameter ratio, Shoot : root dry weight ratio, height : shoot dry weight ratio, Dickson quality index as quality indicator. The Dickson quality index (Dickson *et al.,* 1960) is a tool to evaluate seedling quality as a function of total dry matter, shoot height, stem base diameter, shoot dry matter and root dry matter, and is given by the expression: Seedling dry weight / [(Height cm/diameter mm) + (Shoot dw/root dry weight)]. The data was suitably analysed and 5% probability level was adopted with the help of CPCS-1 software.

RESULTS AND DISCUSSION

Seedlings of *Prosopis juliflora* (163cm) were the tallest but at par to *Casuarina equisetifolia* (160cm). The pattern of diameter growth was different and maximum thickness was observed in *Albizia lebbeck* (13.71mm) with at par value of *Acacia auriculiformis* (10.98mm). However, as a combined index, the minimum value of sturdiness quotient (height: diameter ratio) was observed in *Leucaena leucocephala* (6.23), which was at par to *Acrocarpus fraxinifolius* (7.01) and *Ailanthus excelsa* (7.76) but statistically lower than other species (Table 1). Sturdiness index reflects the balanced growth of seedlings, comparatively taller seedlings may not withstand the wind pressure in the field, whereas, additional balanced collar diameter should support the seedling for quality. Shoot biomass ranged between 97.45g in *Acacia auriculiformis* to 28.5g in *Leucaena leucocephala* among nitrogen fixing tree seedlings, however, the shoot mass was

Table 1. Growth, biomass* and stock quality of nitrogen fixing tree seedlings

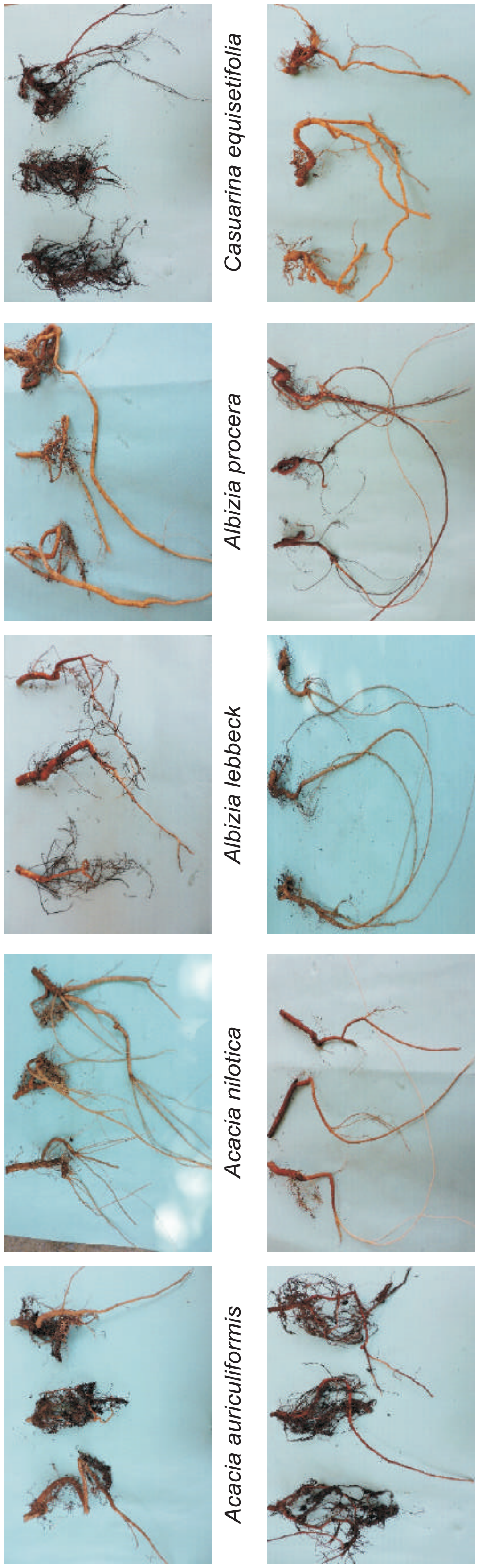
Species	Plant height (cm)	Collar diameter (mm)	Fresh shoot weight (g)	Fresh main root weight (g)	Fresh lateral root weight (g)	Total root weight (g)	Root length (cm)
Acacia nilotica	132.0	9.67	69.48 (33.36)	30.33 (16.33)	6.3 (1.87)	36.6 (18.2)	100.2
Acacia auriculiformis	146.0	10.98	97.45 (38.8)	20.46 (8.35)	4.96 (1.83)	25.36 (10.18)	45.58
Albizia lebbeck	126.7	13.71	91.85 (40.33)	33.45 (17.13)	22.68 (7.0)	56.0 (24.13)	68.33
Albizia procera	71.0	5.23	44.53 (20.44)	29.36 (13.03)	4.73 (1.38)	30.03 (14.41)	56.67
Casuarina equisetifolia	160.0	9.72	66.8 (34.83)	9.88 (6.33)	5.33 (3.13)	15.21 (7.46)	31.50
Casuarina junghuhniana	94.33	7.48	60.61 (25.56)	6.91 (3.01)	2.61 (1.18)	9.52 (4.19)	42.66
Leucaena leucocephala	57.33	9.20	28.5 (14.1)	14.66 (7.06)	1.4 (0.46)	16.0 (7.52)	66.67
Prosopis juliflora	163.0	9.32	88.31 (43.13)	29.55 (12.6)	6.53 (2.87)	36.03 (15.47)	102.5
Acrocarpus fraxinifolius	54.0	7.70	27.4 (9.26)	5.63 (1.86)	1.66 (0.56)	6.29 (2.42)	26.33
Ailanthus excelsa	71.16	9.16	26.73 (9.6)	11.66 (3.0)	3.93 (0.83)	15.53 (3.83)	26.03
CD (p=0.05)	16.29	3.81	21.68 (17.11)	14.01 (5.28)	3.68 (1.98)	6.67 (7.21)	16.94

*Dry biomass in parentheses

minimum in *Ailanthus excelsa* (21.68g) among the species under observations.

Root depth varied from 26.03cm in *Ailanthus excelsa,* a non-nitrogen fixing species but 26.33cm *Acrocarpus fraxinifolius* to 102.5cm in *Prosopis juliflora* in nitrogen fixing species (Plate 1). The maximum root length was statistically at par to the values observed in *Acacia nilotica* (100.2cm) only. The root depth in rest of the species varied from 26.33 to 68.33cm maximum root biomass (fresh and dry) was observed in *Albizia lebbeck* i.e., 40.13 and 19.05, respectively, which was at par to *Acacia nilotica*. Similar variable rooting behavior has been recorded earlier by Chauhan and Kaushal (2005) in leguminous species. Maximum moisture content in root was recorded in AE (a non-nitrogen fixing tree seedling), whereas, the moisture level in nitrogen fixing tree seedling ranged between 61.52 (*Acrocarpus fraxinifolius*) to 50.27 (*Acacia nilotica*). Similarly Moisture content in seedling (shoor+root) was also maximum in both the non-nitrogen fixing tree seedlings i.e., *Ailanthus excelsa* (68.70%) and *Acrocarpus fraxinifolius* (63.76%), whereas, moisture content ranged between 60.01% in *Acacia auriculiformis* to 49.4% in *Casuarina equisetifolia*. Shoot and root dry biomass ratio, which is also an indicator of quality ranged between 1.42 in *Albizia procera* to 6.10 in *Casuarina junghuhniana*. Another quality indicator i.e., height : shoot dry weight values in both non-nitrogen fixing species was found comparatively more than nitrogen fixing species, where the values were found in a very narrow range (3.14 to 4.59), indicating better establish potential in nitrogen fixing tree species.

Different species differ in their root characteristics but their selection based on root mass and distribution can be paramount to selection of suitable species though root distribution depends on the genotype but is also governed by the prevailing soil conditions (Crow, 2005). Root based indices showed consistency with little variation in index values, whereas, the values of height : diameter ratio showed high variation among the species i.e., ranging from 6.23 to 17.48 (Fig.1). Shoot: root weight ratio and sturdiness quotient are important measurements for seedling survival and predict seedling performance (Mañas *et al.,* 2009). Lower values of shoot: root ratio and sturdiness quotient are considered a favourable quality indicator (Chauhan and Sharma, 1997). The Dickson quality index (QI) integrating the aspects of total plant mass, the sturdiness quotient and (RL/SH) ratio explains over all plant potential for survival and growth in the field. Values in increasing order show increased potential for field planting establishment success. Johnson and Cline (1991) also recorded Dickson quality



Casuarina equisetifolia *Ailanthus excelsa*
Albizia procera *Acrocarpus fraxinifolius*
Albizia lebbeck *Prosopis juliflora*
Acacia nilotica *Leucaena leucocephala*
Acacia auriculiformis *Casuarina junghuhniana*

Plate 1. Rooting behavior of one year old nitrogen fixing tree seedlings

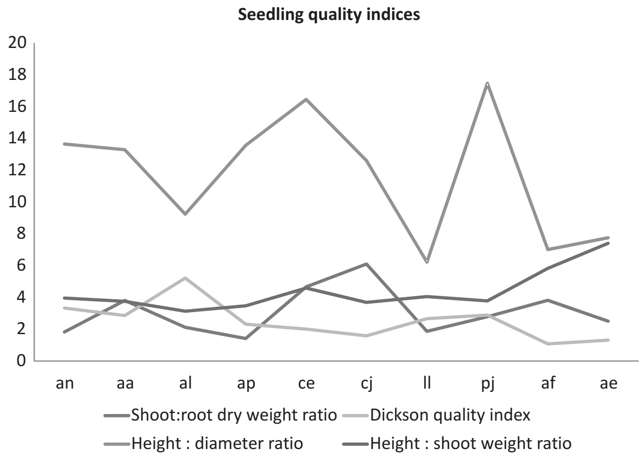


Fig. 1. Seedling quality indices (an, aa, al, ap, ce, cj, ll, pj, af and ae represents *Acacia nilotica; Acacia auriculiformis; Albizia lebbeck; Albizia procera; Casuarina equisetifolia; Casuarina junghuhniana; Leucaena leucocephala; Prosopis juliflora; Acrocarpus fraxinifolius* and *Ailanthus excelsa,* respectively)

index a promising indicator of seedling quality integrating morphological traits and biomass distribution.

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Assessment of Micro Nutrients Status under Seabuckthorn (*Hippophae rhamnoides* L.) Soils in Spiti, Himachal Pradesh

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Abstract: Seabuckthorn *(Hippophae rhamnoides)* is a native shrub of cold deserts belonging to family Elaeagnaceae and is a well known soil binder. The study was carried out in Spiti valley of Himachal Pradesh to assess the effect of seabuckthorn on the status of soil micronutrients in comparison to willow plantation and wasteland. Soil samples were collected at elevations from 3390 m to 4040 m above sea level, where *Hippophae rhamnoides* was found naturally and were chemically analyzed. The results showed that the nutrient percentage and accumulating contents in seabuckthorn plantations were higher as compared to the willow plantation and wasteland. The species-wise trend of these properties was in the order of seabuckthorn > willow > wasteland. The available Fe and Cu increased, whereas available Zn and Mn decreased with an increase in altitude. The soil depth also influenced the status of micronutrients as all three conditions exhibited relatively higher values in the surface layers as compared to sub-surface and bottom layers. Hence, seabuckthorn, a nitrogen fixer with vitamin rich fruit berries and extensive root system plays an important role in increasing soil nutrients and improving soil fertility in the soils of high altitude cold desert Spiti, Himachal Pradesh.

Keywords: Altitude, Cold desert, Micronutrients, Seabuckthorn, Soil fertility

In India, cold desert comes under the trans-Himalayan zone, which are not affected by Indian monsoons because they lie in the rain shadow of the Himalayan mountain systems. Cold deserts are arid regions having extreme climatic conditions, scant rainfall, massive snowfall, high wind velocity, extreme temperature conditions from low to high, high UV radiation and extremely xeric conditions, which are unsuitable for the vegetation (Devi and Thakur, 2011).

These deserts are of vulnerable nature of climate, which may cause great effect on soil health (Charan *et al.,* 2013). The soils at high altitude are coarse textured, have high bulk density; poor water holding capacity, low nutrient availability for growing crops and low soil fertility (Dwivedi *et al.,* 2005; Sharma *et al*., 2006).

In cold desert ecosystem natural resources are limited and only a few plant species like *Hippophae rhamnoides* are adapted to cope up with the harsh climatic conditions. So, knowing the importance of seabuckthorn for ecological, social and economical development, seabuckthorn is the best chosen priority (Singh *et al.,*2010; Singh *et al.,* 2012).

Seabuckthorn (*Hippophae* L.) plants grow in extreme climatic conditions in the temperature ranges of -43 to +40 ˚C and mean annual rainfall varying between 250 and 850 mm (Singh, 2003; Rongsen, 1992). Also, the shrub develops an extensive root system having symbiotic association with microorganism belonging to the genus *Frankia,* which has the ability to fix atmospheric nitrogen and generally improves soil fertility (Tamchos and Kaul, 2015; Yu *et al*., 2015).

Micronutrient deficiencies in soil not only limit the crop production and their quality but also have negative effects on human nutrition and health (Govindaraj *et al*., 2011; Makoi, 2016). Considering the limited availability of nutrients and their importance for plant growth and development in cold deserts, it is important to gain knowledge to overcome this limitation. The present study was designed to assess the effect of seabuckthorn on the micronutrient status of soils along the altitude gradients and soil depth in cold desert region of Spiti.

MATERIAL AND METHODS

The study was conducted in Spiti valley, situated between 32^{0}05'55.1"-78^{0}21'99.8" N latitude and 32^{0}26'72.0"-77^{0}53'81.1" E longitude in the extreme North-East region of Himachal Pradesh, India. The climate of the study area varies from dry temperate, semi arid and alpine type. In winters the study area remains snow covered almost for four months which starts from November and continues till February. August is the hottest month with temperature rising up to 30^{o}C during day time. Rainfall in the area is scanty, which fluctuates from 20 to 200 mm yr^{-1} depending on place to place.

Soil sampling and processing: Soil samples were collected from seabuckthorn stand, willow stand and control land located at six altitudinal zones namely Tabo (3390 m asl), Shichling (3520 m asl), Lingti (3560 m asl), Shego (3615 m asl), Rangrik (3790 m asl) and Hansa (4040 m asl). Soil samples were collected from at soil depths of 0–10 cm, 10–20 cm and 20–30 cm in sealed plastic bags. For obtaining a representative sample, five soil cores were collected within 3 plots and thoroughly mixed to form a composite sample of about 200 g. After removing the plant roots, macrofauna, stones, gravel and other plant residues, the soil was air dried at room temperature, grinded by pestle mortar and passed through 2 mm sieve and then put for analysis for nutrients study.

Analysis of different parameters: DTPA extractable micronutrients Cu, Zn, Fe and Mn were obtained by extracting 10 g soil with 20 ml 0.05 M DTPA + 0.01 M calcium Chloride ($CaCl_2$) + 0.1 M triethanolamine solution. The contents were shaken on a mechanical shaker continuously for 2 hours. Then soil suspension was filtered through a dry filter paper Whatman No. 42 and the estimation of micronutrients (Cu, Zn, Fe and Mn) in the soil was done by the DTPA method in the Atomic Absorption Spectrophotometer (Lindsay and Norvell, 1978).

Fig. 1. Map of study areas (Spiti Valley, HP)

Table 3. Descriptive statistics for soil micronutrients Fe, Mn, Cu and Zn

Parameters	Fcal	Tab F	SD *	SE (m±)	CV (%) **
Fe (mg kg^{-1})	65.714	1.922	0.153	0.108	6.449
Cu (mg kg^{-1})	6.980	1.922	0.131	0.093	16.842
Zn (mg kg^{-1})	1.183	1.922	0.107	0.076	24.853
Mn (mg kg^{-1})	2.553	1.922	0.144	0.102	121.803

*Standard deviation; **Coefficient of variation

RESULTS AND DISCUSSION

Variation of soil micronutrients with altitude under seabuckthorn in Spiti: Soil micronutrients (available Fe, Cu, Zn and Mn) varied greatly in seabuckthorn forest along different altitudes and soil depth in Spiti valley. The available Fe and Cu in seabuckthorn soils ranged from 3.9 to 10.9 mg kg^{-1} and 1.2 to 2.8 mg kg^{-1} (Table 1). The values of available Fe and Cu in seabuckthorn forest were higher in the top soil layer about 3.9 to 11.4 mg kg^{-1} and 1.2 to 3.8 mg kg^{-1}. The contents in the middle layer were of very little difference about 3.5 to 11.5 mg kg^{-1} and 0.9 to 3.4 mg kg^{-1} and in the bottom layer about 3.2 to 10.9 mg kg^{-1} for available Fe and 0.7 to 2.8 mg kg^{-1} for available Cu (Table 1). Also figure 2 shows that at different altitudes in Spiti valley available micronutrients increased with increasing altitude and decreased with increasing soil depth. Vivek and Kanwar (2010) and Saeed *et al*. (2014) also observed that available Fe and Cu

Table 1. Integrated effect of seabuckthorn, willow and wasteland on the soil micronutrients in relation to altitude

Locations	Altitude m asl	Seabuckthorn	Willow	Wasteland	Seabuckthorn	Willow	Wasteland
		Fe (mg kg^{-1})				Cu (mg kg^{-1})	
Tabo	3390	3.53±0.43	3.30±0.33	2.6.0±0.36	0.93±0.30	0.83±0.26	0.70±0.23
Shichling	3520	3.70±0.47	3.50±0.35	2.97±0.40	1.50±0.39	1.07±0.25	0.80±0.25
Lingti	3560	4.33±0.35	3.93±0.40	3.47±0.36	1.70±0.33	1.33±0.38	0.80±0.20
Shego	3615	5.33±0.43	4.50±0.37	3.47±0.36	2.17±0.41	1.90±0.33	1.47±0.40
Rangreek	3790	8.80±0.37	5.97±0.36	5.37±0.32	2.43±0.56	2.13±0.39	1.70±0.32
Hansa	4040	11.17±0.38	8.23±0.46	6.47±0.33	3.33±0.52	3.10±0.30	1.80±0.36
CD (p=0.05)			0.30			0.26	
		Zn (mg kg^{-1})				Mn (mg kg^{-1})	
Tabo	3390	1.53±0.30	1.20±0.32	0.93±0.24	4.13±0.40	3.20±0.33	2.80±0.30
Shichling	3520	1.33±0.32	1.13±0.33	0.80±0.28	3.67±0.42	2.98±0.32	2.37±0.36
Lingti	3560	1.27±0.39	0.97±0.30	0.73±0.20	3.20±0.43	2.53±0.28	2.00±0.30
Shego	3615	1.00±0.33	0.73±0.26	0.67±0.18	2.80±0.43	2.10±0.26	1.64±0.39
Rangreek	3790	0.83±0.35	0.70±0.22	0.57±0.17	2.20±0.51	1.60±0.37	1.37±0.32
Hansa	4040	0.80±0.26	0.70±0.25	0.53±0.15	1.97±0.41	1.17±0.32	1.30±0.26
CD (p = 0.05)			0.21			0.29	

increased with increasing altitude but available Zn and Mn significantly decreased with increasing altitude and soil depth. Also the contents of available Zn and Mn in seabuckthorn soils varied from 4.5 to 1.6 mg kg^{-1} and 1.8 to 0.6 mg kg^{-1}. The status of DTPA−extractable Fe, Cu, Zn and Mn were found to decrease with increasing soil depth. Similar results were authenticated by Dar *et al.* (2012), who found decreasing trend of available micronutrients with increasing soil depth as low temperature reduces rate of mineralisation which leads accumulation of nutrients in the top soil layers then in case of bottom layers.

Integrated effect of seabuckthorn, willow and wasteland on soil micronutrients: The soils at different altitudes of spiti valley showed wide variations in their micronutrient status. The different altitudes and species interaction was significant for the soil available Fe, Cu, Zn, Mn (Table 1). The distribution of soil micronutrients varied greatly under seabuckthorn than willow and wasteland vegetation. Compared with willow and wasteland, soil under seabuckthorn vegetation had higher values of available micronutrients Fe, Cu, Zn and Mn. Also, the soil available Fe, Cu increased with increasing altitudinal gradient and available Zn, Mn were found to decrease. The results are in agreement with the results of He *et al.* (2016) who found that soil nutrient concentrations significantly increased with altitude, likely because low temperature limits the cycling of organic matter at high altitudes.

Soil improvement in the seabuckthorn vegetation: The different species and soil depth interactions were significant (Table 2). The content of micronutrients in the seabuckthorn forest is clearly higher than that of willow forest and wasteland. Also, the micronutrient status was found to have higher values at top surface layers and lower values in sub−surface layers which show that seabuckthorn plantations is one of the important species for soil improvement because of its strong roots. As the decomposition of leaf litter and dead roots would increase the mineralisation which add nutrients leading to increase the content of micronutrients in the soil (Dar, 2012; He *et al.*, 2016). There was difference in the CV of the soil micronutrients (Table 3). The greatest variation was observed in Mn (121%), whereas, the smallest variation was observed in Fe (6%). Other nutrients exhibit a medium variation (16−25%).

A comparison of seabuckthorn, willow and wasteland shows that seabuckthorn had better results than willow and wasteland. This implies that seabuckthorn is more suitable to increase soil micronutrient status in the cold desert area of Spiti, while willow may be less suitable. So plantation ofseabuckthorn in the cold desert can play a very significant role as seabuckthorn soils accumulate higher values of micronutrient than the willow and wasteland. Hence,

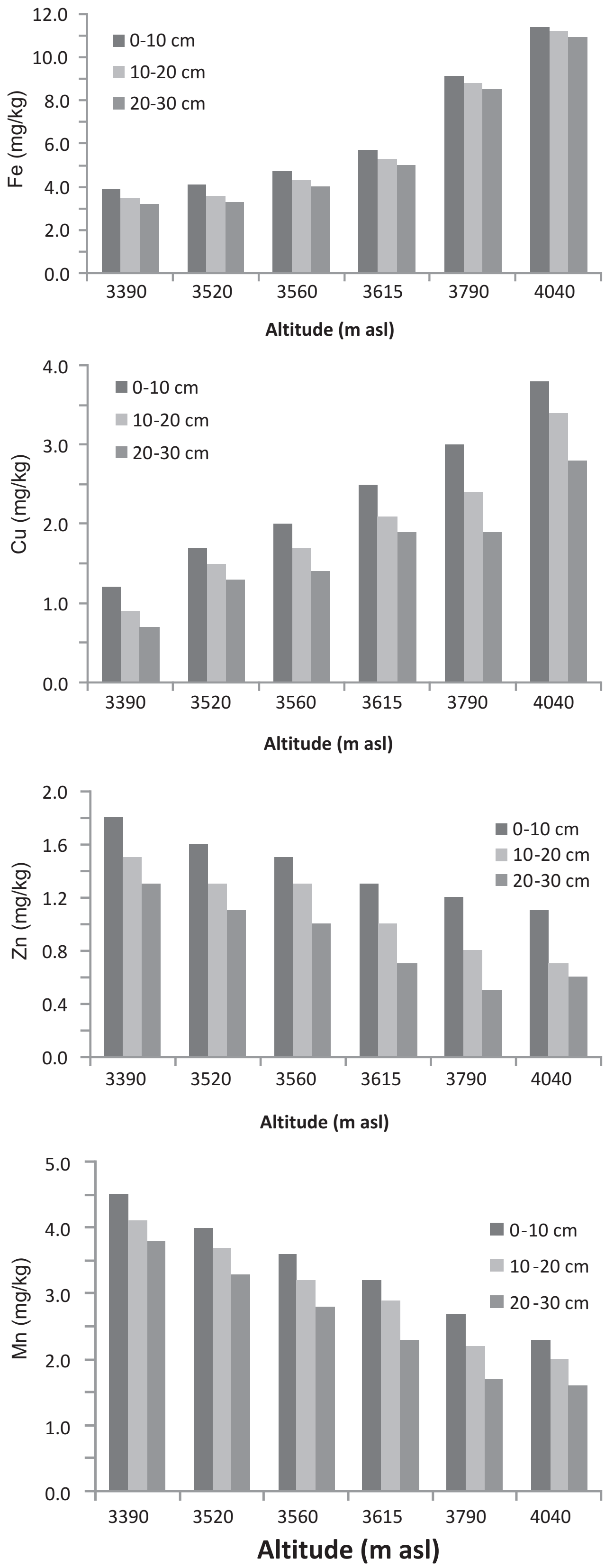

Fig. 2. Variations of different soil nutrients in relation to altitude under seabuckthorn in Spiti. i) available Fe, ii) available Cu, iii) available Zn and iv) available Mn

Table 2. The contents of micronutrients in the seabuckthorn forest, willow forest and wasteland in relation to soil depth (cm)

Species	(0–10)	(10–20)	(20–30)	(0–10)	(10–20)	(20–30)
		Fe (mg kg^{-1})			Mn (mg kg^{-1})	
Seabuckthorn	6.48±2.89	6.12±2.99	5.82±3.00	3.38±0.82	3.02±0.79	2.58±0.87
Willow	5.18±1.79	4.93±1.81	4.60±1.78	2.50±0.79	2.27±0.78	2.02±0.77
Wasteland	4.33±1.43	4.05±1.46	3.78±1.45	2.10±0.68	1.92±0.59	1.72±0.57
CD (p= 0.05)		0.21			0.20	
		Cu (mg kg^{-1})			Zn (mg kg^{-1})	
Seabuckthorn	2.37±0.94	2.00±0.85	1.67±0.70	1.42±0.31	1.10±0.35	0.87±0.39
Willow	2.01±0.84	1.72±0.79	1.45±0.78	1.15±0.32	0.90±0.26	0.67±0.25
Wasteland	1.47±0.51	1.17±0.55	1.00±0.49	0.85±0.28	0.67±0.21	0.60±0.16
CD (p= 0.05)		0.18			0.15	

seabuckthorn has great potential for sustainable environmental protection in cold desert areas of Himalayas and because of its strong root system, nitrogen fixing ability and soil binding property improves soil quality or fertility. Overall results revealed that seabuckthorn is a wonder plant and suggest that planting seabuckthorn vegetation is more advantages for soil improvement and increasing soil fertility in the cold desert regions of Himalayas.

The results presented in this work will improve the use of seabuckthorn in cold desert and hence ensure the farmers welfare ecologically and economically.

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Effect of Irrigation on Young Crop of Common Bamboo Raised from Culm Cuttings in Rainfed Upland

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Abstract: An investigation was carried out to find out the optimum irrigation requirement in young crop of Common bamboo (*Bambusa vulgaris* Schrader ex Wendland) raised from rooed culm cuttings at Orissa University of Agriculture and Technology, Bhubaneswar, India. It is a remunerative bamoo species of the world and is raised suitably from rooted culm cuttings be causeed it does not produce viable seeds. This study consisted of 3 different trials conducted on 2nd year, 3rd year and 4th year crop of *Bambusa vulgaris* raised from rooted culm cuttings in rainfed upland. The clumps were raised from 3 month old rooted culm cuttings at a spacing of 5m x 5m. Spot irrigation applied to individual clump in alternate day @ 4 in 2nd year crop, 8 in 3rdyear crop and 12 litres in 4th year crop. The growth of clumps was remarkably higher in irrigated condition during summer than non-irrigated condition. The optimum irrigation requirement was found be 4 summer months irrigation i.e. February, March, April and May in 2nd year,3rd year as well as 4th year crop@ 4,8 and12 litres of water, respectively in alternate day per clump.

Keywords: Bamboo, *Bambusa vulgaris*, Irrigation, Culm cutting

The common bamboo (*Bambusa vulgaris* Schrader ex Wendland) is a remunerative bamoo species of the world. The most part of bamboo growing areas in tropics particularly in coastal areas. This can be grown in rainfed uplands successfully provided optimum irrigation can be given in initial years of the plantation. It is necessary to know the optimum irrigation requirement in young crop of this bamboo raised from rooed culm cuttings. It is raised suitably from rooted culm cuttings because it does not produce viable seeds (Koshy and Jee, 2001; Bhol, 2006). The response of irrigation to different species of bamboo has been studied by different workers (Pandalai *et al.*, 2002; Kleinhenz *et al.*, 2003; Kleinhenz and Midmmore, 2002; Qui *et al.*, 1992) with increase in various growth and yield parameter at different stages of crop. Hence, the present investigation was conducted to find out the optimum irrigation requirement in young crop of this bamboo raised from rooed culm cuttings.

MATERIAL AND METHODS

The investigation was carried out at Orissa University of Agriculture and Technology, Bhubaneswar, India.This study consisted of 3 different trials conducted on 2nd year, 3rd year and 4th year crop of *Bambusa vulgaris* raised from rooted culm cuttings in rainfed upland. The clumps were raised from 3 month old rooted culm cuttings at a spacing of 5m x 5m. In each year crop 6 different treatments were imposed on 144 separate clumps, hence a total of 432 clumps were studied during the period of investigation. There were six treatments in randomisedblock design. The timings of treatments were made in such a way that the effect of the treatments could be assessed in the same year of growth. Watering was done by spot irrigation method involving irrigation of individual clump by making ditches in the form of shallow crowbar holes of 10 cm deep in the root zone around the clump and pouring water in the holes. Irrigation was applied to individual clump in alternate day @ 4 litresin 2nd, 8 litres in 3rdand 12 litres in 4thyear crop. NPK fertilizer was applied @100 : 50 : 50 gram in 2nd, 150 : 75 : 75 gram in 3rd and 250 : 125 : 125 gram in 4th year crop per clump.

RESULTS AND DISCUSSION

The results of optimization of **irrigation** requirement in young crop of *Bambusa vulgaris* raised from rooted culm cuttingsin 2nd, 3rd and 4th year crop. In 1st year irrigation was not necessary because during its active growth period it received monsoon rain.

The different levels of irrigation during summer months reflected marked bearing on total number of culms in clump. Four and five summer months irrigation per year (T_4 and T_5) recorded significantly higher number of total culms (4.28 and 4.34, respectively) over others. However, T_4 and T_5 remained statistically at par with each other. Total number of culms increased with increase of duration of irrigation. All levels of irrigation registered significantly more number of culms over control (3.34 culms per clump). The number of new culms recruited per clump was prominently influenced by different levels of irrigation. Four and five summer months irrigation per year (T_4 and T_5) recruited significantly higher number of culms over others, however, the former two remained statistically at par with each other. Four summer months

(February, March, April and May) irrigation per year was observed to be optimum as far the number of new culms recruited is concerned. All levels of irrigation recruited more number of newculms in comparison to control. The new culm recruited varied from 1.90 to 2.90 per clump under various irrigation regimes.

The height of dominating culm also exhibited differential growth under different irrigation levels. The height growth was enhanced consistently with increase in level of irrigation. The four months of summer irrigation (February to May) and five months of summer irrigation (January to May) considerably increased the height growth, in comparison to other levels of irrigation. The height growth, however, under four (T_4) and five (T_5) months of irrigation was at par. All levels of irrigation witnessed significantly higher height growth over control (3.20 m). The dbh of dominating culm was also influenced prominently under different levels of irrigation. The similar trend was noticed in dbh growth as in case of height. The value of dbh ranged from 1.64 cm to 2.20 cm under different levels of irrigation. The number of internodes responded in similar pattern as that of height to different levels of summer irrigation. The number of internodes varied from 17.80 to 23.90 under different irrigation regimes.

The data indicates a wide variation in total number of culms under different levels of irrigation. The total numbers of culms were significantly higher under 4 and 5 summer months irrigation (T_4 and T_5), which were statistically at par with each other. The total number of culms progressively increased from control (zero irrigation) upto 5 summer months irrigation (T_5) as the level of irrigation increased. The total number of culms per culmp varied from 8.70 to 10.20 under different irrigation treatments.The number of new culms recruited was strongly influenced by irrigation. The number of new recruitment significantly exceeded from control (T_0) upto 4 summer months irrigation per year (T_4). The new culm recruitment varied from 4.35 to 5.82 per clump under different treatments. T_4 was observed to be the optimum level of irrigation i.e. irrigation during February, March, April and May.

The height of dominating culm manifested significant differences among the treatments. Four summer months irrigation (February to May) and five summer months irrigation (January to May) which were at par with each other reflected significantly more height than others. The three months summer irrigation (T_3) pushed the height at par with four summer months irrigation. The height ranged from 5.25 to 6.50m. The dbh of dominating culm was also significantly influenced by different levels of irrigation. The four and five summer months irrigation (T_4 and T_5) put considerably more dbh in comparison to others, but remained at par with each

Table 1. Effect of irrigation on 2nd year crop of Common bamboo raised from rooted culm cuttings

Treatments	Total no. of culms clump^{-1}	No. of new culms recruited clump^{-1}	Height of dominating culm (m)	DBH of dominating culm (cm)	No. of internodes in dominating
T_0 (Control)	3.34	1.90	3.20	1.64	17.80
T_1 (1 summer month irrigation per year)	3.58	2.14	3.42	1.75	19.00
T_2 (2 summer months irrigation per year)	3.72	2.30	3.66	1.87	20.30
T_3 (3 summer months irrigation per year)	4.00	2.58	3.96	2.02	22.00
T_4(4 summer months irrigation per year)	4.28	2.84	4.24	2.17	23.56
T_5 (5 summer months irrigation per year)	4.34	2.90	4.32	2.20	23.90
CD (p=0.05)	0.15	0.12	0.16	0.08	0.87

Table 2. Effect of irrigation on 3rd year crop of Common bamboo raised from rooted culm cuttings

Treatments	Total no. of culms clump^{-1}	No. of new culms recruited clump^{-1}	Height of dominating culm (m)	DBH of dominating culm (cm)	No. of internodes in dominating culm
T_0	8.70	4.35	5.25	2.78	26.20
T_1	8.92	4.58	5.45	2.90	27.22
T_2	9.28	4.93	5.75	3.05	28.70
T_3	9.68	5.33	6.10	3.23	30.46
T_4	10.02	5.68	6.38	3.38	31.86
T_5	10.20	5.82	6.50	3.44	32.52
CD (p=0.05)	0.33	0.22	0.23	0.11	1.23

other. It increased with increase of irrigateon regime. The range of variation was 2.78 to 3.44 cm. The number of internodes in dominating culm was also markedly influenced by irrigation. T_4 and T_5 which performed alike exhibited significantly more values over others. The performance of T_0 and T_1 was statistically similar. The number of internodes varied from 26.20 to 32.52 under different treatments.

Fourth year: The data reflects that total number of culms per clump was remarkably influenced by different levels of summer irrigation in 4th year. The four and five summer months irrigation (T_4 and T_5) exhibited significantly higher number of culms over control (T_o), one summer month irrigation (T_1) and two summer months irrigation (T_2). However, performance of T_3 (three summer months irrigation) was at par with T_4 and T_2. The total number of culms increased towards higher level of irrigation. It ranged from 16.10 to 17.20 per clump among treatments.The number of new culms recruited was also influenced by levels of irrigation. The four and five summer months irrigation (T_4 and T_5) recruited prominently higher number of new culms in comparison to others. However, T_4 and T_5 performed statistically alike. The number of new recruitment progressively increased with increase of irrigation regime. It varied from 5.90 to 7.00 per clump. The level of irrigation put marked bearing on height growth of dominating culm. The height was enhanced with increase of irrigation level and reached maximum (8.60m) at T_5. However, values at T_5 were at par with T_4. The range of height growth was 7.52–8.60 m.

The dbh of dominating culm was also influenced by duration of irrigation in summer months. The four and five summer months irrigation (T_4 and T_5) put appreciably higher collar diameter over others. Parity in performance was observed between T_0 and T_1 as well as between T_4 and T_5. The values ranged from 4.10 cm to 4.70 cm under different irrigation levels. The number of internodes in dominating culm responded to different irrigation levels in similar trend as in case of height growth. It varied from 36.60 to 42.00 numbers among the irrigation levels. In the present investigation on 2nd year crop of *common bamboo,* increasing the regime of irrigation progressively increased growth and yield parameters namely total number of culms, number of new culms recruited, height, dbh of culms and number of internodes in culms over control. Significant differences in the above parameters were observed even at one summer month irrigation per year during May. Although there was progressive increase in the above parameters upto five summer months irrigation per year during January, February, March, April and May, the optimum level of irrigation was found to be four summer months irrigation per year i.e. from February to May.In 3rd year crop, response of growth parameters to summer irrigation was positively correlated with the levels of irrigation. The response of plant growth was optimum upto four summer months per year beyond which the increase in the growth parameters were at par with the former. In the 4th year crop different growth parameters were positively correlated with increasing regimes of summer irrigation. However, four summer months irrigation per year was found to be optimum for enhancing growth and yield attributes.

Pandalai *et al.* (2002); Kleinhenz and Midmmore (2002) and Kleinhenz *et al.* (2003) reported the increase in various growth and yield parameters at different stages of bamboo crop with application of irrigation. Significant increase in plant growth and yield was observed even at one summer month irrigation per year during May. This might be due to activation of rhizome during this month for which the water use efficiency of the crop increased resulting in enhanced growth and yield. The four and five summer months irrigation, which were at par with each other, put significantly higher growth over others. Hence, four summer months irrigation from February to May instead of five irrigation from January to May was optimum for enhancing growth and yield because during January the temperature is comparatively low and rhizomes are dormant to utilize the soil moisture whereas from February onwards rhizome activation takes place with

Table 3. Effect of irrigation on 4th year crop of common bamboo raised from rooted culm cuttings

Treatments	Total no. of culms clump^{-1}	No. of new culms recruited clump^{-1}	Height of dominating culm (m)	DBH of dominating culm (cm)	No. of internodes in dominating culm
T_0	16.10	5.90	7.52	4.10	36.60
T_1	16.30	6.11	7.72	4.20	37.57
T_2	16.54	6.35	7.86	4.28	38.25
T_3	16.86	6.66	8.18	4.45	39.80
T_4	17.14	6.95	8.46	4.61	41.16
T_5	17.20	7.00	8.60	4.70	42.00
CD (p=0.05)	0.53	0.21	0.26	0.13	1.30

increase of in temperature, thereby increasing water use efficiency of plants.

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Growth Performance of Soybean Varieties under Different Light Intensities

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Abstract: The paper reports the impact of different light intensities on the growth of Soybean varieties viz. BSS-2 and RAUS-5. Dry matter accumulation, relative growth rate (RGR) , net assimilation rate (NAR) were maximum in full light and leaf area ratio (LAR) , specific leaf area (SLA) and shoot/root ratio were maximum in shaded condition in both the varieties. Shading caused delayed initiation of flowering as well as reduced number of fruits in both the varieties. Yield was higher in full light condition. RAUS-5 performed better in all treatments of shading.

Keywords: Soybean, Light intensities , Growth performance, Yield

Light affects and regulates plant life in a very large variety of ways and growth of plants is affected by the total amount of light available from the sun in a particular habitat. Plants in general differ in their photo-morphogenetic response under different light intensities. Most of the early researchers were confined towards an understanding of the agronomic evaluations of crop plants for a better yield. Hence, the effect of seasonal fluctuations of light was taken as a necessary prerequisite for judging the usefulness of the plants in the desired agro-climatic conditions. Light intensity affects photosynthesis, and this, in turn, is related to the accumulation of organic matter and biomass. Moreover, to sustain higher photosynthetic capacity or survival, plants modify their morphology and biomass allocation at different light conditions (Gonzalez *et al*., 2004; Feng *et al*., 2004; Lin *et al*., 2004). Soybean is an important pulse because it is a high value legume having multiple importance as food, feed and industrial uses with high protein content, good quality of edible oil with appreciable amount of minerals and vitamins. Thus, due attention is required to enhance the production of pulses not only to meet the dietary requirement of protein but also to raise the awareness about pulses for achieving nutritional, food security and environmental sustainability. Keeping in mind above facts, the present paper has been devoted to workout comparative adaptability of two varieties of soybean under three levels of light regimes with respect to various morphological, derived and reproductive growth parameters.

MATERIAL AND METHODS

Earthen pots of 20 cm. height and of 15 and 8 cm diameter at the inside top and bottom respectively, were filled with a mixture of powdered field soil, sandy soil and farmyard manure (5:2:3). All pots had equal amount of soil in them. Seeds of the two varieties of Soybean (BSS-2 and RAUS-5) were sown in these pots on 1st June 2013 at T.N.B. College, Bhagalpur. It is geographically located at 25° 15' 0" North latitude and 87° 0' 0" East longitude on the southern alluvial plains of River Ganga. After a week of sowing only one seedling was kept in each pot except in intra-varietal competition treatments. Pots were watered every alternate day to their field capacity from the date of sowing till the final harvests. White muslin cloth and mosquito net were used to cover bamboo tents under which artificial shading on plants were created. Three light regimes were S_I – Full light under natural day condition (100%) , S_{II} – Light under netted cloth cover (90%) , S_{III} – Diffused light under muslin cloth cover (70%). All the experimental pots were randomly arranged and ample space was provided in between pots to eliminate shading. Six weekly harvests were taken. At each harvest 3 plants were randomly selected in each treatment. The monoliths were washed with fine jet of water to remove soil particles. Root, shoot and leaves were separated. Leaf area was estimated by graphic method. Plants parts (root, stem and leaves) were dried separately at 80 ± 2°C in an oven for 48 hrs and stored in a desiccator before weighing. The 7th harvest was taken under each treatment at their full maturity for the estimation of fruit and seed yield per plant. The growth performance were calculated such as dry matter accumulation, relative growth rate (RGR), net assimilation rate (NAR), leaf area ratio (LAR), specific leaf area (SLA), leaf weight ratio (LWR) and shoot/root ratio.

RESULTS AND DISCUSSION

The light intensity had significant influence on growth and morphological characters. The dry weight accumulation was maximum in full light in both the varieties which diminished with shading. RAUS-5 had maximum dry weight. BSS-2 and RAUS-5 shows minimum dry weight in SIII condition. In general, maximum biomass was observed in full light condition and that reduction in light quanta resulted into lesser amount of biomass. Comparatively, RAUS-5 appeared better performing in full light condition. Light intensity exceeds the light compensation point, as light intensity increases, photosynthetic rate is gradually increased, and photosynthetic rate is more than respiration intensity, which promotes the accumulation of organic matter in plants. The dry weight accumulation pattern has generally been reported to be more in the natural light for many of the plants (Liao *et al*., 2005). The increase in leaf area was maximum in SIII condition and minimum in full sun light (SI) condition in both the varieties. The increase in leaf area in both the varieties with reduction of light from 90 to 70 per cent showed its adaptability to shading. These adaptations maximize the capture of the available light, meeting the demand for photosynthesis (Steinger *et al*., 2003). In general, the leaf area increased with shading in both the varieties (Table 1).

The relative growth rate was maximum in SII in BSS-2 while, it was maximum in SI in case of RAUS-5. In both the varieties, RGR was minimum in SIII condition. The overall RGR was maximum in SI and minimum in SIII in both the varieties. The overall RGR decreased with reduction in light in both the varieties. The overall net assimilation rate was higher in full sun light in all the harvests in both the varieties while it was minimum in SIII condition in both the varieties. The NAR was definitely higherin the full light condition in both the varieties particularly in the log phase of the growth. Plant relative growth rate (RGR) is determined by their genetic background and by environmental conditions (Rafael *et al*. 2005). Variation in the reduction of RGR under lowered temperatures was due to changes in both NAR and LAR (De Swart *et al*., 2007) They concluded that NAR was the most important factor to explain variations in RGR in plants of the same genus or species, and even between closely related plant species. This feature was indicative of the physiological adaptability of the varieties in which they appeared alike (Table 2).

The leaf area ratio increased with reduction in light, being maximum in SIII condition for both the varieties and it was minimum in full sun light in both the varieties in all the harvests. From the higher values of LAR with reduction in light condition, adaptability of the varieties for compensating the RGR was evidenced. In general, the common feature of higher LAR with reduction in light was reported by other workers like Matsuda *et al*. (2011). He indicated that the inverse relationship between NAR and LAI can be interpreted as the result of changes in light interception per unit leaf area, which is positively correlated with NAR. Under 70 per cent light, RAUS-5 had higher LAR which was indicative of its having more survival value over the BSS-2. Decreasing light intensities caused an increase in LAR with the result that light captured by the leaves increased. The specific leaf area (SLA) increased with reduction in light in both the varieties being maximum in SIII in all the harvests. The SLA was found minimum in SI for both the varieties. BSS-2 shows higher SLA than RAUS-5 in SIII conditions. From data of SLA, the corroborative behaviour of the attributes of LAR was witnessed also. The short duration of plant was reflected in the uniform values of SLA in the both varieties particularly in which BSS-2 appeared more adaptive. Generally, an increase in SLA with decreasing light intensity might compensate for the reduced photosynthesis per unit leaf area and cause overall photosynthesis per plant to be equal. The highest value for SLA in more shaded treatments could be

Table 1. Morphological growth attributes of soybean varieties (BSS-2 and RAUS-5) under different shading regimes

Harvest	Varieties	Dry weight plant (mg)			Leaf area (cm^2)		
		SI	SII	SIII	SI	SII	SIII
1	BSS-2	390	320	280	41.30	57.62	97.37
	RAUS-5	490	333	300	65.57	76.22	98.59
2	BSS-2	1100	920	560	81.58	215.97	236.77
	RAUS-5	1370	940	540	79.03	155.46	239.91
3	BSS-2	3490	2010	1540	372.61	390.94	471.42
	RAUS-5	3530	2210	1840	307.88	385.85	472.02
4	BSS-2	6080	4700	3440	620.08	772.55	926.20
	RAUS-5	7080	4910	3830	627.90	720.83	955.93
5	BSS-2	9830	7090	5360	1028.51	1239.69	1350.00
	RAUS-5	9290	7330	5320	1091.56	1295.36	1477.26
6	BSS-2	16360	13620	8750	1385.95	1527.96	1704.00
	RAUS-5	19080	11510	7960	1452.15	1595.38	1965.18

Table 2. Derived growth parameters of soybean varieties (BSS-2 and RAUS-5) under different shading regimes

Treatment between harvests	Varieties	RGR (mg/mg/week)			NAR ($mg/cm^2/week$)		
		SI	SII	SIII	SI	SII	SIII
1-2	BSS-2	1.04	1.06	0.69	11.99	5.00	1.79
	RAUS-5	1.03	1.05	0.59	12.42	5.47	1.51
2-3	BSS-2	1.15	0.78	1.01	12.48	3.68	2.88
	RAUS-5	0.95	0.85	1.22	12.84	5.02	3.75
3-4	BSS-2	0.56	0.85	0.80	5.34	4.79	2.84
	RAUS-5	0.70	0.80	0.74	7.88	5.00	3.75
4-5	BSS-2	0.48	0.41	0.44	4.68	2.40	1.72
	RAUS-5	0.27	0.40	0.33	2.62	2.49	1.26
5-6	BSS-2	0.50	0.65	0.49	5.48	4.77	2.20
	RAUS-5	0.72	0.45	0.40	7.87	1.85	1.57

due to the increase in leaf area and a reduction in thickness caused by shading (Table 3). The leaf weight ratio (LWR) was found maximum in SII in BSS-2 and in SIII in case of RAUS-5. It was minimum in SI in case of RAUS-5 and in BSS-2 it was minimum in SIII conditions. LWR was maximum in SII in case of BSS-2, which reflects it's non-adaptability in non-shaded condition. LWR increased with shading in RAUS-5 and hence, it is a good measure of adaptability at varietal level.

Table 3. Derived growth parameters of soybean varieties (BSS-2 and RAUS-5) under different shading regimes

Harvest	Varieties	LAR (cm^2/mg)			SLA (cm^2/mg)		
		SI	SII	SIII	SI	SII	SIII
1	BSS-2	0.11	0.18	0.35	0.30	0.52	0.97
	RAUS-5	0.13	0.23	0.33	0.50	0.59	0.82
2	BSS-2	0.07	0.23	0.42	0.20	0.60	1.25
	RAUS-5	0.06	0.17	0.44	0.15	0.47	1.26
3	BSS-2	0.11	0.19	0.31	0.26	0.43	0.68
	RAUS-5	0.09	0.17	0.26	0.27	0.42	0.64
4	BSS-2	0.10	0.16	0.27	0.27	0.46	0.72
	RAUS-5	0.08	0.15	0.25	0.22	0.39	0.66
5	BSS-2	0.10	0.17	0.25	0.26	0.46	0.75
	RAUS-5	0.12	0.18	0.28	0.32	0.52	0.88
6	BSS-2	0.08	0.11	0.19	0.23	0.29	0.55
	RAUS-5	0.08	0.13	0.25	0.20	0.36	0.62

The S/R ratio was higher under lower level of illumination in both the varieties (Table 4). This feature is of significance with regard to shade tolerance. BSS-2 and RAUS-5 has maximum S/R ratio in SIII condition. Higher allocation to roots in response to full sunlight and the consequent decline of shoot to root ratio has already been observed by several authors and its considered a morphological adaptation to increase, at the whole plant level, the ability to supply water in environments characterized by high evapo-transpirational demand by the atmosphere (Ruter, 2002). In full light condition, the initiation of flowering occurred on 57th and 55th days after sowing and it was delayed in SII and SIII on 59th and 56th days in BSS-2 and RAUS-5, respectively. Thus RAUS-5 showed earlierness in flowering. The adverse effect of shading for floral initiation was witnessed in BSS-2 whose flowering was delayed by 2 days. Such delaying in the initiation of flowering due to shading has also been observed by many workers (Dogra *et al*., 2014; Kumar and Kishor, 2015).

Table 4. Derived growth parameters of soybean varieties (BSS-2 and RAUS-5) under different shading regimes

Harvest	Varieties	LWR (mg/mg)			S/R ratio		
		SI	SII	SIII	SI	SII	SIII
1	BS-2	0.35	0.34	0.36	1.18	1.50	1.25
	RAUS-5	0.27	0.39	0.41	2.00	1.33	1.25
2	BSS-2	0.37	0.39	0.34	2.18	1.85	1.06
	RAUS-5	0.39	0.35	0.36	1.47	1.77	1.00
3	BSS-2	0.42	0.45	0.45	1.27	1.78	2.74
	RAUS-5	0.33	0.42	0.41	1.43	1.78	1.77
4	BSS-2	0.38	0.36	0.37	1.04	1.22	2.43
	RAUS-5	0.40	0.37	0.38	1.19	1.80	2.79
5	BSS-2	0.41	0.38	0.34	1.64	1.57	3.75
	RAUS-5	0.37	0.34	0.31	1.90	1.62	2.65
6	BSS-2	0.37	0.39	0.35	2.04	2.24	3.17
	RAUS-5	0.37	0.39	0.40	2.02	1.41	2.04

Number of flowers plant^{-1} and number of pods plant^{-1} were maximum in SI and it reduced in SII and SIII in both the varieties. The number of flowers plant^{-1} and number of pods plant^{-1} was higher in RAUS-5 than BSS-2. Number of flower and number of pod was reduced with shading. Number of seeds plant^{-1} was higher in SI and minimum in SIII in both the varieties. Weight of 100 seeds of both the varieties reduced with shading. As regards the number of flowers, pods, seeds plant^{-1} and weight of 100 seeds also reduced with shading for both the varieties as reported by Kurosaki *et al*. (2003). The presently study revealed that both the grain weight and the economic yield increased under increasing light intensity and low irradiance treatment diminish grain yield (Table 5).

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Table 5. Effect of different shading regimes on reproductive attributes of soybean varieties

Varieties	Days of flowering premordia after sowing			No. of flowers/ plant			No. of fruits/plant			No. of seeds/plant			Weight of 100 seeds (gm)		
	SI	SII	SIII	SI	SII	SIII	SI	SII	SIII	SI	SII	SIII	SI	SII	SIII
BSS-2	57	59	59	4	3	3	140	125	106	364	326	231	12.76	11.09	9.92
RAUS-5	55	56	56	5	3	2	154	134	113	401	349	294	13.54	12.08	11.46

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Effect of Seed Infestation in *Albizia lebbeck* Under Different Conditions

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Abstract: Five important pests were observed on the pods namely, larvae and adults of *Bruchidis albizziae* Arora, *B. saundersi* (Jekel), *B. aurus* Arora, *Caryendon gonagra* and larvae of *Stathmopoda basiplectra* and the seed chalcid (*Bruchidophagus sp.)*. The pest spectrum was same in all the three plantation types. The mean seed infestation was the lowest in agroforestry (22.23 %) and highest in block plantation (30.76 %). Bruchids played a greater role in seed damage and did not vary in relation to plantation type. The chalcid-damaged seeds had better germination potential than bruchid damaged one. Comparing the seedlings vigour of insect damaged seed; it is significantly lower than the seedlings emerged from healthy seeds.

Keywords: *Albizia,* Bruchid, Seed chalcid, Lepidoptera, Germination

The genus *Albizia* (Mimosidae: Leguminousae) are medium sized deciduous tree, confined to tropical and sub tropical Asia, Africa and Australia. Twelve species of this genus are distributed in India. Being a nitrogen-fixing tree, it is recommended for reclamation of wastelands, agroforestry, afforestation, shelterbelts and windbreaks (Gupta, 1993). The shallow root system makes it a good soil binding and suited for soil conservation and erosion control. Multiplications of these species mainly through direct sowing on seedlings raised in poly bags (Singh *et al*., 1991). *A. lebbeck*, apart from enhancing the growth of the companion crop (maize) and improving its grain yield, it also had an added advantage because of tits remaining longer as mulching material in the soil because of its slow rate of decomposition. It can survive frequent pruning with no dieback. *A. lebbeck* is a good potential candidate for alley cropping (Okogun *et al*., 2000).

MATERIAL AND METHODS

The study was conducted at ICAR-Central Agroforestry Research Institute, Jhansi, Uttar Pradesh, India (24° 11' N latitude, 78° 17' E longitude and 271 m above msl). Full-grown trees were selected for this study.

Sample collection, categorization and identification of species: The samples were collected from ten trees each of naturally growing solitary trees, block plantation and agroforestry with companion crops. 50 pods were collected per tree and served as a sample of each category. Adult bruchid emergence holes on the pods were counted to determine the degree of infestation. The pods were categorized into four groups on a modified scale as given by Lale and Okunada (2000), based on the number of emergence holes on the pods (severity of infestation) uninfestated pods (no holes on pods), mildly infested pods (1-2 holes per pods), moderately infested pods (2-4 holes per pods) and highly infested pods (>4 or more holes per pods).

Fifty pods were selected from each category to measure pod length and number of seeds per pod. Seeds were classified into mature, immature and damaged seeds. The casual organisms were recorded based on the size of the exit holes or presence of the insect. The damage causal organism was recorded based on the seed of the exit holes or presence of the insect. Loss in seed biomass was calculated from the formula quoted by Vir and Jindal (1994) i.e., Loss in seed biomass = (x-y/n X z/x X 100), Where, z is the percentage of infested seeds per tree, x is the weight of a constant number of healthy seeds (100), and y is the weight of a constant number of infested seeds (100). This may be further simplified i.e., Loss in seed biomass = Z (1-y/x)

Germination potential of infested and healthy seeds: Infested and non-infested seeds were studies for their germination potential. Fifty seed each of bruchid, chalcid infested seeds and unaffected healthy seeds were taken in and replicated thrice. The seeds were treated with acid scarification and hot water. The seeds without treatment served as control. The experiment was set in a completely random stastical design. Seeds were evaluated for the germination and germination index.

RESULTS AND DISCUSSION

Pests observed in pods: Five important pests were observed on the pods namely, larvae and adults of

Bruchidius albizziae Arora, *B. saundersi* (Jekel), *B. aureus* Arora (Bruchidae: Coleoptra), *Caryedon gonagra* (Bruchidae: coleoptra) and the larvae of *Stathmopoda basiplectra* (Heiodinidae: Lepidoptera) and the seed chalcid, *Bruchidophagus sp* (Chalcidae: Hymenoptera). Two hymenopteran parasitoida also observed on the lepidoptran larvae viz., *Chelonus blackburnii* and an unidentified parasitoid. Two hymenopteran parasitoids were also recorded on the bruchids, *Uscana* sp and another. Many authors have reported the three-bruchid species observed on *A. lebbeck*. *B. albizziae* has been reported as the major seed pest in central India. *Stathmopoda* larvae have also been recorded on *Albizia* seeds in other pest of India. The seed chalcid has also been recorded in other parts on India of *A. lebbeck*. Pankajam *et al.* (1998) has recorded Bruchidophagus on *A. lebbeck* for the first time. Other species then the ones observed were also recorded such as *Bruchus bilineatophygus* in Rajasthan. *Bruchidius sparsemaculatus* was recorded as a new pest of *A. lebbeck* in Delhi, India (Verma *et al.,* 1987).

Exit holes per pod: The pods were classified based on exit holes (Table 1) and the per cent pod with high infestation was low in all three plantation through the highest of 4 per cent was recorded in block plantation. The majority of pods under the category of mild infestation followed by moderate infestation.

Seed parameters of healthy and infected seeds: The seeds parameters of healthy and infected seeds are shown in Table 2. The 100 seed weight of bruchid-infested seeds ranged from 7.99–8.93g and the mean loss in seed weight was 28.18 per cent and loss in seed biomass was 16.74 per cent. The seed weight of chalcid infested seeds ranged from 6.31–7.01 g and the mean loss in seed weight was 43.31 per cent and loss in seed biomass was 25.73 per cent. Similarly the seed weight of lepidoptran infested seeds ranged from 5.89–6.52 g and the mean loss in seed weight was 47.59 per cent and loss in seed biomass was 28.22 per cent. The 100 seed weight of healthy seeds ranged from 10.99–11.97 g.

Table 1. Classification of pod infestation based on pod holes

Pod holes pod^{-1}	Agroforestry	Block	Solitary
0	12	11	17
1	50	32	26
2	25	26	29
3	9	27	20
4	6	12	8
5	2	4	0
6	0	0	0
7	0	0	0
8	0	1	0
Mild infestation	Mild to moderate	Mild infestation	Infestation

The loss in seed weight and seed biomass was maximum in seeds damaged by lepidoptera followed by bruchids and the least in chalcid infected seeds. The hundred seed weights of chalcid seeds were the highest among damaged seeds. The current session's seeds predated by endophagous bruchid beetles tended to be smaller (in terms of volume), and for *A. tortilis*, more aspherical (Garner and Witkowski, 1997). Szentesi and Jermy (1995) states that seed size and morphology play an important role in bruchid infestation.

Seed health in relation to different plantation types: The total seeds pod^{-1} in solitary trees and block plantation did not

Table 2. Seed parameters of healthy and infected seeds

Pod character	Mean	SD	Range	(CV) %
Bruchid infested seeds				
Weight of 100 infested seeds (g)	8.42	0.41	7.99–8.93	0.05
Loss in seed weight (%)	28.18	2.51	25.46–32.13	0.09
Loss in seed biomass (%)	16.75	1.49	15.13–19.09	0.09
Chalcid infested seeds				
Weight of 100 infested seeds (g)	6.65	0.27	6.31–7.01	0.04
Loss in seed weight (%)	43.31	1.92	40.54–45.67	0.04
Loss in seed biomass (%)	25.73	1.14	24.08–17.13	0.04
Lepidoptera infested seeds				
Weight of 100 infested seeds (g)	6.16	0.24	5.89–6.52	0.04
Loss in seed weight (%)	47.59	1.58	45.62–49.59	0.03
Loss in seed biomass (%)	28.22	0.94	24.08–29.46	0.03
Healthy seeds				
Weight of 100 infested seeds (g)	11.72	0.42		0.04

differ stastically but there was significantly difference between them and agroforestry plantation (Table 3). The maximum was observed in block plantation (9.89) and the minimum in agroforestry plantations (8.07). The percentage of seed infection showed significant variation ranging from a minimum of 22.2 per cent in agroforestry and a maximum of 30.76 per cent in block plantation.

The per cent damage by the three major groups of pests varied significantly among the three plantation types. The per cent bruchid damage was the highest in all three plantation types but did not differ statistically. The difference in per cent lepidopteron damage was highly significant with the highest damage of 46.70 per cent in solitary plantations followed by 12.00 per cent damage in agroforestry, which was as per with the minimum damage of 3 per cent in block plantation (Table 3). The seed infestation was also observed lowest in agroforestry by Schaefer and Siva (1990); Andow (1991) and Chauhan *et al.* (2017). On the other hand, bruchidis were found to increase under agroforestry if the tree and crop were taxonomically related such as *Acacias* and groundnut (Satya vir *et al.,* 1996; Singal and Toky, 1990). Bruchidus were the major source of damage, which is endorsed by the reports of many workers (Delobel, 1995; Singh and Bhandari, 1988; Chauhan *et al.,* 2017).

Effect of seed infestation on germination in *A. lebbeck*: Among the three seed treatments, scarification with sulphuric acid gave 88 per cent germination followed by hot water treatment (64.00), while the untreated seeds recorded only 19 per cent germination (Table 4). Among the three types of seeds used, normal healthy seeds recorded the highest germination percentage irrespective of seed treatment with a mean 57 per cent across treatments followed by chalcid damaged seeds was less than 1 per cent. The vigour index was highest in healthy seeds that were scarified with sulphuric acid (1475) followed by healthy seeds with hot water treatment (614). Seed predation reduces germination irrespective of the pest involved. But chalcid damaged seeds had better germination potential then bruchid damaged seeds. Almanza *et al.* (2003) in *Mimosa* sp., another leguminous tree, have elucidated the detrimental effect of seed infestation on its germination potential. Germination rate of 0.5–17% have been recorded in bruchid infested seeds of other Acacia species (Lamprey *et al.,* 1974; Miller, 1994; Mucunguzi, 1995), however, germination rates were higher in seed without bruchid damage (Hoffman *et al.,* 1989). Wiegand *et al.* (1999) reported that the bruchids may improve germinability in those rare cases where the seed embryo of Acacia tree is not destroyed by the beetle, because the bruchid exit hole increase permeability of the seed coat

Table 3. Classification of seed health and casual organism in *Albizia lebbeck*

Tree sample	Total seeds pod^{-1}	Per cent infested	Per cent immature	Per cent healthy	Per cent damaged by		
					Bruchid	Lepidopteran	Chalcid
Solitary	8.84	25.68	20.97	7.03	49.43	46.71	4.30
Agroforestry	9.89	22.23	17.48	8.19	37.05	3.02	60.34
Block	8.07	30.76	16.84	6.72	44.36	12.61	42.78
CD1 (p=0.05)	1.79*	8.43*	NS	NS	NS	26.70**	33.56**
CD2 (p=0.01)	2.36	NS	NS	NS	NS	35.33	44.39

* −Significant at 0.05% probability; ** −Significant at 0.05% probability; NS−Non significant

Table 4. Germination studies in *Albizia lebbeck*

Seed treatment	Seed quality	Germination %	Vigour index 1	Vigour index 2
Seed scarification	Bruchid damage	2.00	12.70	–
	Chalcid damage	3.00	13.60	–
	Healthy	88.00	1475.50	34.81
	Mean	31.00	500.6	
Hot water treatment	Bruchid damage	0.00	0.00	–
	Chalcid damage	0.00	0.00	–
	Healthy	64.00	614.17	16.54
	Mean	21.33	204.72	
Without treatment	Bruchid damage	0.00	0.00	–
	Chalcid damage	10.00	119.100	7.23
	Healthy	19.00	182.70	6.54
	Mean	9.67	100.57	

and thus enhances germination. It is important to point out that the parasitism by bruchids did not improve the germination of the Mimosa species studied (Almanza *et al.,* 2003).

The vigour of seedling emerged from healthy seeds was significantly higher than damaged seeds. Acid scarification of damaged seeds gave some amount of germination through the seedling vigour was greatly reduced. Sonesson (1994) states that with reduce initial reserves, due to seeds damaged by pests, the seedling may be a poorer competitor than its better-provisioned counterparts.

CONCLUSION

Five important pests were observed on the pods namely, larvae and adults of *Bruchidius albizziae* Arora, *B. saundersi* (Jekel), *B. aureus* Arora (Bruchidae: Coleoptra), *Caryedon gonagra* (Bruchidae: coleoptra) and the larvae of Stathmopoda basiplectra (Heiodinidae: Lepidoptera) and the seed chalcid, *Bruchidophagus sp* (Chalcidae: Hymenoptera). The pest spectrum was the same in all three-plantation types. Bruchid played a grater role in seed damage and did not vary in relation to plantation type. It is obvious from this study that seed pests play an important role in seed size, maturity and viability of seeds in *Albizia lebbeck*.

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Horticultural and Yield Related Traits as Influenced by Grafting Tomato Cultivars on Potato Rootstocks for Higher Returns

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Abstract: Pomato is an innovative plant developed by grafting tomato as scion on potato as rootstock. Tomato and potato plants being genetically closely related can be grafted together and grown as one single plant producing both tomatoes and potatoes as they belong to the same family. With no systematic research work done in India on this aspect, the study was conducted to determine the effect of grafting tomato cultivars (Avtar-7711 and GS-600) on potato rootstocks (Kufri Himsona, Kufri Himalini and Kufri Giriraj). The experiment was laid inside a naturally ventilated quonset polyhouse. Kufri Himalini was the best rootstock for tomato scion. The effect of tongue grafting was more pronounced on yield related traits of either of the crop species. GS-600 was the best compatible scion for potato rootstocks. Rootstock-scion combination of Kufri Himalini and GS-600 was the best recombinant on the basis of yield and component traits. Pomato resulted in cost-benefit ratio of 1:2.12 which was significantly higher than sole cultivation of tomato (1:1.93) and potato (1:0.26). Pomato will provide higher returns to the growers in addition to efficiently utilizing the available resources.

Keywords: Pomato, Potato-tomato grafts, Interspecific grafting, Solanaceae, Rootstock

Pomato, a two-in-one plant producing potatoes underground and tomatoes above ground became quite popular soon after its release very recently in 2015 in the United States. Though, the idea dates back to early 1900's, when a botanist Luther Burbank successfully grafted a potato top onto a tomato, and suggested that the reverse combination will also work. But it was first developed on a commercial scale by a British horticultural mail order company in the year 2013 after experimenting the plants for almost a decade before releasing it. It became very popular among the professional horticulturists and amateur gardening lovers and is popularly known by many names such as; Tomtato, Double Up: Potato Tom, Ketchup'n'Fries, etc. Unlike these western countries the scenario in India is entirely different as no systematic research work was done on this aspect. Moreover, for a country like India where industrial development and urbanization at its peak coupled with immensely increasing population leading to severe deterioration to the environment in addition to shrinking the cultivable farm land is posing a great challenge to meet the quality food requirements with the available resources. So the future only relies on such kind of innovative technologies in agriculture, if developed timely. Tomato and potato plants being closely related can be grafted together and grown as one single plant producing both tomatoes and potatoes. Since, the success of this plant lies in identifying and combining potato and tomato plants through grafting in best compatible combination thereby establishing a symbiotic relation with respect to various growth and developmental processes between the potato rootstock and tomato scion growing and developing as a single plant. In light of these facts the present study was undertaken in order to generate substantial practical and useful information regarding this technology which would be surely helpful for further researchers in improving this technology.

MATERIAL AND METHODS

The study was conducted at CSK Himachal Pradesh Krishi Vishvavidyalaya, Palampur in a 250m^2 modified naturally ventilated quonset polyhouse using two potential indeterminate tomato hybrids Avtar-7711 (S1) and GS-600 (S2) as scions during September 2015 to May 2016. Three potato cultivars, viz. Kufri Himsona (V1), Kufri Himalini (V2) and Kufri Giriraj (V3) were used as rootstocks. These rootstocks were the recommended mid maturing varieties for cultivation in mid-hills of Himachal Pradesh. Seedlings of tomato hybrids were raised on soil-less media consisting of Cocopeat:Vermiculite:Perlite in the proportion of 3:1:1 in plastic plug-trays in a growth chamber during the second week of August 2015 and the seed potato tubers were planted in the polyhouse where the experiment was to be laid in the first week of September 2015. To ensure similar rootstock-scion stem diameter at grafting, the seedlings of tomato scion cultivars were raised 3 weeks earlier than sowing of potato rootstocks. The experiment was laid in a Randomized Block Design with plot size of 3×1m and plants were spaced at 70×30cm, thus accommodating eighteen plants per plot. Plants were grafted in the polyhouse itself employing two grafting methods Tongue grafting (G1) and Cleft grafting (G2) approximately 10cm (4 inches) above the soil level. Different graft combinations were made (Table 1).

The potato rootstock and tomato scion were joined together ensuring contact of their cambium layers. The graft union was clipped securely using plastic/silicon clips or with a self adhesive clear tape. Non-grafted plots of tomato (cv. Avtar-7711) and potato (cv. Kufri Giriraj) served as controls. Proper conditions for healing of grafted plants were maintained by providing shade with 50% agro UV stabilized shade net. To maintain optimum humidity inside polyhouse, the fogging system was put on at frequent intervals during the day time to avoid water loss form grafted plants and to hasten the healing process. All necessary cultural operations recommended for protected cultivation were carried out to raise a healthy crop. Potatoes were harvested when matured, carefully causing least damage to the root system and tomatoes were allowed to grow further. Plants were watered immediately after digging of potato tubers covering the exposed roots with soil properly. During the experimentation, the maximum and minimum temperatures ranged from 16.62 to 30.55°C and 3.73 to 17.04°C, respectively and maximum relative humidity varied between 53 to 86%.

Table 1. Graft combinations

Treatments	(Rootstock + Grafting + Scion)		
V1G1S1	Kufri Himsona	+ Tongue grafting	+ Avtar (7711)
V1G1S2	Kufri Himsona	+ Tongue grafting	+ GS-600
V1G2S1	Kufri Himsona	+ Cleft grafting	+ Avtar (7711)
V1G2S2	Kufri Himsona	+ Cleft grafting	+ GS-600
V2G1S1	Kufri Himalini	+ Tongue grafting	+ Avtar (7711)
V2G1S2	Kufri Himalini	+ Tongue grafting	+ GS-600
V2G2S1	Kufri Himalini	+ Cleft grafting	+ Avtar (7711)
V2G2S2	Kufri Himalini	+ Cleft grafting	+ GS-600
V3G1S1	Kufri Giriraj	+ Tongue grafting	+ Avtar (7711)
V3G1S2	Kufri Giriraj	+ Tongue grafting	+ GS-600
V3G2S1	Kufri Giriraj	+ Cleft grafting	+ Avtar (7711)
V3G2S2	Kufri Giriraj	+ Cleft grafting	+ GS-600
Control-I	Non-grafted potato (Kufri Giriraj)		
Control-II	Non-grafted tomato (Avtar-7711)		

Observations were recorded on various horticultural and yield related traits for potato as well as for tomato from five randomly selected plants per plot. The cost-benefit ratio was also worked.

RESULTS AND DISCUSSIONS

The different rootstocks, grafting techniques and scions used in the study had a significant effect on various horticultural and yield parameters for either of the crop species. Non-grafted plants (control) recorded higher number of tubers per plant (5.03) than other grafted treatment combinations. Similar observations were reported by Peres *et al.* (2005). They observed that tomato scions were less effective to promote tuberization as potato itself. Non-grafted plants (control) produced significantly higher tuber yield per plant (561.98 g) and tuber yield per square meter (3.37 kg) than other grafted treatment combinations which may be due to the partitioning of assimilates between potato tubers and tomato fruits, being produced on the same plant. The combinations V3G1S1 (V3=Kufri Giriraj, G1=Tongue grafting and S1=Avtar-7711) and V2G1S2 (V2=Kufri Himalini, G1=Tongue grafting and S2=GS-600) recorded significantly higher average tuber weights than non-grafted (control) plants. Less number of tubers formed in the grafted plants may have led to this increase in individual tuber weight. Peres *et al.* (2005) also reported that all tomato grafts exhibited a reduced tuber dry weight when compared to the potato scion. There was no significant effect of different rootstocks, grafting methods and scions on days to harvest of potato.

In tomato the non-grafted (control) plants produced flowers earlier and took less days to first harvest than other grafted treatment combinations (Table 3). Ibrahim *et al.* (2001) and Khah *et al.* (2006) also reported earliness in performance of non-grafted plants in absence of the shock that is imposed on grafted plants due to grafting operation. Maximum number of marketable fruits per plant, marketable fruit yield and harvest duration were recorded in treatment combination V2G1S2 (V2=Kufri Himalini, G1=Tongue grafting and S2=GS-600). Grafting scion over vigorous rootstock in compatible combination improves cytokinin content in scion and improves fruit load on the plant. The findings of Marsic and Osvald (2004), Davis *et al.* (2008) and Voutsela *et al.* (2012) confirms the above results for higher yield in grafted plants due to improved water and nutrient uptake in grafted plants. The findings of King *et al.* (2010) corroborate the above results for longer harvest duration in grafted plants. Treatment combination V1G2S2 (V1=Kufri Himsona, G2=Cleft grafting and S2=GS-600) resulted maximum average fruit weight in tomato. Similar observations in grafted plants were reported by Pogonyi *et al.* (2005), Khah *et al.* (2006), Rouphael *et al.* (2010), Turhan *et al.* (2011) and Gajc-Wolska *et al.* (2014). Maximum fruit length and fruit width were found in treatment combination V2G2S1 (V2=Kufri Himalini, G2=Cleft grafting and S1=Avtar-7711). Gisbert *et al.* (2011) observed that rootstocks affected fruit length and it may be due to changes in the concentration of growth regulators induced by the rootstock, whereas, Cardoso *et al.* (2006) observed no significant effect on fruit width in grafted plants. Except for treatments V2G2S2 and V3G2S2, all other treatments having GS-600 (S2) as scion recorded higher harvest duration than non-grafted (control) plants, the highest being 97.33 days in treatment V2G1S2 (V2=Kufri Himalini, G1=Tongue grafting and S2=GS-600). The increased vigour in grafted plants due to enhanced water and mineral uptake results in vigorous root and foliar growth which tends to support a long season crop along with improved resistance to various diseases. The findings of King *et al.* (2010) corroborate the above findings. Non-grafted plants (control) recorded significantly higher plant height than other grafted treatment combinations. These results are in conformity with the findings of Ibrahim *et al.* (2001) and Khah *et al.* (2006) who reported that plant height was not significantly affected by grafting. This could be due to the fact that grafted plants were initially subjected to stress following the grafting operation resulting in reduced metabolic

Table 2. Observations recorded for potato produced on grafted pomato plants vs. control-I (Non-grafted potato plants)

Characters/ Treatments	Number of tubers per plant	Tuber yield per plant (g)	Average tuber weight (g)	Yield per square meter (kg)	Days to harvest
V1G1S1	3.85	275.37	71.52	1.65	155.00
V1G1S2	4.14	319.97	77.29	1.92	155.33
V1G2S1	3.64	295.97	81.31	1.78	155.67
V1G2S2	4.49	393.24	87.58	2.36	155.33
V2G1S1	4.81	436.45	90.74	2.62	155.33
V2G1S2	3.73	471.80	126.49	2.83	155.00
V2G2S1	4.15	455.02	109.64	2.73	155.00
V2G2S2	3.21	334.84	104.31	2.01	155.67
V3G1S1	2.96	411.55	139.04	2.47	155.67
V3G1S2	4.03	380.67	94.46	2.28	155.00
V3G2S1	3.44	256.77	74.64	1.54	155.33
V3G2S2	3.13	344.99	110.22	2.07	155.33
Control-I	5.03	561.98	111.73	3.37	155.67
CD (p = 0.05)	0.07	0.90	1.87	0.01	NS

Table 3. Observations recorded for tomato produced on grafted pomato plants vs. Control-II (Non-grafted tomato plants)

Characters/ Treatments	Days to first flowering	Days to first harvest	Number of marketable fruits plant^{-1}	Marketable fruit yield plant^{-1} (kg)	Average fruit weight (g)	Marketable fruit yield per square meter (kg)	Fruit length (cm)	Fruit width (cm)	Harvest duration (Days)	Plant height (cm)
V1G1S1	61.67	153.00	7.69	0.43	55.92	2.58	4.49	4.73	64.33	253.84
V1G1S2	53.67	149.67	14.58	1.09	74.76	6.54	4.61	5.19	84.33	269.67
V1G2S1	64.00	161.67	4.54	0.28	61.67	1.68	5.15	5.47	48.67	253.47
V1G2S2	55.67	152.67	18.25	1.63	89.32	9.78	4.93	5.38	89.67	276.34
V2G1S1	48.00	149.33	7.39	0.45	60.89	2.70	5.12	5.06	57.33	263.27
V2G1S2	47.67	144.67	22.55	1.74	77.16	10.44	5.03	5.63	97.33	236.37
V2G2S1	55.33	163.00	5.56	0.46	82.73	2.76	5.42	5.72	59.00	270.28
V2G2S2	53.67	151.33	12.34	0.83	67.26	4.98	4.64	5.28	82.67	245.28
V3G1S1	54.33	155.00	4.19	0.31	73.99	1.86	5.10	5.00	54.33	265.72
V3G1S2	47.33	140.00	11.22	0.95	84.67	5.70	4.83	5.45	94.33	270.19
V3G2S1	64.33	163.00	5.56	0.29	52.16	1.74	4.63	4.60	39.33	222.84
V3G2S2	49.33	151.00	21.50	1.44	66.98	8.64	4.78	5.16	83.00	254.41
Control-II	33.33	116.33	18.80	1.56	82.98	9.36	5.34	5.43	80.67	312.44
CD (p =0.05)	1.35	1.76	0.36	0.07	5.21	0.41	0.10	0.10	2.72	0.09

Table 4. Cost–benefit analysis (per m^2)

A. Cost		Pomato		Tomato (sole)	Potato (sole)
i)	Input cost (Rs./m^2)	37.05		31.38	21.51
ii)	Labour cost (Rs./m^2)	38.98		32.48	24.24
Total cost (Rs./m^2)		76.03		63.86	45.75
B. Returns		Tomato	Potato	–	–
i)	Yield (kg m^{-2})	10.44	2.83	9.36	3.37
ii)	Sale rate (Rs. kg^{-1})	20.00	10.00	20.00	10.00
iii)	Gross Returns (Rs. m^{-2})	237.10		187.20	33.70
iv)	Net Returns (Rs. m^{-2})	161.07		123.34	12.05
Cost: Beneft/m^2/Rupee		1:2.12		1:1.93	1:0.26

and growth characteristics during the early phase of development. Cost–benefit analysis for potato and tomato revealed that, pomato resulted in cost–benefit ratio of 1:2.12 which was significantly higher than sole cultivation of tomato (1:1.93) and potato (1:0.26) under protected conditions (Table 4).

CONCLUSION

The study revealed that Kufri Himalini was the best rootstock for tomato scion, Tongue grafting; the best grafting method and GS-600 was the best compatible scion for potato rootstocks. As far as the best Rootstock–scion combination is

Table 5. Effects of rootstocks, grafting methods and scions on various traits in potato

Characters/Treatments	Number of tubers plant^{-1}	Tuber yield plant^{-1} (g)	Average tuber weight (g)	Yield per square meter (Kg)	Days to harvest
A. Rootstocks					
Kufri Himsona (V1)	4.03	321.14	79.43	1.93	155.33
Kufri Himalini (V2)	3.97	424.53	107.83	2.55	155.25
Kufri Giriraj (V3)	3.39	348.50	104.49	2.09	155.33
CD (p = 0.05)	0.03	0.45	0.93	0.003	NS
B. Grafting methods					
Tongue grafting (G1)	3.92	382.64	99.89	2.30	155.22
Cleft grafting (G2)	3.68	346.80	94.62	2.08	155.39
CD (p = 0.05)	0.03	0.37	0.76	0.002	NS
C. Scions					
Avtar–7711 (S1)	3.81	355.19	94.46	2.13	155.33
GS-600 (S2)	3.79	374.25	100.04	2.25	155.28
CD (p = 0.05)	NS	0.37	0.76	0.002	NS

Table 6. Effects of rootstocks, grafting methods and scions on various traits in tomato

Characters/ Treatments	Days to first flowering	Days to first harvest	Number of marketable fruits plant^{-1}	Marketable fruit yield plant^{-1} (kg)	Average fruit weight (g)	Marketable fruit yield per square metre (kg)	Fruit length (cm)	Fruit width (cm)	Harvest duration (days)	Plant height (cm)
Rootstocks										
Kufri Himsona (V1)	58.75	154.25	11.26	0.86	70.52	5.15	4.79	5.19	71.75	263.33
Kufri Himalini (V2)	51.17	152.08	11.96	0.87	71.90	5.22	5.05	5.42	74.08	253.80
Kufri Giriraj (V3)	53.83	152.25	10.62	0.75	69.18	4.47	4.83	5.05	67.75	253.29
CD (p = 0.05)	0.68	0.88	0.18	0.03	NS	0.21	0.05	0.05	1.36	0.05
Grafting methods										
Tongue grafting (G1)	52.11	148.61	11.27	0.83	71.13	4.97	4.86	5.18	75.33	259.84
Cleft grafting (G2)	57.06	157.11	11.29	0.82	69.94	4.93	4.92	5.27	67.06	253.77
CD (p = 0.05)	0.55	0.72	NS	NS	NS	NS	0.04	0.04	1.11	0.04
Scions										
Avtar–7711 (S1)	57.94	157.50	5.82	0.37	64.39	2.21	4.98	5.10	53.83	254.90
GS-600 (S2)	51.22	148.22	16.74	1.28	76.68	7.68	4.80	5.35	88.56	258.71
CD (p = 0.05)	0.55	0.72	0.15	0.03	2.13	0.17	0.04	0.04	1.11	0.04

concerned, Kufri Himalini and GS-600 was found to be the best recombinant on the basis of yield and component traits. From the study, it is further concluded that tomato and potato plants when grafted in compatible combinations increases crop production per unit area and that too from a per unit plant resulting in higher returns to the grower in addition to efficient utilization of land and other resources available, especially in the urban and peri-urban areas where farming land is the most limiting one. Further research works more focused on physiological aspects of this plant in addition to different yield and quality parameters will be surely helpful in the refinement of this technology.

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Population Diversity and Cyclicityof Fruit Fly (*Bactrocera* spp.) in Sapota Orchard under South Gujarat Condition

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Abstract: An investigation on population diversity and cyclicity of fruit fly, *Bactrocera spp.* was carried out in sapota orchards by using modified "Nauroji Stonehouse" fruit fly trap throughout the year from 2013 to 2015. *Bactocera dorsalis* was the dominating species with more than 95% population over *B. correcta* and *B. zonata*. The fruit fly activity observed low at early period of fruit maturity in December to February (14.33–66.00 males/trap). However, population reached at its peak during April (306.67–520.67 males/trap) and May (535.67–1099.33 males/trap) with the late fruiting phase, which coincided with the mango fruiting stage under South Gujarat agro-ecological situation. The correlation study revealed that the temperature and evaporation had positive role in the increasing population build up of fruit fly with declining morning relative humidity during summer period with significant regression effect of minimum temperature, evening relative humidity, bright sunshine hours and evaporation. The mass trapping campaign can be initiated February onwards to bring down the male adult fruit fly population below decisive level and to escape advance fruit damage during fruiting phase.

Keywords: Fruit fly, *Bactrocera spp.*, Population diversity, Cyclicity, Sapota

In South Gujarat agro-ecological region, sapota or Chiku *[Manilkara achras* (Mill.) Forsberg] is an important fruit crop, which showed a phenomenal growth and attained the status of major fruit crop after mango and banana. Navsari, Valsad and Surat are major sapota growing districts and generally established in mixed orchard diversity with mango. Fruit quality is of prime importance in subsistence and commercial horticulture, which concern with crop cultivation practices as well as infestation of insect pest. With reverence to this, fruit fly, *Bactrocera* spp. (Diptera: Tephritidae) is a vital insect pest in sapota from consumption and export point of fruit quality. Fruit fly is polyphagous pest with wide range of tropical, subtropical fruits and vegetables as well as has high reproductive potential, adaptability to climate and overlapping of generations, management in orchard is difficult through chemical means. The more host diversity in cropping pattern, fruit fly shift from one to another under complimentary ecological factors. Similarly, different fruit fly species exist in same host and causes enormous losses in horticultural crops. Therefore, management of fruit fly is very vital at right time in orchard to avoid subsequent loss. Different types of traps used in integrated pest management and among them, plywood lure traps are highly successful and feasible in mass trapping of fruit flies. Earlier, the major population of *B. dorsalis* over *B. zonata* and *B. correcta* was reported from the same locality in sapota and mango orchard (Anonymous, 2006) and there are no further reports about species diversity study during last one decade. With this, an investigation trial was formulated to supervise the current profusion of fruit fly population diversity and to assess the impact of weather parameters with host availability in sapota orchards for adoption of proper timing of mass trapping.

MATERIAL AND METHODS

The experiment was investigated at sapota (cv. Kalipatti) orchard of Fruit Research Station, Navsari Agricultural University, Gandevi during three consecutive year of 2013, 2014 and 2015 to explore the population cyclicity of fruit fly (*Bactrocera* spp.). For monitoring purpose, one ha orchard area was selected and kept free from insecticidal application. Ten methyl eugenol based modified 'Naurogji Stonehouse traps' (plywood block) developed under Navsari Agricultural University were installed @ 10 traps ha^{-1} round the year at 4–5 feet height from ground level on sapota tree and plywood blocks were changed regularly at two months interval. The observation based on adult male fruit fly catches (Y) was done at each standard meteorological week and coefficient correlation in relation to previous and current weather parameters *viz.*, maximum (X_1) and minimum (X_2) temperature, morning (X_3) and evening (X_4) relative humidity, bright sunshine hrs (X_5), rainfall (X_6) and evaporation (X_7) was analyzed. The trapped male adult population was further examined with regression equation to measure the per cent variability in fruit fly incidence elucidated by each weather variables for previous as well as current weekly weather data. Fruit fly male adult samples were collected and sent to

Division of Entomology and Nematology, ICAR-Indian Institute of Horticultural Research, Bengaluru (Karnataka) for confirmation of the insect species.

RESULTS AND DISCUSSION

On development of fruits, fruit flies deposit their eggs on the physiologically ripen fruits, maggots feed on fruit pulp, which results in softened and discoloration of fruit tissue. The affected fruit drops early prematurely, get distorted and market value affected, which are also not suitable for consumption. The noticed fruit fly species in sapota were *Bactrocera dorsalis, B. correcta* and *B. zonata*. Among all these species, *B. dorsalis* was the most dominating with more than 95 per cent of population in sapota orchard. Similar species diversity was also identified in specimens collected from mango orchards. Previously, the similar fruit fly diversity was reported at Gandevi location, wherein *B. dorsalis* was a major species as compare to *B. zonata* and *B. correcta* in sapota and mango orchard of South Gujarat condition (Anonymous, 2006). Currently, the species diversity with more than 90% dominance of *B. dorsalis* over *B. correcta* and *B. zonata* was reported in mango in same ecological region (Anonymous, 2015 & 2016).

The result based on monitoring of adult male fruit fly population at weekly interval in sapota at different crop stage are presented in Table 1. The data on population occurrence indicated that fruit fly was trapped throughout the year in sapota orchard with varying intensity at different crop stages. During 2013, fruit fly adult population exhibiting peak activity during April (442 to 620 males trap^{-1}) and May (830 to 1275 males trap^{-1}), while it was lowest (9 to 66 males trap^{-1}) during January at peak fruiting stage. From June to September, the population trend remains between 150 to 300 males trap^{-1} at overlapping fruit development of sapota, which decline from second fortnight of October and remain below 100 males trap^{-1} till December.

The analogous population catches trend was reported in succeeding years of 2014 and 2015, wherein the crest phase of population was noticed during April and May in a increasing trend and declined later on after July and it was lowest during January. The fruit fly activity during 2015 season was slightly less as compare to earlier seasons. The overall data on the monitoring study of fruit fly adult population indicated that male catches were traced throughout the year in sapota orchard due to round the year fruit availability to pest (Fig. 1). However, population reached at its peak after second fortnight of April (520.67 to 688.33 males trap^{-1}) and May (535.67 to 1099.33 males trap^{-1}) during summer season. From June onwards, the fruit fly population catches were showed turn down tendency and reported between 100 to 250 males/trap till September during monsoon period of fruit development and lower down below 100 males trap^{-1} after October onwards. While the lowest fruit fly activity was noted during peak fruiting phase of January (14.33 to 50.67 males trap^{-1}) to February (42.00 to 66.00 males trap^{-1}) during winter.

The parallel type of population fluctuation of fruit fly catches during April to August was also noticed in earlier reports in same ecological situation (Bansode, 2009; Anonymous, 1998, 2000 & 2010). Besides, the finding is in agreement with the reports of Kumar *et al.* (1997) who reported from South Gujarat that major activity of fruit fly coincided with fruiting season. Recently, Nandre and Shukla (2014) also recorded the highest population of fruit fly during March to August and lower during December to January in sapota as well as Kalipatti variety categories as highly susceptible to *B. dorsalis* under at same location (Nandre and Shukla, 2013). In contrast to this may be due to regional variability and cropping pattern, Ravulapenta *et al.* (2014) reported *B. dorsalis* and *B. zonata* diversity of fruit fly under hill zone of Karnataka and activity was observed during October to January with maximum infestation in December in sapota orchard.

In concern to fruit fly abundance in mango, the adult occurrence was higher during May to July at fruiting stage in Paria having parallel ecosystem. The species diversity was also same with dominance of *B. dorsalis* over *B. correcta* and *B. zonata* (Anonymous, 2015 and 2016). Besides, the peak seasonal activity of the fruit fly was noticed during July in mango orchard under South Gujarat condition of Bharuch (Patel *et al.*, 2014). This indicated that the fruit fly population remains throughout the year in sapota which augmented gradually due to peak fruiting phase of mango. The span between April to June is a peak flowering and late fruiting stage of sapota during summer period, which overlap with fruit ripening phase of mango adjutant to sapota orchard periphery. This may be the reason that fruit fly showed crest activity span in sapota orchard and sapota-mango mixed orchard during May to June under South Gujarat agro-ecological situation. Besides this might be the fruit shape of sapota, which is rounded during summer period provide more volume to fruit fly as compare to elliptical-round shape observed in winter season.

The correlation coefficient data recorded during 2013 and 2014 (Table 2) indicated that the fruit fly population had positive significant relation with preceding and current maximum-minimum temperature along with evaporation, while negative correlation with morning relative humidity. In regard to the correlation coefficient data of 2015, the fruit fly population had positive significant relation with preceding

Table 1. Weekly population cyclicityof fruit fly (*Bactrocera* spp.) during 2013–15

Months	Standard week	Crop stage	Mean fruit fly adult population/trap			
			2013	2014	2015	Avg.
January	01	Peak fruiting	10	20	20	16.67
	02		9	16	18	14.33
	03		26	33	17	25.33
	04		56	46	33	45.00
	05		41	72	39	50.67
	Avg.		28.40	37.40	25.40	30.40
February	06	Peak fruiting	36	48	42	42.00
	07		42	55	47	48.00
	08		41	61	42	48.00
	09		68	91	39	66.00
	Avg.		46.75	63.75	42.50	51.00
March	10	Flowering initiation and fruiting	98	87	95	93.33
	11		136	102	88	108.67
	12		195	162	134	163.67
	13		280	217	152	216.33
	Avg.		177.25	142	117.25	145.5
April	14	Peak flowering and fruiting	442	296	182	306.67
	15		568	479	265	437.33
	16		516	619	427	520.67
	17		620	708	737	688.33
	Avg.		536.50	525.50	402.75	488.25
May	18	Peak flowering and late fruiting	830	861	1048	913.00
	19		1183	1074	1041	1099.33
	20		1275	1222	712	1069.67
	21		921	1138	321	793.33
	22		555	803	249	535.67
	Avg.		952.80	1019.60	674.20	882.20
June	23	Late flowering	305	558	106	323.00
	24		168	296	141	201.67
	25		182	212	173	189.00
	26		285	318	142	248.33
	Avg.		235.00	346.00	140.50	240.50
July	27	Fruit development and late flowering	212	232	161	201.67
	28		157	285	121	187.67
	29		194	260	108	187.33
	30		227	209	130	188.67
	Avg.		197.50	246.50	130.00	191.33
August	31	Fruit development	271	168	276	238.33
	32		306	188	222	238.67
	33		281	169	255	235.00
	34		247	178	156	193.67
	35		302	163	130	198.33
	Avg.		281.40	173.20	207.80	220.80

Cont...

September	36	Fruit development	235	143	101	159.67
	37		252	126	84	154.00
	38		207	137	79	141.00
	39		175	113	46	111.33
	Avg.		217.25	129.75	77.50	141.50
October	40	New foliage flush and fruiting initiation	148	102	29	93.00
	41		121	87	27	78.33
	42		92	65	39	65.33
	43		66	52	43	53.67
	Avg.		106.75	76.50	34.50	72.58
November	44	New foliage flush and fruiting initiation	73	44	42	53.00
	45		84	52	51	62.33
	46		56	56	97	69.67
	47		66	39	60	55.00
	Avg.		69.75	47.75	62.50	60.00
December	48	Peak fruiting and new foliage	44	30	52	42.00
	49		32	21	37	30.00
	50		38	19	30	29.00
	51		26	26	57	36.33
	52		22	22	89	44.33
	Avg.		32.40	23.60	53.00	36.33

Table 2. Correlation of fruit fly (*Bactrocera* spp.) with weather factors during 2013–15

Year	Weather parameters						
	Temperature (^{0}C)		Relative Humidity (%)		Bright sunshine hrs.	Rainfall (mm)	Evaporation (mm/day)
	Max.	Min.	Mor.	Eve.			
2013	0.424** (0.438)**	0.449** (0.535)**	-0.434** (-0.408)**	0.106 (0.160)	0.167 (0.064)	-0.078 (-0.060)	0.592** (0.622)**
2014	0.487** (0.463)**	0.421** (0.499)**	-0.365** (-0.414)**	0.049 (0.110)	0.088 (-0.025)	-0.078 (-0.059)	0.654** (0.684)**
2015	0.064 (0.106)	0.361** (0.424)**	-0.165 (-0.144)	0.073 (0.097)	0.108 (0.101)	-0.005 (-0.068)	0.491** (0.550)**
Avg.	0.388** (0.392)**	0.441** (0.519)**	-0.383** (-0.352)*	0.083 (0.138)	0.151 (0.056)	-0.065 (-0.056)	0.679** (0.709)**

* Significant at 5% level and ** at 1% level.
# Value in parentheses are current weekly data and values in outside are preceding weekly data.

and current minimum temperature and evaporation only. The preceding and current maximum temperature and morning relative humidity had no role in increasing fruit fly population during 2015 as observed in earlier seasons of 2013 and 2014 may be due to variability in weather situation of 2015 along with low population occurrence. The correlation study revealed that the increasing maximum-minimum temperature and evaporation rate increases the population of adult fruit fly with low morning relative humidity in sapota, which is coincide with the fruiting phase of crop phenology during summer season.

The regression coefficient corresponding to same weather parameters were found significant to fruit fly population (Table 3). During 2013 season, regression coefficient of evening relative humidity, bright sunshine hrs and evaporation both in preceding and current weather situation was found significant with the variability of 72 and 76%, respectively. While in regression equation of 2014, minimum and maximum temperature along with evening relative humidity, bright sunshine hrs and evaporation were showed significant relation against fruit fly catches data and could explain the expression to the extent of 52 and 61 per cent in former and current weather condition, respectively. Exception to above parameters, current maximum temperature and evening relative humidity regression coefficient was non-significant during 2014. The ecological

Table 3. Regression equations of fruit fly (*Bactrocera* spp.) in sapota during 2013–15

Year	Regression equation		R^2
2013	Preceding	$Y = -384.718 - 2.790X_1 - 2.212X_2 - 10.021X_3 + 15.687X_4 + 60.430X_5 + 0.538X_6 + 105.936X_7 + 162.461$	0.72
	Current	$Y = -775.565 + 1.247X_1 - 2.502X_2 - 3.999X_3 + 12.754X_4 + 19.542X_5 + 0.163X_6 + 140.918X_7 + 150.599$	0.76
2014	Preceding	$Y = -327.987 + 8.488X_1 + 5.787X_2 - 6.778X_3 + 3.693X_4 + 18.316X_5 + 0.854X_6 + 94.804X_7 + 224.611$	0.52
	Current	$Y = 396.143 - 15.806X_1 + 21.544X_2 - 6.132X_3 - 2.229X_4 + 10.922X_5 + 0.927X_6 + 109.672X_7 + 203.494$	0.61
2015	Preceding	$Y = -351.714 - 12.657X_1 + 20.348X_2 - 0.078X_3 + 1.340X_4 + 42.036X_5 + 0.661X_6 + 41.717X_7 + 195.304$	0.38
	Current	$Y = -432.845 - 11.087X_1 + 21.894X_2 - 1.074X_3 + 2.756X_4 + 42.602X_5 + 0.194X_6 + 45.917X_7 + 180.935$	0.47
Avg.	Preceding	$Y = 80.242 - 40.418X_1 + 16.499X_2 - 6.320X_3 + 11.776X_4 + 95.840X_5 + 0.794X_6 + 108.103X_7 + 150.002$	0.72
	Current	$Y = 311.639 - 38.184X_1 + 20.858X_2 - 6.556X_3 + 8.099X_4 + 61.622X_5 + 0.357X_6 + 116.003X_7 + 140.893$	0.75

situation during 2015 differed slightly and regression equation of minimum temperature, bright sunshine hrs and evaporation in respect to preceding and current weather condition was found significant with lower variability only up to 38 and 47 per cent, respectively as compared to previous two years circumstances. Besides, there was significant effect of only current evening relative humidity on fruit fly catches.

On an average, ecological situation indicated that the preceding and current minimum temperature, evening relative humidity, bright sunshine hrs and evaporation, regression coefficient was observed significant in relation to fruit fly catches in sapota orchard. The R^2 value in fruit fly population catches in average weather condition explained the variability up to 72 and 75 per cent in previous and current weather situation, respectively. There was variation in significance level of coefficient of correlation and regression with respect to maximum temperature and morning relative humidity and this may be due to high temperature and humidity fluctuations during summer period in coastal area.

In earlier reports of sapota, maximum and minimum temperature as well as relative humidity played a major and significant role in deciding fruit fly population with 64.3 per cent variability based on three years data (Anonymous, 1998).While in mango orchard of Paria, regression equation of minimum temperature and evening relative humidity had significant effect with 58 per cent variability during 2015–16 (Anonymous, 2016) and only significant relationship in minimum temperature with 74% variability during 2014–15 (Anonymous, 2015). These findings confirm the fact of present research.

The current investigation showed that the current weather situation had more influence on population activity under trapping method as compared preceding condition. In regards to coefficient of correlation and regression results, the minimum temperature, evening relative humidity and evaporation persuades the fruit fly activity in sapota orchard,

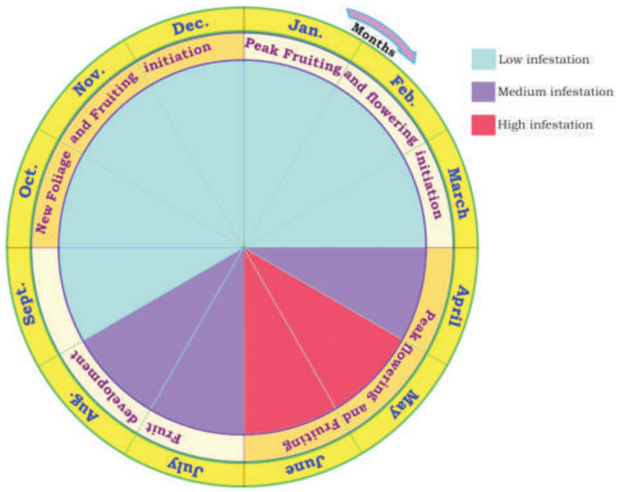

Fig. 1. Pest calendar of fruit fly (*Bactrocera* spp.) population

which mainly coincide with the fruiting stage of mango. The egg laying in early phase of mango succeeds with increased activity at ripening period of summer season may had positive discrimination with humidity under mixed sapota–mango orchard situation of South Gujarat condition. Such type of temperature dependent phenological synchrony was observed between host fruit availability and fruit fly trap catch in oriental fruit fly, *B. dorsalis* at Bengaluru (Jayanthi *et al.*, 2014).

Under present investigation trial, *B. dorsalis* was observed as lead species in sapota located in periphery of mango orchard in South Gujarat condition. The population monitoring data indicated that fruit fly adult males were active throughout the year due to its round the year overlapping bearing pattern of sapota. The population reached highest during April and May with the late fruiting stage of sapota during summer period, which was influenced gradually due to the succeeding mango fruiting stage under South Gujarat agro-ecological situation. Among weather parameters, temperature along with evaporation and humidity play an important role in fluctuating fruit fly population trend during different growth period of sapota. These ecological factors have relationship with the fruiting phase of host-plant phenology of sapota as well as mango in nearby periphery, which also showed interaction with pest occurrence indicates the clue for predictability of fruit fly management at appropriate timing. Therefore, mass trapping campaign can be initiated from February onwards to bring down the male adult fruit fly population below decisive level and to escape succeeding fruit damage during fruiting phase.

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Estimation of Optimal Pesticide Application Time on Guava (*Psidium guajava*) Based on Temporal Foraging Activity of Pollinators

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Abstract: The present study on the foraging initiation, foraging cessation and foraging duration day^{-1} of the pollinators was accomplished to determine the arduous pollinators of guava and to create conscience about the wise use of pesticides during the specified time of blooming orchards. The foraging initiation and cessation of pollinators was recorded on sunny days with normal weather conditions in order to determine the arduous pollinators' species on the basis of foraging duration day^{-1} of guava. The longest foraging duration/ day and latest foraging cessation of *Haematobia irritans* Linnaeus was observed while *Apis cerana* Fab. initiated earliest foraging. Among pollinators of guava, *Apis spp., H. irritans* and *Lucilia sericata* Meigen were the most arduous pollinators under Medziphema conditions. On the basis of foraging activities of different species and their conservation strategy, it is imperative that pest control by chemical may be admissible only at "Environmental Economic Injury Level" (EEIL) to avoid pollinators' exposure to toxic pesticides.

Keywords: Insect pollinators, Foraging initiation, Foraging cessation, Foraging duration, Pollinators conservation

Guava is a popular fruit crop as it has a high nutritional value with rich source of citric acid, minerals and vitamins C and makes a significant contribution in food and nutritional security. It bears hermaphrodite flower and the stigma is protruded above the anthers and thus, even self-pollination is unusual without help of pollinators (Pommer and Murakami, 2009). Among pollinators, honey bees act to perform a major proportion with 92.86 and the rest 7.14% of other dipterans and coleopterans (Rajagopal and Eswarappa, 2005). Plant–pollinator interactions are one of the most important examples of variable mutualism in nature having major implications for plant and ecosystem service. The economic value of pollination worldwide amounted to €153 billion, which represented 9.5 per cent of the value of the world's agricultural production used for human food (Gallai *et al.*, 2009). In 2013−14, India had grown guava on 268200 ha, produced 3667900 mt and the productivity was 13.7 mt ha^{-1} (Indian Horticulture Database, 2014). The application of pesticides at blooming stage restrains the productivity in comparison to crop protection by dint of pollination deficit. In regard to pollinators, the application of pesticides affects the learning performance, behavior, neurophysiology and ultimately its survival (Desneux *et al*., 2007). Agrochemicals are considered to be potential drivers of declining wild and domesticated pollinators (Potts *et al*., 2010). The decline of pollinators can result in loss of pollination services, which have important negative ecological and economic impacts that could significantly affect the maintenance of wild plant diversity, wider ecosystem stability, crop production, food security and human welfare (Biesmeijer *et al.*, 2006). Crop protection is an essential component of sustainable agriculture and among all the methods of crop protection, chemical control is a practicable management and most preferred by farmers/orchardists through application of foliar pesticide spray during blooming period which is harmful to pollinators. The technical union between pollinators' conservation and crop protection practices is adventurous and at the same time, attainable. It is a fact that insect pollinators are at a greater particular risk from pesticide use (Brittain, 2010). The time adjustment of pesticide application may prove to be more lucrative for crop protection as well as conservation of pollinators.

The foraging activity of pollinators varied significantly among pollinators' species and in honeybee, it depends on temperature, solar radiation, and wind speed (Vicens and Bosch, 2000). The ecological threshold for commencement and cessation of flight activity of each honeybee species varied from one another in view of temperature, light intensity and solar radiation where the three also serves as the most important factors affecting foraging behavior (Abrol, 2006). The foraging population correlated significantly and positively with air temperature, light intensity, solar radiation and nectar-sugar concentration but negatively with relative humidity (Abrol, 2010). This affirms that the role of weather conditions has a great impact on the foraging activity of various insect pollinators (Chambo *et al.*, 2017). The application of pesticides during foraging of pollinators is hazardous for them. However, proper knowledge on foraging cessation of pollinators helps to create conscience and wise use of pesticides at specified time of blooming stage which was missing in all earlier studies. Hence, the present investigation was envisaged to unequivocally substantiate and determine the dominant and arduous pollinators of guava on the basis of foraging activities and above all, to advocate the specified time of pesticide application during blooming period to conserve the pollinators.

MATERIAL AND METHODS

The experiment was conducted at Central Institute of Horticulture, Medziphema, Nagaland, located at the foot hills of Pauna mountains in the Himalayan range at an altitude of 314 m above mean sea level, situated at 25º75' N latitude and 93º86' E longitude. The area has sub-tropical climate with warm summers and cold winters; the mean minimum and maximum temperatures range from 9 to 21˚C and 21to 31˚C, respectively. The observations of foraging activities of all the pollinators were recorded on sunny days with normal weather conditions for two years, from 22nd to 25th standard week during 2015 to 2016.

The data for foraging activities of insect pollinators of guava were observed from initiation of blooms to cessation during the experimental years. The commencement and cessation of foraging by all forager species was recorded once in a week from each and every side across the plants located in all the directions of the Guava farm. The first appearance of a particular pollinator's species on the blooms of guava was recorded as the commencement of foraging activity whereas the last visit before complete disappearance from the blooms indicated the cessation of the activity. All the key foragers were described to species level in the field wherever possible and when identity of the species could not be determined at the time of observation, they were denoted according to their stature and body colour. The identification of the unidentified insect pollinators was carried out at Insect Identification Service, Division of Entomology, IARI, New Delhi. The experiment was allocated six treatments (key pollinators) and replicated thrice.

RESULTS AND DISCUSSION

The guava insect visitors belong to hymenoptera, diptera and coleoptera order and all these groups were observed to forage only for pollen and not to collect nectar. The coleopterans ate pollen, carried wee number of pollen and were the rarest to touch the stigma. Therefore, coleopterans were excluded from pollinator groups. The foraging initiation of pollinators is a significant consequent observed in the morning hours of the day and explicated in (Table 1). The foraging initiation of all the pollinator species varied during the entire blooming period of guava. The earliest foraging initiation was recorded with *A. cerana (04:50 h)* followed by *A. dorsata, H. irritans, L. sericata* and *A. florea* whereas the latest foraging initiation was with *X. tenuiscapa* (06:27 h) as recorded in 2014 and a similar trend was recorded during 2015.

The foraging cessation of all pollinators' species varied during the blooming period of guava. The pollinator species, which ceases its foraging activity very late was *H. irritans* (15:23 h) followed by *L. sericata, A. cerana* and *A. dorsata* and *A. florea* while *X. tenuiscapa ceased its foraging activity very early in the day at 10:49 h* in 2014 and an almost similar trend was recorded during 2015. The visit frequency of *Apis* spp. also decreased after 1100 h of the day.

The foraging duration of insect pollinators in a day is a momentous consequent explicated in Table 3. The foraging duration of all the species varied during the blooming period of guava. The maximum foraging duration was recorded of *H. irritans* (10.43 hrs) followed by *L. sericata, A. cerana* and *A.*

Table 1. Time of foraging initiation of insect pollinators (h)

Standard week	*Apis cerana*	*Apis dorsata*	*Apis florea*	*Xylocopa tenuiscapa*	*Lucilia sericata*	*Haematobia irritans*
Year 2014						
22nd	04:45	04:49	05:26	06:33	05:27	04:40
23rd	04:53	04:52	04:59	06:48	04:54	04:54
24th	04:46	05:08	05:15	06:05	04:52	04:50
25th	04:59	04:54	05:22	06:25	04:56	05:27
Mean	04:50	04:55	05:15	06:27	05:02	04:57
Year 2015						
22nd	05:09	05:14	05:21	07:15	05:19	05:01
23rd	04:57	05:08	05:19	07:07	05:26	04:55
24th	04:49	04:52	05:31	07:05	05:05	05:09
25th	04:55	04:59	05:13	06:55	05:08	05:17
Mean	04:57	05:03	05:21	07:05	05:14	05:05

Table 2. Time of foraging cessation of insect pollinators (h)

Standard week	*Apis cerana*	*Apis dorsata*	*Apis florea*	*Xylocopa tenuiscapa*	*Lucilia sericata*	*Haematobia irritans*
Year 2014						
22nd	11:32	11:28	11:19	11:32	14:25	15:24
23rd	11:23	11:23	10:55	10:53	14:48	15:36
24th	11:29	11:16	11:02	09:55	14:53	15:29
25th	11:30	11:32	10:32	10:56	14:23	15:06
Mean	11:28	11:24	10:57	10:49	14:37	15:23
Year 2015						
22nd	11:13	11:31	11:25	10:42	14:49	15:49
23rd	11:27	11:21	11:08	10:21	14:14	15:36
24th	11:32	11:04	10:41	10:52	14:35	14:51
25th	11:19	11:06	10:25	11:27	13:53	15:18
Mean	11:22	11:15	10:54	10:50	14:22	15:23

Table 3. Foraging duration of insect pollinators (h)

Standard week	*Apis cerana*	*Apis dorsata*	*Apis florea*	*Xylocopa tenuiscapa*	*Lucilia sericata*	*Haematobia irritans*
Year 2014						
22nd	6.78	6.65	5.88	4.98	8.97	10.73
23rd	6.50	6.52	5.93	4.08	9.90	10.70
24th	6.72	5.13	5.78	3.83	10.02	10.65
25th	6.52	6.63	4.17	4.52	9.45	9.65
Mean	6.62	6.23	5.43	4.35	9.58	10.43
Year 2015						
22nd	6.07	6.28	6.07	3.38	9.50	10.80
23rd	6.50	6.22	5.82	3.23	8.80	10.68
24th	6.72	6.20	5.17	3.75	9.50	9.70
25th	6.40	6.12	5.20	4.53	8.75	10.02
Mean	6.42	6.20	5.55	3.72	9.13	10.30

dorsata and *A. florea* while the minimum foraging duration was of *X. tenuiscapa* (4.35 hrs) in 2014 and a similar trend was recorded during 2015. The foraging initiation, which began with *H. irritans* was followed by *A. cerana* and *A. dorsata whereas the latest foraging* cessation was observed with *H. irritans*.

The foraging initiation of insect pollinators is driven by weather conditions, abundance of flowers and diverse foraging source. The present studies were in conformity with the results of other research workers. Temperature and luminosity regulate the foraging activities of bees (Polatto *et al*., 2014). In most of the flies and both their sexes, become active at 20˚C (Yee, 2002). The highest flower density (peak flowering) might prevail at 23rd and 24th standard weeks. Most of the bees strongly prefer large number of flowering plant species (Putra and Nakamura, 2009). *Apis* spp. ceased their foraging after 1100 h and this may be attributed to the fact that biting away of floral parts caused flowers to become defaced and brownish. As such, the floral reward which is pollen becomes insignificant in quantity and moreover, their advertisement as beautiful natural attraction becomes unappealing after 1100 h. The exploited floral reward and unappealing advertisement cannot attract the pollinators; especially the bees and therefore, they usually did not visit guava flowers.

CONCLUSION

Among guava pollinators, *H. irritans* has the longest foraging duration day^{-1} and latest foraging cessation while the foraging commencement of *A. cerana* is the earliest foraging initiation in this niche. Conversely, the *X. tenuiscapa* lagged behind in foraging duration, foraging initiation and early cessation of foraging in this niche. Among the guava pollinators, *Apis* spp., *H. irritans* and *L. sericata* are arduous pollinators. On the basis of foraging cessation of pollinators, application of pesticides for pest management should be admissible only after total cessation of foraging by pollinators which would in turn help in augmentation and conservation of these pollinators and maximize the pollination and enhance the crop productivity.

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Studies on the Multiplication of Apple Clonal Rootstocks through Cuttings

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Abstract: The present investigation with ten treatments comprising of IBA application (three concentrations) and its combination with a basal wounding of cuttings (two procedures) were given to three rootstocks viz., i) MM111, ii) MM106 and iii) Merton 793. IBA was used at 1000, 2000 and 3000 ppm and wounding treatments included i) basal split and ii) vertical incision. In all there were nine combinations of IBA and wounding treatments and compared with control. The highest percentage of rooted cuttings (74.07 %), length of main roots (12.42cm), diameter of main roots (3.81 mm), length of main shoot (133.20 cm), diameter of main shoot (173.3mm, total number of leaves (127.10), total phenol content (23.68 mg g^{-1}) and carbohydrate-nitrogen ratio (59.61) were recorded in the cuttings treated with IBA 2000 ppm + split. Among different rootstocks, maximum rooting was recorded in MM 111 rootstock as compared to MM106 and Merton793 rootstocks. Among the IBA and wounding treatments, IBA 2000 ppm in combination with basal split was found to be superior to other treatments in terms of rooting of cuttings, growth and other physiological parameters.

Keywords: Apple, IBA, Cutting, Rooting, Wounding

Apple plants are traditionally propagated through grafting and budding on seedling rootstocks in the nursery. The seedling rootstocks are not true to type due to cross pollination and thus shows variability in growth and productivity of scion variety. To avoid this problem, the plantation of apple are required to be on clonal rootstocks. Though, clonal rootstocks are employed mainly all over the world but in India, seedlings still continues to be the most widely and commonly used rootstock. Although, the clonal rootstocks can produce uniform plantation with precocity in bearing, yet could not pick up due to lack of irrigation facilities and good soil conditions. However, there is adequate scope for its use in apple orchards with the inception of the concept of high density planting especially in low lying areas having flat land and deep soils.

Apple clonal rootstocks are generally propagated through layering, cuttings and micro-propagation. Clonal propagation of rootstocks through cuttings is of special importance as it is an additional tool to increase the production of rootstocks in addition to layering. But most of the clonal rootstocks are difficult-to-root, so this method could not be used commercially so far. At the time of grafting shoot portion of rootstock, which is more than 80% (30-60cm) of its length goes waste above the grafting point. This part of rootstock can also be used for cuttings and converted into rooted plantlets to increase multiplication rate of clonal rootstocks manifold and help in its commercialization in the state.

Among the clonal rootstocks Merton 793, MM 111 and MM 106 are more suitable for agro-climatic conditions of North West Himalayas. Merton 793 has been proved to be an excellent rootstock because it is adapted to a wider range of soil, precocious, produces a vigorous tree, resistant to woolly apple aphid and collar rot. It has been also used successfully on replant situations. On the other hand, MM 111 is a good rootstock for poor soils and dry areas where extra vigour is required for better cropping. It is an excellent rootstock for spur bearing varieties. Similarly, MM106 produces trees with moderate vigour and heavy cropping potential.

Most of these apple clonal rootstocks are difficult-to-root and require some preconditioning treatments and use of growth regulators for better rooting. The application of auxins like IBA and NAA are essential for the rooting of cuttings of clonal rootstocks, but some preconditioning treatments can enhance the absorption of the rooting agents and increase the rooting surface area of basal end and break the tissues impediments for root initiation. The response to wounding in the presence of IBA induced the stimulation of nodular callus from the region of the inner cortex and cambium, which is exposed by wounding and help in development of roots (Howard *et al*., 1984). Keeping in view all these points, the present studies were carried out to ascertain the effect of preconditioning treatments in addition to plant growth regulators on rooting ability of apple clonal rootstocks viz. Merton793, MM111, MM106 with the objectives to study the effect of IBA and wounding on rooting of apple clonal rootstock cuttings and study the rooting behaviour of different clonal rootstock cuttings.

MATERIAL AND METHODS

The experimental orchard of department is located at 30˚51´ North latitude and 77˚88´ East longitude at an elevation of 1320 meters above mean sea level (MSL). The climate of the area is typically sub-temperate. Cuttings of Merton 793, MM111 and MM106 rootstocks were collected from the nursery area of the Department of Fruit Science, Dr YS Parmar University of Horticulture and Forestry at Nauni, Solan (HP).

The entire programme of study comprised of seven treatments viz., T_1 (IBA 1000 ppm), T_2 (IBA 2000 ppm), T_3 (IBA 3000 ppm), T_4 (IBA1000 ppm + Basal split), T_5 (IBA 2000 ppm + Basal split), T_6 (IBA 3000 ppm + Basal split), T_7 (IBA1000 ppm + Basal incision), T_8 (IBA2000 ppm + Basal incision), $T_{9.}$ (IBA3000 ppm + Basal incision) and T_{10} (Control: Without IBA and wounding). Hardwood cuttings of apple clonal rootstocks of the size 25–30 cm long and thickness of 0.5–1.0cm were collected in the month of December-January when plants were dormant. While preparing the cuttings, care was taken to give a straight cut slightly below a node on the basal end and a slanting cut slightly above a node on the apical end. The propagation beds were prepared by mixing vermicompost, cocopeat, sand and forest soil in 1:1:1:1 ratio. A stock solution of 10,000 ppm was prepared by dissolving 5 gm IBA in 50 per cent ethanol and making the final volume to 500 ml with ethanol and distilled water (v/v). From the stock solution, three different IBA solutions viz. 1000 ppm, 2000 ppm and 3000 ppm were prepared by using ethanol and distilled water (1:1) and by applying the formula $N_1V_1 = N_2V_2$. Whereas, in control cuttings were treated with ethanol + distilled water only. A quick dip for 5 seconds was given to the cuttings.

Using a knife, cuttings were wounded at the base in one of the two ways i.e., four shallow diametrically opposite incisions at the base penetrating only into the outer cortex and extending upwards up to 25 mm, and a basal split through the diameter of the cutting and extending upwards for 25 mm. The basal portion of the cutting was dipped for 5 seconds in IBA solution. The treated cuttings were then placed in shade for few seconds to ensure sufficient absorption of IBA before planting in a nursery bed. The cuttings under control were treated with ethanol + distilled water. The cuttings were planted in the propagation beds in rows. The planting distance between row to row was kept as 15 cm, whereas distance between adjacent cuttings was kept as 10 cm, the entire experiment was laid out in RBD with three replications and twenty cuttings in each replication. The cuttings were planted in the afternoon as suggested by Hartmann and Kester (1983). The data obtained from the present investigations were subjected to statistical analysis as per procedure described by Gomez and Gomez (1984).

RESULTS AND DISCUSSION

The results obtained in the present studies have revealed that IBA and wounding exerted a significant effect on percentage of rooted cuttings. The maximum (74.07%) rooting was recorded in the cuttings treated with IBA 2000 ppm + Basal Split), which was significantly higher than other treatments. The minimum (31.85%) rooting was observed under control. It is clear from the data that percentage of rooting in cuttings were also influenced significantly by different rootstocks. The maximum (71.77%) rooted cuttings were observed in MM111 rootstock, which was significantly higher than cuttings of other rootstocks. The minimum (31.11%) rooted cuttings were found in Merton 793 rootstock.

The interaction between treatment and rootstock was also found to be significant. The maximum (91.11%) rooting was recorded in MM111 cuttings when treated with IBA 2000 ppm + Basal split (T_5) presented in Table 1. These results indicated that the application of 2000 ppm IBA had a direct influence on the stimulation of root initiation. In addition, exogenous application of auxin break starch in to simple sugars, which is needed to a greater extent for the production of new cells and for the increased respiratory activity in the regenerating tissues at the time of initiation of new root primordia (Nanda, 1975). Further, the results are also in agreement with Hitchcock and Zimmerman (1942), who reported that application of a small quantity of IBA or NAA gave excellent rooting in most of fruit species. Growth regulators hasten the formation of root primordia thereby, helping in rooting of cuttings (Stoutemeyer, 1954).

Higher response of some genotypes may have attributed to high availability of endogenous natural auxins in plant tissue (Salisbury and Ross, 2005). Certain level of endogenous auxins are also present in the cuttings, therefore treating cuttings with IBA could optimize the auxin level in the cuttings and consequently improve the percentage of rooted cuttings. Melgarejo *et al.* (2008); Saroj *et al.* (2008); Polat and Caliskan (2009) had also reported that the rooting in apple rootstock can be increased by wounding and use of growth regulators such as IBA.

It is evident from the data presented in Fig. 1 that IBA alone or in combination with wounding improved the length of main roots. The maximum root length (30.72cm) was recorded in the cuttings treated with IBA 2000 ppm + Basal split (T_5), which was statistically at par with IBA 1000 ppm + Basal split (T_4). The minimum (12.42cm) root length was recorded under control. The influence of different rootstocks on the length of main roots was also found significant. The maximum length (22.49cm) was observed in MM111, which was statistically at par with

MM106, however, minimum root length (17.8cm) was observed in Merton793 rootstock cuttings. The interaction effect of treatments and rootstock on root length was also found significant. The maximum length of main roots (31.71 cm) was recorded in MM111 rootstock, when treated with IBA 2000 ppm + Basal split (T_5), which was statistically at par with T_5 (MM106), T_4 (MM106), T_5 (Merton 793), T_2 (MM111), T_6 (MM111), T_3 (MM111), T_4 (MM111) , T_7 (MM106), T_7 (Merton 793), T_2 (MM106), T_6 (MM106) and T_8 (MM106). The process of differentiation is the capability of previously developed differentiated cells to initiate cell division and to form a new meristematic growing point (Hartmann *et al*., 2007). These results are in accordance with the findings of Sun and Bassuk (1991), who reported that etiolation and IBA treatment increased number of roots in MM106 cuttings. Hartmann *et al*. (2007) reported that IBA is the best auxin for general use because it is non-toxic to plants over a wide concentration range and it is effective in promoting rooting of a large number of plant species. Application of IBA may have triggered the early anticlinal cell division and root primordial formation than NAA (Ali *et al*., 2009).

The data (Fig. 2) revealed that IBA and wounding also exerted a significant effect on diameter of main roots. The maximum root diameter (3.81 mm) was recorded under the treatment IBA 2000 ppm + Basal split (T_5), which was significantly higher than all other treatments. The minimum root diameter (0.92mm) was observed under control. It is clear from the data that there were no significant difference among rootstocks pertaining to diameter of main roots. The interaction between treatment and rootstock on diameter of main roots was also found significant. The maximum diameter of main roots (4.11mm) was recorded in MM111 rootstock, when treated with IBA 2000 ppm + Basal split (T_5), which was statistically at par with T_5 in Merton 793 and MM111, respectively. These confirmations are also in agreement with Abousalim *et al*. (1993), who also observed that maximum number of roots and diameter in cuttings treated with IBA at 4000 ppm. IBA 1000 ppm was found highly effective in increasing diameter of the largest root in stem cuttings of Santa Rosa plum (Chauhan and Reddy, 1974),

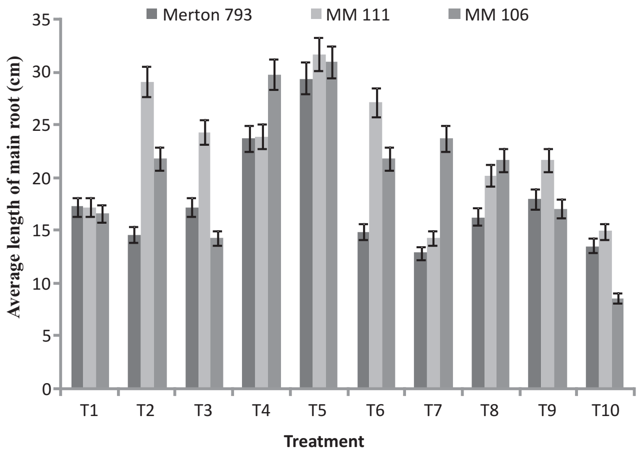

Fig. 1. Effect of IBA and wounding on average length of main roots (cm) in different clonal rootstocks of apple

Table 1. Effect of IBA and wounding on per cent rooting of cuttings in different clonal rootstocks of apple

Treatments	Rootstocks			Mean
	Merton 793	MM 111	MM 106	
T_1 : IBA 1000 ppm	22.23	66.66	55.55	48.15
T_2 : IBA 2000 ppm	28.89	75.55	66.66	57.03
T_3 : IBA 3000 ppm	24.44	68.89	60.00	51.11
T_4 : IBA1000 ppm + Basal split	33.33	80.00	64.44	59.26
T_5 : IBA 2000 ppm + Basal split	46.66	91.11	84.44	74.07
T_6 : IBA 3000 ppm + Basal split	35.55	77.77	68.89	60.74
T_7 : IBA1000 ppm + Basal incision	31.11	64.44	57.77	51.11
T_8 : IBA2000 ppm + Basal incision	40.00	86.66	71.11	65.92
T_9 : IBA3000 ppm + Basal incision	35.55	62.22	55.55	51.11
T_{10} : Control (Without IBA and wounding)	13.33	44.44	37.77	31.85
Mean	31.11	71.77	62.22	

Figures in the parentheses are arc sine transformed values

CD (p=0.05)

Treatment (T) = 1.14 (0.74)

Rootstock (R) = 0.62 (0.41)

Treatment x Rootstock (TxR) = 1.97 (1.28)

Pecan cv. Colby (Rathore, 1985) and Mahan (Sharma and Rosanglura, 1987).

The maximum (133.20cm) shoot length was recorded in the cuttings treated with IBA 2000 ppm + Basal split (T_5), which was significantly higher than all other treatments. The minimum shoot length (65.89cm) was recorded under control. Different rootstocks also exerted a significant influence on length of main shoot. The maximum length of main shoot (116.5cm) was observed in MM111 rootstock cuttings, while minimum (81.70cm) was recorded in MM106 rootstock cuttings. The interaction between treatment and rootstock on length of main shoot was also found significant. The maximum (145.30cm) length of main shoot was observed in MM111, when treated with IBA 2000 ppm + Basal split (T_5), which was significantly higher than all other treatments (Fig. 3). The interaction between treatment and rootstock on diameter of main shoot was also found significant (Fig. 4). The highest (174.3 mm) shoot diameter was recorded in MM111, when treated with IBA 2000 ppm + Basal split (T_5), which was statistically at par with T_5 (MM106), T_5 (Merton 793) and T_8 (Merton 793) (Fig. 4). The present results also get the support from the findings of Mukhtar *et al*. (2001), who observed highest rooting parameters in olive cuttings cvs. Coratina and Frantoio, when treated with IBA 4000 ppm, which might have further aided in faster development of shoot characters. The effect of auxin in vascular differentiation is well established and it is also known to stimulate both cambial activity and xylem development in many woody species and it is required for formation of the primordium initial cells (Davis and Hassing, 1990).

The IBA and wounding exerted a significant effect on number of leaves. The maximum number of leaves (127.10) was observed in the cuttings treated with IBA 2000 ppm + Basal split (T_5), which was statistically higher than all other treatments (Fig. 5). The minimum leaf number (56.11) was observed in control. It is clear from the data that different rootstocks also exerted significant influence on number of leaves. The highest (120.40) number of leaves was recorded in MM111 rootstock. The lowest (65.53) number of leaves was observed under MM106 rootstock. The interaction between treatment and rootstock on number of leaves was also found to be significant. The maximum (146.00) number of leaves was observed in MM111 rootstock, when treated with IBA 2000 ppm + Basal split (T_5), which was statistically at par with T_5 (Merton 793), T_2 (MM111), T_4 (MM111), T_3 (MM111), T_6 (MM111) and T_1 (MM111). The minimum leaf number (16.33) was recorded in MM106 rootstock under control. This may be due to the utilization of foods in the development of new leaves instead of development of root. This indirect effect of auxin on sprouting highlights the role of certain materials produced in the roots, responsible for sprouting.

The IBA and wounding alone or in combination exerted a significant effect on total phenol content (Table 2). The highest (23.68 mg g^{-1}) total phenol content was recorded in

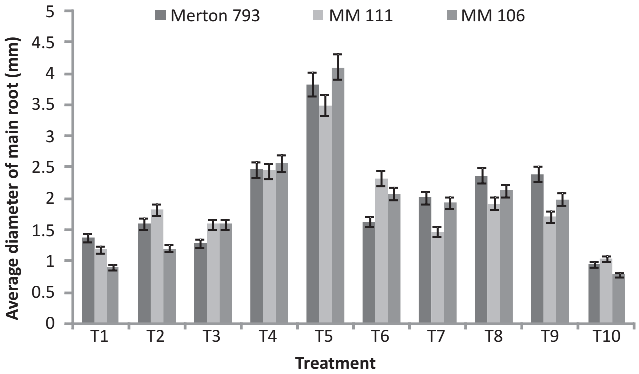

Fig. 2. Effect of IBA and wounding on average diameter of main roots (mm) in different clonal rootstocks of apple

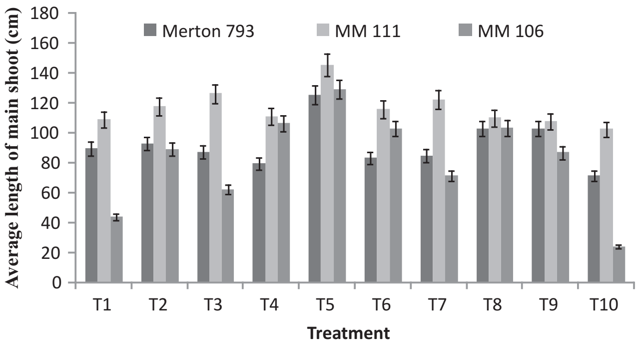

Fig. 3. Effect of IBA and wounding on average length of main shoot (cm) in different clonal rootstocks of apple

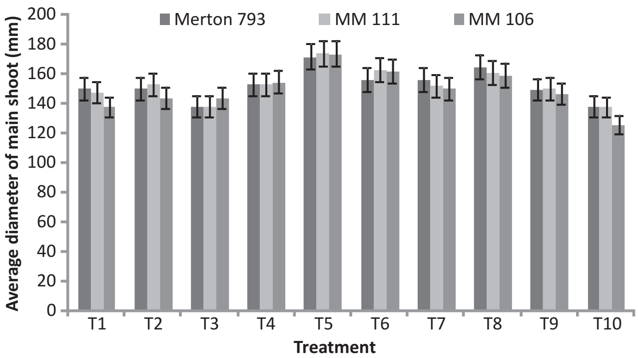

Fig. 4. Effect of IBA and wounding on average diameter of main shoot (mm) in different clonal rootstocks of apple

the cuttings treated with IBA 2000 ppm + Basal split (T_5), which was significantly higher than all other treatments. The interaction between treatment and rootstock on total phenol content was also found to be significant. Phenolic compounds play a paramount role in rooting of stem cuttings. They form a part of 'rhizocaline' as well as 'rooting cofactors' which partly protect the root inducing naturally occurring auxin IAA from destruction due to enzyme IAA oxidase (Schneider and Wightman, 1974). These results are in congruence with those of Gautam (1986), who reported a positive correlation of total phenol and O.D phenol with rooting ability of cuttings in some *Prunus* cultivars and rootstocks. Bhatia and Jindal (2000) also observed the highest total phenols in the shoots of semi-dwarfing MM106 rootstock followed by M4, MM109 and seedling rootstocks.

The highest carbohydrate-nitrogen ratio (59.61) was recorded in the cuttings treated with IBA 2000 ppm + Basal split (T_5). This treatment had significantly higher carbohydrate-nitrogen ratio than all other treatments (Table 3). Different rootstocks also exerted a significant influence on

Table 2. Effect of IBA and wounding on total phenol content (mg g^{-1}) in different clonal rootstocks of apple

Treatments	Rootstocks			Mean
	Merton 793	MM 111	MM 106	
T_1 : IBA 1000 ppm	19.20	18.93	17.67	18.60
T_2 : IBA 2000 ppm	20.40	20.83	19.37	20.20
T_3 : IBA 3000 ppm	18.53	19.33	20.10	19.32
T_4 : IBA1000 ppm + Basal split	22.50	21.67	19.07	21.08
T_5 : IBA 2000 ppm + Basal split	24.37	23.93	22.75	23.68
T_6 : IBA 3000 ppm + Basal split	19.80	18.97	19.20	19.32
T_7 : IBA1000 ppm + Basal incision	19.03	20.13	21.30	20.16
T_8 : IBA2000 ppm + Basal incision	20.87	19.47	19.67	20.00
T_9 : IBA3000 ppm + Basal incision	20.13	19.20	20.13	19.82
T_{10} : Control (Without IBA and wounding)	17.73	18.50	17.23	17.82
Mean	20.26	20.10	19.65	

CD (p=0.05)

Treatment (T)	=	1.45
Rootstock (R)	=	NS
Treatment x Rootstock (TxR)	=	1.25

Table 3. Effect of IBA wounding on Carbohydrate -Nitrogen Ratio in different clonal rootstocks of apple

Treatments	Rootstocks			Mean
	Merton 793	MM 111	MM 106	
T_1 : IBA 1000 ppm	27.69	40.00	32.80	33.50
T_2 : IBA 2000 ppm	42.28	55.25	39.85	45.79
T_3 : IBA 3000 ppm	26.25	34.91	28.26	29.81
T_4 : IBA1000 ppm + Basal split	39.51	49.61	48.98	46.03
T_5 : IBA 2000 ppm + Basal split	58.78	63.34	56.71	59.61
T_6 : IBA 3000 ppm + Basal split	40.17	36.50	35.25	37.31
T_7 : IBA1000 ppm + Basal incision	38.80	41.95	40.24	40.33
T_8 : IBA2000 ppm + Basal incision	42.00	46.48	44.44	44.31
T_9 : IBA3000 ppm + Basal incision	41.60	34.46	26.63	34.23
T_{10} : Control (Without IBA and wounding)	23.27	22.63	21.95	22.62
Mean	38.04	42.51	37.51	

CD (p=0.05)

Treatment (T)	=	1.15
Rootstock (R)	=	0.63
Treatment x Rootstock (TxR)	=	2.00

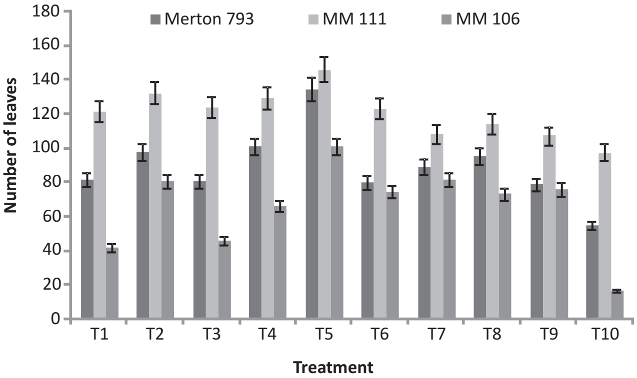

Fig. 5. Effect of IBA and wounding on total number of leaves in different clonal rootstocks of apple

carbohydrate– nitrogen ratio (C:N). The maximum carbohydrate-nitrogen ratio (42.51) was recorded in MM111 rootstock, while minimum (37.51) was found in MM106 rootstock cuttings, which was statistically at par with Merton 793. Interaction effect between treatment and rootstock on carbohydrate-nitrogen ratio was found significant. The maximum carbohydrate-nitrogen ratio (63.34) was found in MM111 rootstock under the treatment IBA 2000 ppm + Basal split (T_5), while, minimum (21.95) carbohydrate-nitrogen ratio was observed in MM106 rootstock in control. The increase in the level of carbohydrate in the auxin treated cuttings, support the contention that auxin induce hydrolysis of complex substances. Stock plants under high carbohydrate–nitrogen ratio are optimal for rooting in cuttings under mist. Devis (1973) supported that auxin control the *de novo* synthesis of hydrolytic enzymes by altering all the levels of nuclic acid and protein synthesis. Stoltz (1986) also reported that rooting is favoured by high C/N ratio.

Among the different concentrations of IBA and wounding alone or in combination, the IBA 2000 ppm + Basal split (T_5) was found best treatment. Among different rootstocks MM111 was observed to be the best in terms of root, shoot and biochemical aspects.

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Dissipation of Pre-mix Chlorpyrifos and Cypermethrin in Cauliflower Grown under Mid hill Conditions of Himachal Pradesh

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Abstract: Persistence of chlorpyrifos and cypermethrin was studied on cauliflower after application of their individual as well as ready-mix formulations. Chlorpyrifos and cypermethrin were applied at the recommended rate of 500 g a.i ha^{-1} and 50 g a.i. ha^{-1} respectively both individualy as well as in the form of ready-mix formulation and at double the recommended rate i.e. 1000 g a.i ha^{-1} and 100 g a.i ha^{-1} both individualy as well as in the form of ready-mix formulations. Chlorpyrifos and cypermethrin residues in curds reached below the limit of determination in 10 and 7 days respectively when applied at recommended rate and in 15 and 10 days when applied at double the recommended rate. Chlorpyrifos deposits in ready-mix formulation treatment, reduced to half in 1.18-1.46 days and cypermethrin deposits required 1.31-1.71 days to reduce to half but when applied individually, chloryrifos initial deposits were reduced to their half in 1.25-1.50 days and cypermethrin deposits became half in 1.38-1.69 days. In soil, residues of chloryrifos persisted upto 10 days, whereas residues of cypermethrin were below determination limit in 10^{th} day sampling in individual insecticides when applied at the recommended rate. The study revealed that the persistence behavior in curds were almost same when applied individually or as ready-mix insecticides.

Keywords: Dissipation, Chlorpyrifos, Cypermethrin, Cauliflower, Residues, Ready-Mix formulation

Vegetables are of direct concern with respect to the buildup of pesticides residues from point of health hazards to consumers, as they are consumed afresh immediately after field harvest without giving much time for dissipation of residues. Among cole crops, cauliflower (*Brassica oleracea* var. *botrytis* L.) is an important vegetable in India and is grown extensively in Himachal Pradesh region as a cash crop. One of the major constraints in commercial growth of this crop is the heavy damage caused to it by insect-pests. Hence, various insecticides are being used by farmers in Himachal Pradesh for their effective control. This crop is susceptible to attack by a large number of pests including diamond back moth, leaf eating caterpillar and aphids (Deeplata and Rao, 2012). In order to prevent the damage to the crop the farmers rely heavily on the usage of many pesticides viz. quinalphos, phosalone, fenvalerate, cypermethrin, deltamethrin etc. (Rijal *et al*., 2006). Improper and injudicious use of pesticide, besides posing health threat to the farm workers, also leave harmful pesticide residues on the crop and soil and causes development of pest resistance leading to the losses to the crops (Kumar and Singh, 2014). To combat this menace, usage of insecticide mixtures is a promising option.

In India, a large number of ready-mix insecticide formulations have been registered for use on various crops (Regupathy *et al*., 2004). Ready-mix insecticide formulations have been found effective against insect pests of many vegetables (Dharne and Kabre, 2009; Kumar and Shivaraju, 2009). In cauliflower, chlorpyrifos and cypermethrin separately or in ready-mix, have been found effective in controlling insect-pests (Tripathi *et al*., 2003; Mishra 2002; Sarangdevot *et al*., 2010 a & b). This effectiveness of these two insecticides on cauliflower has propelled the use of combination product (chlorpyrifos 50% + cypermethrin 5%) on cauliflower. However, information available on the persistence behavior of these ready-mix products in/on cauliflower curds and soil are scare under present environmental conditions.

Therefore, the present studies were contemplated with an objective to study the persistence behavior of pre mix chlorpyrifos and cypermethrin and its comparison with the residue status when applied individually, following spray application.

MATERIAL AND METHODS

The experiment was laid out in randomized block design at the experimental farm of the Department of Entomology, UHF Nauni, Solan (H.P.) during 2010 and 2011 and each treatment was replicated thrice. The experiment was conducted in the months of January and February for both years where maximum temperature ranged between 16^{0}C-24^{0}C and minimum temperature ranged between 4^{0}C-36.8^{0}C whereas RH ranged between 39-68.5% and maximum of 36.9mm rainfall was observed during the period of experiment. The crop was raised by following package of practices of vegetable crops (Anonymous, 2010). Cauliflower (*Brassica oleracea* var. *botrytis* L.) variety Pusa

Snowball-1 was sprayed at curd formation stage with recommended dose of chlorpyrifos (Lethal 20EC) @ 500 g a.i./ha, cypermethrin (Challenger 25EC) @ 50 g a.i. ha^{-1} and the ready-mix formulation Cannon 55EC (chlorpyrifos 50% and cypermethrin 5%) @ 500+ 50 g a.i. ha^{-1} i.e. 1 ml/lt and at double recommended rate. A total of two sprays were given at 15 days interval. Control plots spray with only water were maintained simultaneously for comparison. After the second spray, curd samples (1kg) from each replication were collected randomly at 0 (2 hours after spray), 1, 3, 5, 7, 10 and 15 days intervals. Soil samples (1 kg) from each replication were collected on 0, 10 and 20 days after application. The cauliflower curds were homogenized and analysed for respective insecticides. Soil samples were shade dried and sieved. Cauliflower curd samples were analyzed according to multi residue method (Sharma, 2007). Homogenized cauliflower curd sample (100 g) was extracted with 200 mL of acetone, filtered through Buchner funnel under low suction and rinsed with 50 mL acetone. From total extract, an aliquot of 60 ml (30 g equivalent of sample) was transferred to 1 litre separatory flask and extracted with 200 ml mixture of hexane and dichloromethane (1:1, v/v). The separatory flask was shaken vigorously for 1 min and then allowed the phases to separate into organic and aqueous phase. The lower aqueous phase was transferred to another 1 litre separatory flask and remaining organic phase was retained in the same separatory flask. Ten millilitre saturated sodium chloride solution was added to the left amount of aqueous phase and again partitioned twice with 100 ml dichloromethane. Lower aqueous phase was discarded and upper organic phase was transferred to the 1^{st}separatory flask. Pooled organic phase was passed through anhydrous sodium sulfate and evaporated to dryness by using vacuum rotary evaporator at 40^0C. Finally, the residues were taken up in 3 mL (1+2) acetone for cleanup. One millilitre sample extract was diluted with 10 ml of acetone: hexane (1:9) mixture, loaded on 4 g Florisil column (22 mmi.d.), overlaid with 2 g layer of sodium sulphate and eluted with 50 mL solvent mixture (50 % dichloromethane: 48.5 % hexane: 1.5 % acetonitrile). Another fraction, 2 mL of sample was loaded on a charcoal column which was prepared by placing one inch layer of Celite 545, 6 g absorbent mixture (1:4 w/w Charcoal: Celite 545) and then overlaid with 2 g sodium sulfate. The sample extract was loaded on to the column and eluted with 200 ml of 2:1 acetone: dichloromethane mixture. Eluate from both the column fractions was pooled evaporated to dryness in vacuum rotary evaporator at 50^0C. The residues were redissolved in 3 mL toluene and injected one µl into gas chromatograph for residue estimation.

Soil samples were analyzed according to the multi residue method (Brar, 2003). A dried and sieved representative soil sample of 20 g was mixed with 0.5 g activated charcoal + 0.5 gFlorisil and packed in 2×40 cm glass column containing about 5 cm layer of anhydrous sodium sulphate over a plug of cotton at the bottom. Eluted the column with 50 mL mixture of acetone and hexane (1:4). The eluate was evaporated to dryness and residues were taken up in 1mL toluene. Finally, one µl was injected into gas chromatograph for residue estimation.

Residues were estimated by using Gas-Chromatograph (Agilent 6890N) having ECD detector and DB-5 Ultra Performance Capillary column (Cross-linked Methyl Silicon, length 30 m, 0.250 mm internal diameter with 0.25 µm film thickness). The analytical method employed to estimate residues was validated by spiking the control curd and soil samples at five different levels viz., 0.05, 0.10, 0.20, 0.50 and 1.0 $mgkg^{-1}$.The limit of determination (LOD) of chlorpyrifos was 0.01 $mgkg^{-1}$in curds while in soil, it was 0.05$mgkg^{-1}$and for cypermethrin curds and soil, LOD was 0.05 mg kg^{-1}.

RESULTS AND DISCUSSION

Recovery of chlorpyrifos was between 90.00-94.00 per cent with relative standard deviation (RSD) of 0.112-1.030 per cent in curds and 90.00-93.00 per cent with 0.032-0.940 per cent RSD in soil fortified samples (Table 1). Recovery of cypermethrin was between 90.00-92.00 per cent in curds and 87.80-92.00 per cent recovery in soil fortified samples. The results are in agreement with Pal (2011) who has observed recovery 86.60-92.31 per cent for cypermethrin in capsicum fruits. Brar (2003) reported 78.60 recovery of pyrethroids in soil. The decrease in level of residues in individual and ready-mix insecticides treatments at different days interval in curds are presented in Fig. 1. The two years climatic conditions showed that there was not much variation in the residue data.

Chlorpyrifos initial deposits on cauliflower curds from mixture (Cannon 55EC) and individual insecticide formulation (Lethal 20EC) were 1.815-1.931 $mgkg^{-1}$which dissipated to 0.023-0.041 $mgkg^{-1}$ and 1.213-1.256 $mgkg^{-1}$ which dissipated to 0.022-0.025 $mgkg^{-1}$ on 7^{th} day, respectively at recommended rate. In double the recommended rate, initial deposits of chlorpyrifos from mixture were 3.526-3.651 $mgkg^{-1}$which dissipated to 0.022-0.029 $mgkg^{-1}$and whereas initial deposits of chlorpyrifos from individual application were 2.164-2.179 $mgkg^{-1}$which dissipated to 0.013-0.022 $mgkg^{-1}$ in 10 days. Two years persistence data showed that they followed almost the same dissipation pattern whether applied individually or as ready-mix formulation. Our findings are in agreement with Reddy and Rao (2002), who observed 1.22 $mgkg^{-1}$ initial deposits of chlorpyrifos on grapes at 0.05 per cent spray concentration.

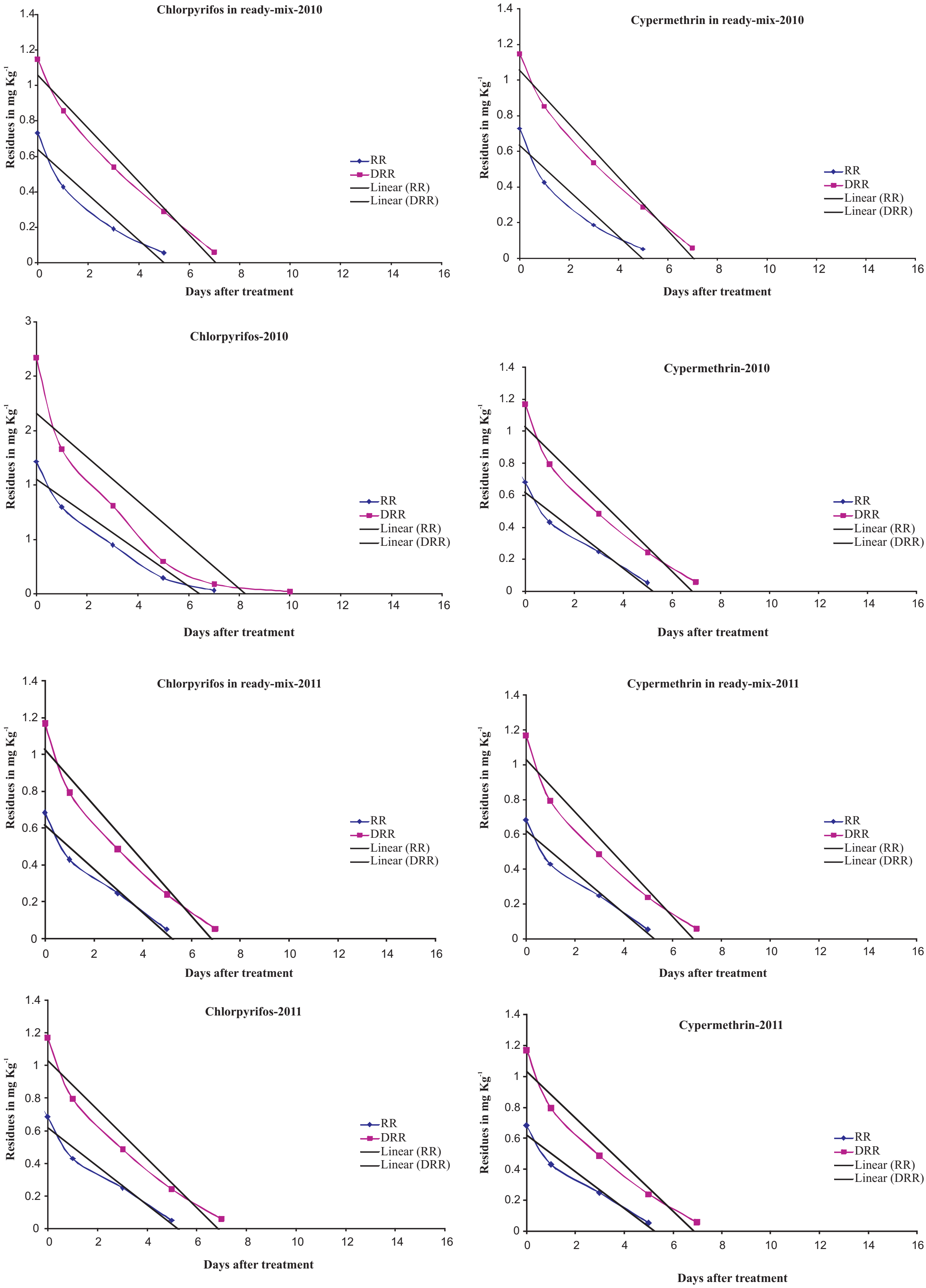

Fig. 1. Dissipation behavior of chlorpyrifos and cypermethrin on cauliflower curds

Initial deposits of cypermethrin on cauliflower curds from mixture with chlorpyrifos applied @ 50 g a.i. ha^{-1} were 0.728–0.752 $mgkg^{-1}$ whereas at double recommended rate, the initial deposits were 1.145–1.176 mg kg^{-1}. When applied individually, cypermethrin initial deposits at recommended rate were 0.629–0.681 $mgkg^{-1}$ and at double the recommended rate cypermethrin deposits were 1.139–1.167 $mgkg^{-1}$.

There is decline in residues with the time lapse at both the level of application. The persistence of insecticides is generally expressed in terms of RL_{50} i.e. time required for the disappearance of insecticide initial deposits to 50 per cent. The RL_{50} values are often obtained by fitting first-order kinetics to observed degradation pattern (Table 2).

Studies suggested safe waiting period of 8 days for chlorpyrifos and 0 day for cypermethrin as their initial deposits were below the Codex MRL at recommended rate on cauliflower whether applied individually or in ready-mix formulation on the basis of MRLs as per Codex Alimentarius Commission: 0.05 $mgkg^{-1}$ for chlorpyrifos and 2.0 $mgkg^{-1}$ cypermethrin on cauliflower.

Chlorpyrifos residues 0.200-0.235 $mgkg^{-1}$ and 0.310–0.342 $mgkg^{-1}$ were detected in soil at the recommended and double the recommended rate, respectively in ready-mix formulation which became non-detectable on 20^{th} day at both the doses (Table 3). When chlorpyrifos applied individually on the crop then residues in soil also became non-detectable on 20 days sampled soil at both rates. Gupta *et al*. (2011) observed no chlorpyrifos residues in soil on the day of application at single dose and detected residues (0.012 $mgkg^{-1}$) at double dose which became below detection level after 3 days of Action 55EC (chlorpyrifos 50% + cypermethrin 5%) application @ 0.8 and 1.6 Lha^{-1} on tomato crop.

Cypermethrin residues in soil were below determination limit on 0 day at recommended rate (50 g ai ha^{-1}) and at double the recommended rate, 0.073-0.078 $mgkg^{-1}$ cypermethrin residues were detected in cauliflower cropped soil (Table 3). However, in individually applied cypermethrin, its residues were detected in soil on 0 day and became below the determination limit in 10 days. Present findings are in

Table 1. Recovery of chlorpyrifos and cypermethrin from cauliflower curds and soil samples

Insecticides	Curds			Soil	
	Fortification level, (mg/kg)	Mean recovery (%)	Relative standard deviation (% RSD)	Mean recovery (%)	Relative standard deviation (% RSD)
Chlorpyrifos	0.01	90.00	1.030	–	–
	0.05	92.00	0.987	92.00	0.767
	0.10	93.00	0.858	93.00	0.231
	0.50	91.00	0.178	91.00	0.099
	1.00	94.00	0.112	92.60	0.032
Cypermethrin	0.05	90.00	0.988	90.00	1.003
	0.10	90.00	0.525	88.00	0.933
	0.20	92.00	0.498	90.00	0.704
	0.50	90.00	0.160	87.80	0.104
	1.00	92.00	0.062	92.00	0.049

Table 2. Statistical constants of chlorpyrifos and cypermethrin on cauliflower curds

Years, Insecticides	Dosage	Chlorpyrifos			Cypermethrin		
		Regression equation (y=—)	r	RL50	Regression equation (y=—)	r	RL50
2010, Combination	RR	0.401-0.221X	-0.951	1.36	-0.128-0.223X	-0.995	1.34
	DRR	0.617-0.218X	-0.993	1.38	0.143-0.174X	-0.960	1.72
Individual	RR	0.178-0.232X	-0.977	1.29	-0.163-0.212X	-0.983	1.41
	DRR	0.431-0.220X	-0.990	1.36	0.113-0.178X	-0.978	1.68
2011, Combination	RR	0.468-0.254X	-0.931	1.18	-0.098-0.230X	-0.996	1.31
	DRR	0.618-0.206X	-0.992	1.46	0.157-0.175X	-0.954	1.71
Individual	RR	0.204-0.239X	-0.972	1.25	-0.124-0.217X	-0.973	1.38
	DRR	0.404-0.200X	-0.994	1.50	0.123-0.178X	-0.975	1.69

RR=Recommended rate, DRR=Double recommended rate, r=Correlation, RL50=Residue half-life

Table 3. Residues of chlorpyrifos (500 g a.i. ha^{-1}) and cypermethrin (50 g a.i. ha^{-1}) and their double doses in cauliflower cropped soil

Interval (Days)	2010				2011			
	Combination		Individual		Combination		Individual	
	Chlorpyrifos	Cypermethrin	Chlorpyrifos	Cypermethrin	Chlorpyrifos	Cypermethrin	Chlorpyrifos	Cypermethrin
	Residues±SD (mg kg^{-1})	Residues±SD (mg kg^{-1})	Residues±SD (mg kg^{-1})	Residues±SD (mg kg^{-1})	Residues±SD (mg kg^{-1})	Residues±SD (mg kg^{-1})	Residues±SD (mg kg^{-1})	Residues±SD (mg kg^{-1})
0	0.200±0.003 (RD)	BDL	0.338±0.004	0.077±0.007	0.235±0.003	BDL	0.368±0.003	0.080±0.007
	0.310±0.008 (DD)	0.073±0.001	0.698±0.005	0.096±0.003	0.342±0.002	0.078±0.001	0.703±0.006	0.105±0.004
10	0.051±0.004 (RD)	BDL	0.167±0.002	BDL	0.052 ±0.003	BDL	0.188±0.003	BDL
	0.042±0.001 (DD)	BDL	0.198±0.003	BDL	0.052±0.001	BDL	0.208±0.004	BDL
20	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL

BDL−Below determination limit

accordance with findings of Gupta *et al.* (2011) who observed cypermethrin residues below detection limit in soil samples after the application of Roket 44EC @ 1ml lt^{-1} (profenofos 400 g a.i. ha^{-1} and cypermethrin 40 g a.i. ha^{-1}) on tomato crop. Studies revealed that when individual insecticides were applied alone on cauliflower crop then higher residues were detected in soil in comparison to their application in ready−mix formulation.

CONCLUSION

The chlorpyrifos and cypermethrin persistence behavior in curds was almost same whether applied individually or as ready−mix formulation. The safe waiting period of 8 days for chlorpyrifos and 1 day for cypermethrin is recommended whether applied individually or as ready−mix formulation on cauliflower curds.

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Effect of Shoot Pruning on Polyhouse Grown Cucumber (*Cucumis sativus* L.)

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Abstract: The treatment comprising of single stem was early and had maximum fruit weight, length, breadth, harvest duration, vine length and minimum inter nodal length. Whereas, the treatment comprising of three stems with side shoot pruning after three leaves obtained maximum number of fruit plant^{-1}, fruit yield plant^{-1}, fruit yield m^{-2} area, net returns and output input ratio.

Keywords: Inter-nodal length, Protected cultivation, Quality, Yield

Cucumber *(Cucumis sativus L.)* is an annual trailing vine vegetable and belongs to the family cucurbitaceae. It is a warm season crop and has little or no tolerance to frost but under the protected environment it can be grown throughout the year. The optimum temperature for growing is between 20-30°C. Under open environment, cucumber can be grown in both summer and rainy seasons, but keeping in view its low productivity due to various abiotic (low temperature and unpredictable weather) and biotic (red pumpkin beetle, fruit fly and incidence of downy/powdery mildew) stresses in open environment during spring summer or rainy-autumn seasons, growing of cucumber in protected environments can be a remunerative venture.

In protected cultivation, profits are greatly dependent on the quantity and quality of the produce. Pruning of leaves and side shoots contribute to the ultimate yield in various ways. Training maximizes the plant ability to obtain the sunlight needed for growth. It is also important to maintain adequate air movement around the plant to reduce risk of fungus and insect problems. On the other hand dense canopy of leaves shade the fruits, causing them to be pale. Relatively high perishability has made cucumber plants to be more vulnerable to intensive crop management and unfavorable environmental conditions. Excessive pruning of leaves sometimes causes the plants to cease producing flowering. Therefore, it is important to maintain sufficient foliage on the plant. Keeping these facts in view, the present investigation was taken up to study the effect of training/pruning techniques on yield and quality of cucumber and to work out the economics of production.

MATERIAL AND METHODS

Experiment was conducted during spring-summer season 2015-16 with private sector parthenocarpic cucumber hybrid in naturally ventilated polyhouse at CSK Himachal Pradesh Krishi Vishvavidyalaya, Palampur. Nursery was raised in soil-less media (cocopeat: perlite: vermiculite in the ratio of 3:1:1) in growth chamber and was transplanted under polyhouse in March. The experiment was carried out in a Randomized Block Design with seven treatments *viz*., single stem, single stem with side shoot pruning after three leaves, two stems, two stems with side shoot pruning after three leaves, three stems, three stems with side shoot pruning after three leaves and control (no pruning). Each treatment was replicated three times and spaced at 70 × 30 cm. The observation were recorded on five plants taken randomly for the characters *viz;* days to flowering, days to first picking, fruit length (cm), fruit breadth (cm), fruit weight (g), number of fruits plant^{-1}, fruit yield plant^{-1} (kg), fruit yield (kg) m^{-2} area, harvest duration (days), inter-nodal length (cm) and vine length (m). For total soluble solids (° brix) the fruits were taken from the 5th picking.

RESULTS AND DISCUSSION

Earliness: Plants pruned to single stem took minimum number of days to flowering and first picking, which was statistically at par with treatment comprising of single stem with side shoot pruning after three leaves. The most probable reason for early female flower appearance in single stem plants was that the length of main shoot grew faster. Plants with single stem appeared to have quick absorption and utilization of nutrients and the various physiological processes boosted up at faster rate with a favorable balance between synthesis and utilization in flower induction. The findings are in accordance with the findings of earlier workers Premalatha *et al. (*2006) and Ekwu *et al. (*2013).

Fruit length, breadth and weight: Plants pruned to single stem had maximum fruit length, which was statistically at par with all other treatments expect control (no pruning).

Maximum fruit breadth and weight was in single stem plants, which was statistically at par with treatment comprising of single stem with side shoot pruning after three leaves. Because sufficient amount of assimilates were available for young fruits in single shoot plants, but the reverse situation was under control (no pruning), where sink to source ratio was high. So, due to more sink, the assimilate availability was low and it has direct effect on breadth and weight of fruits.

Number of fruits plant^{-1}: Plants pruned to three stems with side shoot pruning after three leaves had maximum number of fruits plant^{-1}. The most probable reason was that the availability of more number of fruit producing shoots. In case of unpruned plants there was excessive vegetative growth, so number of fruits plant^{-1} was lesser than three stems plants.

Yield: Fruit yield plant^{-1} and fruit yield m^{-2} area was maximum in plants pruned to three stems with side shoot pruning after three leaves, which was significantly at par with treatment comprising of three stem. The reason for more fruit yield plant^{-1} in three stems was probably due to pruning of plants into one and two stems might have resulted in excessive removal of branches, thus affecting the photosynthates capacity of the plants. Earlier workers Okafor, 2007 and Umekwe *et al.* (2015) also observed similar results.

Harvest duration: Maximum harvest duration was in plants pruned to single stem, which was statistically at par with treatment comprising of single stem with side shoot pruning after three leaves. Early appearance of pistilate flowers at lower nodes coupled with exposure of fruits to sunlight and aeration could be the reasons for early pickings and longer harvest duration in plants pruned to single stem.

Table 1. Effect of shoot pruning on yield and related characters of cucumber

Treatment	Days to 50 per cent flowering	Days to first picking	Fruit length (cm)	Fruit breadth (cm)	Fruit weight (g)	Number of fruits plant^{-1}	Fruit yield plant^{-1} (Kg)	Fruit yield m^{-2} (kg)	Harvest duration (days)
Single stem	25.00	36.27	16.78	4.50	134.87	13.43	1.80	8.57	54.67
Single stem with side shoot pruning after three leaves	25.33	36.67	16.53	4.47	132.33	15.13	2.00	9.53	54.33
Two stems	26.67	38.39	16.64	4.27	128.10	17.17	2.23	10.63	51.67
Two stems with side shoot pruning after three leaves	27.00	38.67	16.40	4.26	127.63	18.87	2.40	11.43	51.33
Three stems	28.33	40.00	16.23	4.02	124.33	23.33	2.90	13.78	49.33
Three stem with side shoot pruning after three leaves	28.67	40.33	16.12	3.98	123.23	25.20	3.10	14.77	47.67
Control (no pruning)	29.67	41.67	15.63	3.86	119.33	21.83	2.63	12.53	46.67
CD (p=0.05)	1.54	2.11	0.68	0.19	2.91	0.90	0.41	1.94	2.62

Table 2. Effect of shoot pruning on quality and economic characters of cucumber

Treatment	Inter-nodal length (cm)	Vine Length (m)	TSS (° Brix)	Cost of cultivation (Rs. m^{-2})			Gross return (Rs. m^{-2})	Net return (Rs. m^{-2})	Output: input ratio
				Input cost	Labour cost	Total cost			
Single stem	9.48	2.42	2.79	49.74	24.66	74.40	171.33	96.93	2.30
Single stem with side shoot pruning after three leaves	9.52	2.37	2.78	49.74	24.80	74.54	190.67	116.13	2.56
Two stems	9.61	2.25	2.77	49.74	25.77	75.51	212.67	137.16	2.82
Two stems with side shoot pruning after three leaves	9.64	2.22	2.75	49.74	26.02	75.76	228.67	152.91	3.02
Three stems	9.72	2.04	2.76	49.74	27.09	76.83	276.00	199.17	3.59
Three stem with side shoot pruning after three leaves	9.74	2.02	2.74	49.74	27.25	76.99	295.33	218.34	3.83
Control (no pruning)	9.86	1.80	2.76	49.74	23.66	73.40	250.67	177.26	3.41
CD (p=0.05)	0.10	0.16	NS		2.29		38.51	37.27	0.41

Parameters taken for input cost (manures and fertilizers, seed, protrays, nylon ropes for staking, pesticides) and for labour cost (land preparation, manuring, layout, sowing, irrigation, weeding, fertilizer, staking, pruning, plant protection, harvesting (picking of cucumber).

Inter nodal length, vine length and total soluble solids: Minimum inter-nodal length and maximum vine length was noticed when plants were pruned to single stem, which was statistically at par with treatment comprising of single stem with side shoot pruning after three leaves. The reason for minimum inter-nodal length of single stem plants was probably due to the better exposure of the plants to light, enhanced synthesis of photosynthates and more assimilation of carbohydrates. This increase in vine length may be due to pruning of side branches causing flow of nutrients to the axillary branches might have reduced, which in turn lead to flow to the apical tissues leading to elongation of shoot. Similar finding was also reported by Utobo *et al.* (2010). Shoot pruning did not influence the total soluble solids significantly.

Net returns and output: input ratio: Highest net returns and output: input ratio was observed in three stems with side shoot pruning after three leaves, which was statistically at par with treatment comprising of three stems.

CONCLUSION

It was concluded that plants pruned to single stem had higher quality of fruits like fruit length, fruit breadth, fruit weight and also had early flowering, early picking, longer harvest duration, higher vine length and smaller inter-nodal length was recorded in plants pruned to single stem. But plants pruned to three stems with side shoot pruning after three leaves had higher number of fruits plant^{-1}, yield plant^{-1}, higher yield m^{-2} area and also higher economic returns.

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Breeding Biology of the Mallard duck (*Anas platyrhynchos*) in Barrage Oued Charef (Souk Ahras, Northeastern Algeria)

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Abstract: The reproductive biology and nesting site selection of the Mallard duck, *Anas platyrhynchos*, were investigated in a freshwater wetland Northeast Algeria. On the natural ecosystem of Oued Charef, egg-laying occurred from mid-December to late January, with peak in the last week of December. Mean clutch size was 8.41 (n= 25), and incubation period was 26.0 days. Hatching success amounted to 72.1% (25 clutches) and an average of 4.55 chicks hatched per nest. Incubating Mallard usually nested near water edge. Observations recorded suggest the importance of wetland management based on species-specific habitat requirements for conserving this breeding water bird assemblage.

Keywords: *Anas platyrhynchos*, Northeast Algeria, Hatching success, Wetland management

Mallard duck have a large, breeding distribution throughout the Palearctic (Cramp, 1980). Extensive studies on the nesting habitat and nest site selection of the species have been carried out through their range (Arnold *et al.,* 1993;Shah *et al.,* 2008), as well as detailed studies about nest site selection (Hill, 1984; Lu, 2011). Different aspects of the breeding biology of the species have been investigated in both natural and man-made habitats such as constructed islands (Shaffer *et al.,*2006), natural islands (Willms and Crawford,1989), irrigation ponds (González *et al.,* 2010) and marshes (Batt *et al.,* 1979). In Algeria, there have been only one study reported on some aspects of the breeding biology of the species in Tonga lake, North-East of Algeria (Labbaci *et al.,* 2014). However, the breeding phenology and the reproductive success remain poorly known in other localities in Algeria.

Altitude is an environmental gradient along which bird shift their life-history strategies (Lu, 2008; Boyle *et al.,* 2015). Some researchers have reported that birds breeding at a high altitude have a total lower annual reproductive output (Lu, 2008; Zeng and Lu 2009, Lu *et al.,* 2009, 2010 a, b) with a smaller clutches, late start of egg laying and short breeding period than birds at a low altitude (Lu *et al.,* 2008, 2010; Hille and Cooper 2014; Boyle *et al.,* 2015). At a high altitude environment, where the climate is different and the food availability is short in supply and low in quality, birds are expected to adjust their reproductive strategy.

Therefore, in the current study, we tried to develop recommendations for conservation of these high elevation Mallard duck based on knowledge of its nest site characteristics and habitat requirements. We expected that Mallards at our study area start egg laying later and have short breeding period than other populations and our population had high breeding success, and the management plans which may help us to conserve the species in our natural ecosystem have also been proposed.

MATERIAL AND METHODS

Study area: In December 2016 –January 2017, a shallow freshwater wetland, Barrage Oued charef (36° 5'22.91"N 7°23'20.78"E, alt. 920 m, area: 1010 ha), located in souk Ahras province, North-east of Algeria was monitored. Even though the wetland is comprised of aquatic plants, it is surrounded by cereal crops consisted of Chenopodiaceae (*Atriplex halimus, Atriplex patula, Salicornia fruticosa, Salsola fruticosa, Suaeda fruticosa*), Brassicaceae (*Mauricandia arvensis, Matthiola fruticolosa, Diplotaxis éricoïdes, Capsella bursa pastoris*). This wetland harbours an important avifauna. Among the common species there are the Goéland argenté *Larus argentatus*, Mouette rieuse *Chroicocephalus ridibundus*, Grand cormoran *Phalacrocorax carbo*, Grèbe huppé *Podiceps cristatus*, Grèbe castagneux *Tachybaptus ruficollis*, Canard pilet *Anas acuta*, Canard souchet *Anas clypeata*, Canard colvert *Anas platyrhynchos*, Canard siffleur *Anas penelope*, Tadorne de belon *Tadorna tadorna,* Fuligule milouin *Aythya ferina* and vanneau huppé *Vanellus vanellus*.

Data collection: Nests were systematically searched throughout the wetland and monitored every 3-4 days until the hatching of eggs or the failure of the breeding attempt. On finding a nest, I marked it with numbered flag, described the nest site characteristics (cup depth, distance from the nest to mainland, and distance from the nest to the edge of water using a tape measure), and took measurements of the nest and its contents (egg weigh using an electronic balance (0.1 g), and egg length and width using a caliper (0.01 mm). We calculated the egg volumes using Douglas' formula (1990): $Ve=Kv \times L \times W^2$, where $Kv=0.5236-(0.5236 \times 2 \times (L/W)/100)$, L=the length of egg (cm) and W=the width of egg (cm). The date on which incubation commenced was determined if a female flashed from the nest, or the eggs were warm when I checked them. The incubation period was defined as the time from the laying of the last egg to the hatching of the last young.

Laying date was calculated, assuming a laying frequency of one egg day. The clutch was considered complete when on two consecutive days no additional egg was laid. (Lack, 1950). The clutch size was recorded for complete clutches only. We calculated the incubation period for 25 nests.

A nest was considered successful if at least one egg was found hatched. A nest was considered to have been destroyed by predators if the nest bowl contained broken egg fragments with remains of yolk on the ground. A nest was considered to have been abandoned if the hen was absent, the eggs were cold, and there was no evidence that she had returned again. Eggs that failed to hatch were always left in the nests. Nesting success was estimated by Mayfield's (1975) method. Only nesting attempts with a known fate were used to calculate reproductive success.

Statistical analysis: Prior to all analyses, all variables were tested for homoscedasticity using Levene's test and normality using Kolmogorov–Smirnov test. We used linear regression to test for seasonal change in clutch size and incubation period using the Julian date as an independent variable. Results were considered significant at $p < 0.05$. Statistical analyses were done using Minitab software Version 17. Means are given ± standard error.

RESULTS AND DISCUSSION

Nesting site: During my search for active nests (containing at least one egg), 25 nests were located, whereas, the total number of nests at Barrage Oued Charef varied between 35 and 40. Nests consisted of shallow circular depression in the ground with an average of 8.58 mm deep (4.10–17.20) and 73.20 mm of diameter (Table 1). There was neither fresh plant material nor feather within and around the nests, but sometimes a few small dry plants were observed (Fig. 1). Nests were usually located at 18.78 m ± 1.29 from water's edge (5.8–39.28 m). The distance to the water's edge increased as the breeding season progressed (linear regression: $r^2 = 0.784$, $F_{1,26} = 264.170$, $p < 0.0005$).

Timing of breeding and incubation period: The first pairs were observed in our study area on 12 November. The number of pairs increased in the following weeks till the beginning of December. The maximum length of egg laying (first eggs) was 39 days (14 December–23 January). The distribution of first eggs laying dates showed a seasonal increase with a peak in the mid-season (the last week of December, 34.2per cent, *n* = 15) and then a decline (Fig .2). The mean incubation period for the Mallard duck was 26.0 ± 1.0 (25–27 days, *n* = 25). Clutches started later in the season had shorter incubation duration than early clutches did (linear regression: $r^2 = 0.496$, $F_{2,42} = 6.756$, $p = 0.030$) (Fig .3), whereas, there was no evident influence of clutch size (linear regression: $r^2 = 0.0$, $F_{2,42} = 0.0$, $p = 2.0$) and eggs volume (linear regression: $r^2 = 0.003$, $F_{2,42} = 0.044$, $p = 0.935$) on the incubation period.

Table 1. Nest and egg measurements of duck breeding at Barrage Oued Charef, Algeria, 2016

	Mean
Nest diameter (cm)	7.32
Cup depth (cm)	0.85
Distance from the nest to Mainland (m)	225.02
Distance from the nest to the edge of water (m)	18.78
Length (mm)	57.5
Width (mm)	35.8
Mass (g)	46.4
Volume (mm^3)	42.2

Fig. 1. Nest of the Mallard duck with two eggs

Egg dimensions and clutch size: Mean egg volume, calculated using the mean volume within each of 25 nests, was 42. 2 mm^3 ±0.05 (*n* = 120 eggs) and the mean ratio of egg shape (length/width) was 1.60 ± 0.02. There was no relationship between egg volume and both laying date (linear regression: $r^2 = 0.002$, $F_{0,42} = 0.129$, $p = 0.624$) and clutch size (linear regression: $r^2 = 0.005$, $F_{0,42} = 0.264$, $p = 0.485$). Egg mass and dimensions are summarized in Table 1. The mean clutch size was 8.41 ± 0.68 (range 1–5, *n* = 25, median and

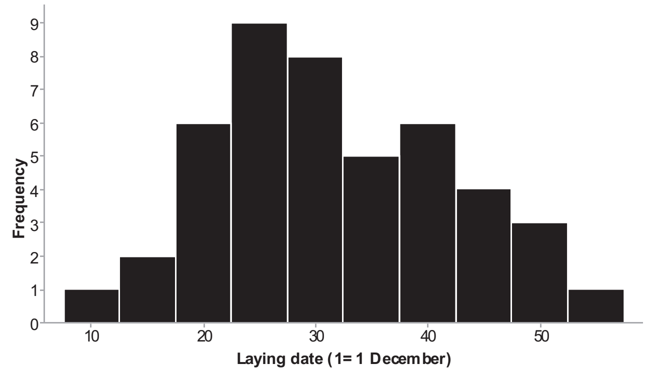

Fig. 2. Distribution of egg-laying dates of the Mallard duck

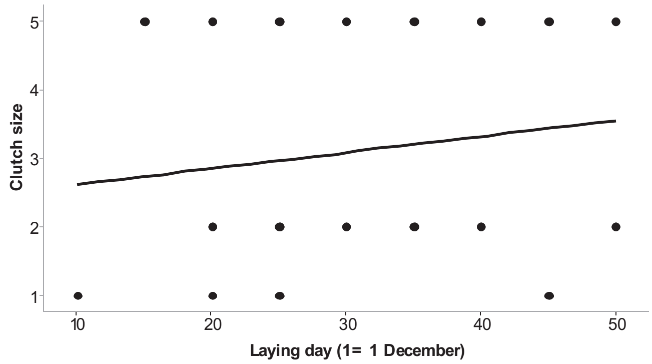

Fig. 4. Seasonal change of clutch size

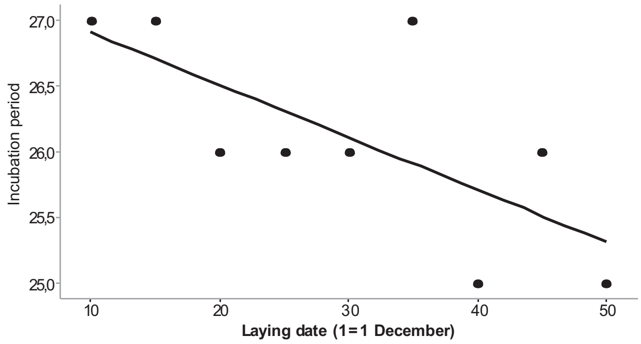

Fig. 3. Seasonal change of the incubation period

mode = 5) with 36per cent, 34per cent, and 30per cent of clutches having five, two and one egg, respectively. There was no significant change of clutch size over the breeding season (linear regression: r^2 = 0.041, $F_{0,42}$ = 0.68, p = 0.420) (Fig. 4).

Breeding success: The mean number of eggs hatched per successful clutches (with at least one chick produced) was 4.55 ± 0.10 (n = 25). The mean number of nestlings fledged was 1.0 ± 0.2 (n = 25) chick per nesting attempt. The number of hatchlings did not varied as breeding season progressed (linear regression: r^2 = 0.004, $F_{0,42}$ = 0.153, p = 0.503). The hatching rate (total number of hatchlings/total number of eggs in nests at hatching) for 120 eggs in 25 clutches was 72.1per cent ± 5.2. Hatching success did not vary significantly according to egg laying dates (linear regression: r^2 = 0.007, $F_{0,42}$ = 0.321, p = 0.340). Nesting success, as calculated by the percentage of nests produced at last one fledgling, was 88.6per cent. The distance to the water's edge did not affect hatching success (linear regression: r^2 = 0.002, $F_{0,42}$ = 0.030, p = 0.712).

Overall, 7.1per cent of nests were trampled, 3.2per cent were predated and 1per cent were failed to hatch. We did not observe any case of nest flooding during the whole breeding season. The results of this study provide basic information on the breeding biology of the Mallard duck occupying Barrage Oued Charef, Northeast Algeria. This species is widespread in North Africa but has only rarely been recorded as breeding in Algeria.

The mean clutch size, egg volume and incubation period compares favourably with the range recorded in Mallard duck populations in India (Shah *et al.,* 2008), Sweden (Asplund 1981) and Canada (Bruce *et al.,* 1979). Although mean clutch size and egg volume did not decrease over the course of breeding season as other authors reported (Shah *et al.,* 2008). The incubation period decreased as breeding season progressed. This is consistent with the influence of climatic conditions on life history traits on birds (Bensouilah *et al.,* 2014; Bensouilah, 2015).

Breeding season: The onset of egg-laying date (from mid-December to late January) is relatively later than those of their lowland counterparts (Finland, mid-April. Hildén, 1964; Louisiana, USA early April; California, USA late February., Nancy *et al.,* 2010). It is known that, the beginning of the breeding season varies with latitude and altitude. It starts early in southern latitudes (Gil-Delgado and Catalá 1989; Cramp and Perrins 1994) and late in high altitudes (Chabi and Isenmann, 1997). It is also influenced by weather conditions and food availability (Meijer *et al.,* 1999; Durant *et al.,* 2007). Moreover, the breeding season is markedly shorter than that recorded in Kashmir (Bates and Lowther, 1952), and North-East of Algeria (Labbaci *et al.,* 2014**).** It may be speculated that the short-laying period may be a different strategy employed by this population as an adaptation to local conditions, which is consistent with the reproductive restriction hypothesis at high altitude of Bears *et al.* (2009).

Recently, new evidence shows that birds in high-elevation had a shorter breeding season (Bears *et al.,* 2009; Martin *et al.,* 2009; Lu *et al.,* 2010; Boyle *et al.,* 2015). In fact, the colder temperatures, experienced at higher elevations are associated with a later start of egg laying, resulting in shorter breeding seasons (Bears *et al.,* 2009; Martin *et al.,* 2009).

Breeding success and nesting site characteristics: Mallards ducks are known to incur high rate of clutches loss owing to predation, flooding and trampling, which are the main causes of breeding failure in many ground nesting species (Newton *et al.,* 1975; Klett *et al.,*1988). Surprisingly, in this Mallards ducks study population, hatching rate is high, averaging 88.6per cent. Hatching success reported by this study is much higher than other Mallards ducks populations, although we did observe a non-significant decline in hatching success as the season progressed. In the present study, most cases of nest failure were associated with the trampling by livestock after the decrease in water level. Thus, it may be speculated that water depth early in the season makes the study area inaccessible for the livestock and mammalian predators, which provide better protection for the population and by consequence breeding pairs experience low egg predation pressure.

To date, it is known that Mallards nested in tall and dense macrophytic vegetation (Hill 1984; Cowardin *et al.,* 1985; Klett *et al.*,1988 ; Lu, 2011). The data contradict these findings (which show vegetation cover of nests was very low). We observed that nests were located in microsites with little vegetation cover and in open habitats. Therefore, it is suggested that individual nest in exposed sites facilitate the early detection of predators. Our result of the average distance to the edge of water are in the line with other studies, which suggest that low distance to the edge of water may provide high accessibility to food resources.(Fazili, 2014; Labbaci *et al.,*2014).

Based on the above observations, further research should focus on the length of breeding season over a longer time-scale with covering a large area; evaluate the link between climatic conditions (temperature and precipitation) and the start of egg laying; evaluation of link between water level, events of trampling and nest mortality; and estimation of daily survival rate, nesting success and identify avian and mammalian predators.

CONCLUSION

Barrage Oued Charef, Northeast Algeria ecosystem can offer good-quality environmental conditions leading to high hatching success in Mallard duck.

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Effect of Aqueous Leaf Extracts of *Flemingia semialata* Roxb. on Seedling Growth of Maize (*Zea mays* L.) and Rice (*Oryza sativa* L.)

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Abstract: Aqueous leaf extract of *F. semialata* was used to investigate its effect on growth and yield of *Zea mays* L. (maize) and *Oryza sativa* L. (rice). There was no inhibitory effect on the shoot and root length of maize and maximum shoot and root elongation ratio were in 100 per cent concentrated leaf extract. However, inhibitory effect on shoot and root was recorded in rice. The inhibitory effect on biomass yield was at lower concentration in maize but no inhibitory effect was on rice, however at higher concentration it had a stimulatory effect on the shoot and root biomass of the crops.

Keywords: *Flemingia semialata*, Aqueous Leaf extracts, Maize, Rice, Inhibitory effect, Stimulatory effect

Flemingia semialata Roxb. (winged-stalk *Flemingia)* is synonymous with *F.* var. *semialata* is a shrub of family Fabaceae closely resembling with *Flemingia congesta* but generally much taller, the petiole is shorter and narrowly winged towards the upper end, glandular dots often absent, the racemes longer (3-6 in.) and laxer and the calyx−teeth narrower. It has potential symbiotic nitrogen fixing ability and tendency of soil and water conservation and therefore used as hedge in improved fallow in Jhum and Alley Cropping (Songachan and Kayang, 2012). The species has nutritive fodder, deep rooting, nitrogen fixing and can withstand long drought, and submergence (Ghosh *et al*., 2017). The species though not indigenous to the state, other species *F. macrophylla* are found occurring naturally in some agricultural fields and in abandoned jhum lands (Anonymous, 2002). Because of its multifarious uses the species has tremendous potential to be introduced in the region as hedge row plant species in alley cropping system and/or in improved fallows with agricultural crops as an alternative to age old shifting cultivation practices.However, many leguminous tree species like *Leucaena leucocephala* and *Acacia* species etc are found to have allelopathic effects on agricultural crops when grown together in the fields (Sahoo *et al*., 2007; Bora *et al*., 1999), there is a need to evaluate the species for its allelopathic effect, its ability to conserve soil and water, nutrient addition in soil etc. when use in different land use systems. Hence, the present study is a part of the preliminary investigation conducted to determine the allelopathic compatibility of aqueous leaf extract of *F. semialata* on early seedling growth of *Zea mays* L. and *Oryza sativa* L. which are common field crops of Mizoram.

MATERIAL AND METHODS

Plant extract: Freshly fallen leaves were collected from Mizoram University, Tanhril (23°44` N, 92º39` E, 775 m above sea level), Aizawl and air dried at room temperature for one week. Leaves were grounded and aqueous extracts were prepared by adding 100g of grounded leaf in 1 litre of distilled water and soak it for 24 h at room temperature. This extract was be used as stock solution to make different concentrations *viz*. 25, 50, 70 and 100 per cent, whereas distilled water is taken as control. The solution was filtered out by using a thin cloth and different concentrations were stored in a conical flask kept at room temperature in the dark to irrigate the seeds. The experiment includes five treatments including distilled water as control.

Pot culture: Ten seeds each of maize and rice were surface sterilized with 0.2 per cent Bivistin and the treated seeds were washed with tap water before sowing in the poly-pot. The treatments were replicated thrice. The poly-pot sown seeds were irrigated with different concentrations of an extract with an equal quantity of 150 ml in alternate days and monitored for 30 days. At two leaf stage, the best performing individual of the crop was selected for evaluation and the remaining nine seedlings were discarded from the poly-pot. After 30 days of sowing, the seedlings were carefully uprooted from the ploy-pots and washed with water to remove adhering soil. The shoot and root lengths were recorded on the same day thereafter the fresh weight of shoots and roots were recorded. The shoots and roots of the test crops are wrapped separately in aluminum foil and placed inside the oven for 24 h at 60ºC to determine the dry weight of the crops. The biomass yield was also recorded accordingly. Percentage of inhibition/stimulation effect on germination over control was calculated using the formula given by Surendra and Pota (1978), I = 100 – (E_2 x 100/E_1), where I is the % inhibition/stimulation, E_1 the response of control and E_2 the response of treatment. Root elongation ratio of shoots and roots of tested crops were also calculated with the formula suggested by Rho and Kil (1986), R = (T/T_r) x 100, where, R is the relative elongation ratio, T is the ratio of treatment crop and T_r is the test ratio of control.

RESULTS AND DISCUSSION

Effects on shoot and root elongation of maize: The higher concentration of aqueous leaf extract showed stimulatory effect in comparison to control. The highest shoot length (3.29 cm) and root length (5.17cm) were at 100 per cent concentration. The significant inhibitory effect of aqueous leaf extract is shown only on the shoot length at 25 per cent concentration. However, at higher concentrations it significantly promoted shoot growth compared to control. No significant reduction was recorded on the root length. Maximum shoot (114.63%) and root (214.52%) elongation ratio was in 100%.

Effect on shoot and root length of rice : The shoot length of rice was not influenced significantly by the treatments in comparison to control though there was marginal effect with the application of different concentrations of aqueous leaf extracts of *F. semialata*. On the other hand, 50 per cent aqueous leaf extract caused significant decrease of root length in rice upto 41 per cent in comparison to control (Table 1). The maximum shoot (104.88%) and root (84.05%) elongation ratio was observed in 75 and 100 per cent concentration, respectively.

Effect on shoot and root biomass of maize: The higher concentrations of aqueous leaf extracts of *F. semialata* slightly favoured both above ground and below ground dry mass accumulation of maize. On the other hand, low concentrations of the extract resulted in marginal reduction in dry mass production. However, the effect was not significantly different compared to control except that the application of higher doses (75 and 100%) of the aqueous leaf extracts could significantly enhance root biomass accumulation in the test crop (Table 2). Overall, the aqueous leaf extracts of *F. semialata* did not have pronounced inhibitory effect on the biomass production of maize.

Effect of aqueous leaf extract on shoot and root biomass of rice: Aqueous leaf extract of *F. semialata* didnot have any remarkable effect on shoot biomass accumulation in rice plant. However, shoot dry matter production was significantly ($p<0.05$) stimulated by the application of 25 per cent of the

Table 1. Effects of aqueous leaf extracts of *F. semialata* on shoot length and root length of maize and rice

Concentrations (%)	Maize			Rice		
	Root length (cm)	Shoot length (cm)	Root: shoot ratio	Root length (cm)	Shoot length (cm)	Root: shoot ratio
Control	2.41	2.87	0.84	1.63	1.23	1.32
25	2.93	2.19	1.36	1.22	1.18	1.03
50	4.01	2.90	1.39	0.96	1.28	0.75
75	4.45	3.08	1.45	1.29	1.29	1.00
100	5.17	3.29	1.57	1.37	1.18	1.16
CD (p=0.05)	1.35	0.50	0.53	0.62	0.12	0.45

Table 2. Effect of aqueous leaf extracts of *F. semialata* on shoot and root biomass of maize and rice

Concentrations	Maize					Rice				
	Fresh wt.(g)		Dry wt.(g)		Root: shoot ratio (Dry wt.)	Fresh wt. (g)		Dry wt. (g)		Root: Shoot (Dry wt.)
	Root	Shoot	Root	Shoot		Root	Shoot	Root	Shoot	
Control	1.07	10.37	0.15	0.92	0.16	0.023	0.357	0.011	0.079	0.139
25	0.69	8.16	0.13	0.71	0.19	0.023	0.543	0.008	0.138	0.058
50	0.96	9.59	0.16	0.91	0.17	0.020	0.377	0.006	0.073	0.083
75	1.49	11.93	0.32	1.18	0.26	0.027	0.457	0.015	0.104	0.143
100	1.29	12.80	0.31	1.26	0.25	0.020	0.393	0.012	0.105	0.110
CD (p=0.05)	0.87	4.17	0.09	0.35	0.10	0.011	0.154	0.007	0.040	0.072

extract. About 75% increase in root biomass was recorded at this treatment compared to control (Table 2).

A stimulatory effect on the root length of maize was recorded as the concentration of leaf extracts increased. The highest root length was observed in 100% and lowest in control. This finding confirm the findings of Dhole *et al*. (2011) where stimulatory effect on seed germination, root-shoot length and seedling growth was found on the effect of aqueous extract of *Portulaca oleracea* L. on *Sorghum vulgare* Pers. and Mubeen *et al*. (2012) who found stimulatory effect on seed germination and seedling growth of rice by allelochemicals of jowar and sunflower. Similar observation was also documented by Musyimi *et al*. (2015), where the shoot height increased significantly with increasing shoot extracts of *T. diversifolia*. However this contradicts the findings of Enyew and Raja (2015), which shows that inhibitory effect on the shoot length increases when the concentrations of *L. camara* leaf powder extract were increased.

However, inhibitory effect is more pronounced in the root length of rice where maximum inhibitory effect was shown in 50% when compared to control. The findings also conform to study by Lalmuanpuii and Sahoo (2011), where the leaf extracts of Teak and subabul inhibited the radicle extension of maize. Decreased in the root length compared to the shoot length when treated with different concentration of leaf extract may be due to early exposure of radicle to plant extracts as compared to plumule during seed germination (Arora, 2013).

The shoot and root biomass of maize also increased with an increase the concentration of leaf extracts. The shoot and root biomass was maximum in 100% and 75% and minimum in 25% when compared to control. These findings are in agreement with the previous results by Bano *et al*. (2012), where neem leaf extracts significantly stimulates root growth of wild oat seedlings. The result is also in conformity with the findings by Musyimi *et al*. (2015) in which *T. diversifolia* leaf extracts stimulated shoot and root dry weights. The root biomass of rice also shows stimulatory effect as the concentration of an extracts increased but the effect was non-significant ($p < 0.05$). Maximum biomass of shoots and roots were found in 25 per cent and 75 per cent as compared to other treatments with higher concentration, however when compared to control, the overall biomass of shoot and root exhibited a stimulatory effect on leaf extracts.

CONCLUSION

The varying degree of inhibition and stimulation observed in the test crops highlights the difference in their response showing the allelopathic compatibility of *F. semialata* with commonly grown agricultural crops. The results also confirm both stimulatory and inhibitory functions of allelochemicals in *F. semialata* leaf extracts. The stimulatory effect on maize and inhibitory effect on rice growth suggests that *F. semialata* can be recommended to be used as intercrop with the former than that with the later in agroforestry systems. However, further investigation needs to be done to assess its phytotoxic behaviour and their specific role in other agricultural crops in different land use systems.

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Mechanical Characterization of Discarded Monofilament Fishnet/Glass Fiber and Polyester Hybrid Composites

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Abstract: In this study, monofilament discarded fishnets of various meshes were substituted as an alternative material for glass fiber in the polyester matrix. Mechanical properties of these materials such as tensile strength, flexural strength and impact resistance were evaluated in accordance with ASTM standards. Dynamic mechanical analyses of storage modulus, loss modulus and damping factor were performed on various composites. These analyses revealed the compatibility of glass fiber as a partial substitute for discarded fishnet in composite manufacturing. The interaction of the reinforcing fibers of fishnet/glass fiber and woven roving with the polyester matrix of composites was revealed by the images ofscanning electron microscopy. ANOVA table was used as comparative studies of the enhanced properties of glass fiber and fishnet composites. The reuse of discarded fishnet in the manufacturing of composites for automobile, structural, aeronautical and marine applications also mitigates the problem of waste disposal.

Keywords: Composites, Polyester, Mechanical properties, Dynamic mechanical analysis

Composite materials have long life, higher strength, lower weight and less maintenance. These properties have led to many engineering applications, particularly in transport and marine sectors. Composite utility significantly reduces energy consumption and the subsequent impact to the environment. Natural fiber composites are likely to be environmentally superior to glass fiber composites. It offers various advantages such as low cost, biodegradability and environmentally friendly. The use of natural fiber composites for (Sapuan *et al.,* 2005) certain engineering applications fails because certain characteristics fail to meet them. The water absorbing ability of the composites induces loss of mechanical property (Wright, 1981).

In recent years, several research programs have been carried out to develop environment-friendly composites with desirable properties. Glass fiber is non-biodegradable and involves high risk during processing. Hence, these materials are minimized for manufacturing and work environments. The glass fiber and polyester resins allow large, thick structures to be produced at reasonable cost. Now a days hybrid composites are used in various sectors because the incorporation of fibers into matrix has led to achieve advanced material property (Selvin *et al.,* 2004) with many positive attributes. However, hybrid composites should be used to meet certain specifications for specific applications. The major function of a hybrid composite is to combine the greatest mechanical behavior of brittle fibers with the admirable impact resistance of ductile fibers (Akhbari *et al.,* 2008; Wang *et al.,* 2008). The mechanical behavior of pultrudedjute/glass fiber-reinforced polyester hybrid composites showed superior strength and modulus, maintained at high temperature because of better hybridization with synthetic fibers (Hazizan Md Akil *et al.,* 2014). The sisal–jute–glass fiber reinforced polyester hybrid composites (Ramesh *et al.,* 2013) with the incorporation of fiber have improved mechanical property. The mechanical properties of the composite depend on the type of fiber, resin, their volume fraction and their production technique. However, the abaca composite is superior to hybrid composite in flexural and impact strength (Vijaya Ramnath *et al*., 2013). The bonding strength between the polypropylene and Urotropine treated jute fiber (Rezaur Rahman Md *et al*., 2008) can be improved to have better mechanical properties at higher fiber content. The impact resistance of a discarded multifilament fishnet hybrid composite has value relatively higher than those of glass fiber composite (Michael Raj et al., 2014). Monofilament fishnet is made from a single fiber of nylon. The characteristic of nylon fiber shows better processing ability, good mechanical properties and high heat resistance (Chemsystemsperp program, 2009).

In 2001, the Ministry of Maritime Affairs and Fisheries, USA reported that about 20,000 tons of discarded fishnets were collected per annum (Kim et al., 2008) and 11.5 million ton of plastic was dumped into landfill (Plastinum Polymer

Technologies, 2009). In India about 7000–8000 metric ton of nylon waste is generated every year (Keshav et al., 1991). A significant amount of solid waste is generated by fishing and port activities. Different categories of fish nets namely gill net, hand net, cast net, etc. are available in the fishing industry. Gill net is the most popular commercial fish net in the world and the meshes vary from 6 mm to 2000 mm. Monofilament fishnet is very tough and has a lesser amount of flexibility than multifilament netting (Adnan Ayaz et al., 2006). After the nets are used for fishing, say for 7–10 years, fishnets get damaged and so they are discarded.

Hence, in the present study, the static and dynamic mechanical behaviors of discarded monofilament fishnet/glass fiber/woven roving with polyester hybrid composites are observed. Morphological study of the various composites is revealed by micrograph images. Discarded fishnet is used as an alternate material of glass fiber in hybrid composites for manufacturing, marine, automobile and structural applications.

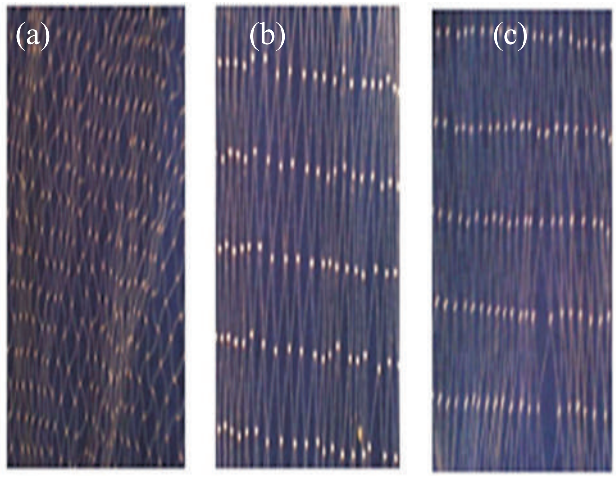


Fig. 1. Fabricated discarded fishnet of different meshes (a)–12 mm, (b)–20 mm, (c)–26 mm

Table 1. Typical properties of fabricated resources

Fabricated materials	Density [g/cm^3]	Elongation at break [%]	Young modulus [GPa]	Tensile strength [MPa]
Glass fiber	2.5	4.8	70–73	2000–3400
Nylon fiber	1.15	15 – 45	2 –4	415.7
Woven roving	2.2	1.6	15.5	260
Polyester resin	1.14	1.8	3.7	57

MATERIAL AND METHODS

Fiber preparation: Each 100 g of three different discarded monofilament fishnets (gill net),of meshes 12 mm, 20 mm and 26 mm were collected from the coastal area in Midalam, Kanyakumari district, South India. The collected fishnets were washed two times with water (pH 7.00) at room temperature (28±2 ºC) and dried in direct sunlight for 1 hour. Glass fiber and woven roving, with a grade of 300 g/m^2 and 600 g/m^2 respectively, were obtained from Binani India products, Chennai.

Treatment of fiber: The stiffness of the discarded monofilament fishnets are more when compared to that of multifilament fishnets. After the monofilament fishnets were dried, they were heated through the closed container (Hand model ironing machine 60 MW capacity) with the temperature 90–120˚C at 1–2 min and cooled through atmospheric temperature. The ironing process temperature of the fishnets varied depending on the twine diameter and mesh size. Hence, the stiffness was reduced in the discarded fishnets and arranged the knots in the direction as shown in Figure 1 and were cut into 400×400 mm using scissors.

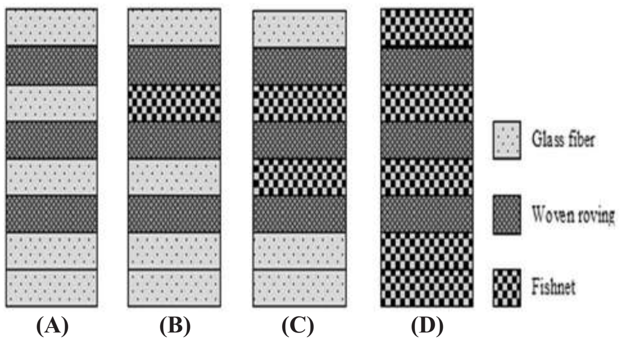
Matrix preparation: The SBA2303–Isothalic unsaturated polyester matrix was used in the fabrication process. The catalyst methyl ethyl ketone peroxide and the accelerator cobalt naphthenate were used; all those AR grade chemicals were obtained from the Ciba Gugye Limited, Chennai, India.

The properties of the materials used for composite building such as glass fiber, discarded fishnet fiber, woven roving and polyester matrix are specified in Table 1.

Preparation of specimens: The fabricated specimens of glass fiber, woven roving and discarded monofilament fishnet with polyester matrix are shown in Figure 2. The specimens were fabricated by hand lay–up method. The twine diameter of the discarded fishnet was 8.656 µm, single knotting and white in color. Fishnet layer was obtained by spreading the fishnet to stretched orientation, glass fiber and woven roving layer were obtained by spreading the mat. Polyester matrix was coated on these glass fibers, woven roving and fishnet reinforcement layers. The polyester resin applied was distributed to the entire surface by means of brush and roller. The processed composite was pressed with roller and the excess resin was removed. All the composite specimens cured at room temperature for 3–4 hr. They were dried and cut into 300×300 mm. In total, ten composite specimens were prepared.

Tensile tests: Tensile testing of composites was measured by using electronic tensile testing machine according to the ASTM D–638 with a crosshead speed of 5 mm/min and a gauge length of 100 mm. The tensile modulus and elongation at the break of the composites were calculated from the load displacement curve. Five specimens were tested for each set of samples and the mean values were reported.

Flexural tests: The flexural test was performed by the three



(GF-Glass fiber, FN-Fishnet and WR-Woven roving) (Composites (A) 5GF/3WR, (B) 4GF/3WR/1FNa–4GF, 3 WR and 1 FN layer of 12 mm mesh, 4GF/3WR/1FNb–4 GF, 3 WR and 1 FN layer of 20 mm mesh, 4GF/3WR/1FNc–4 GF, 3 WR and 1 FN layer of 26 mm mesh, (C) 3GF/3WR/2FNa –3 GF, 3 WR and 2 FN layers of 12 mm mesh, 3GF/3WR/2FNb –3 GF, 3 WR and 2 FN layers of 20 mm mesh, 3GF/3WR/2FNc –3 GF, 3 WR and 2 FN layers of 26 mm mesh and (D) 5FNa/3WR – 5 FN layers of 12 mm mesh and 3 WR, 5FNb/3WR – 5 FN layers of 20 mm mesh and 3 WR, 5FNc/3WR – 5 FN layers of 26 mm mesh and 3WR)

Fig. 2. Fabricated composite layers

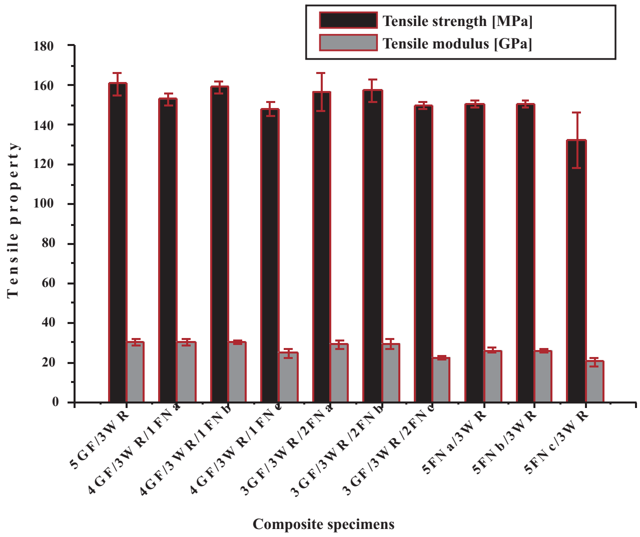


Fig. 3. The effects of the mesh sizes of the tensile properties of fishnet/glass fiber composites with polyester. Error bar represents standard deviation

points bending technique according to ASTM D-790 using the UTM TUE-CN-400 (Sl. No: 2014/136, Fine Spray Associates and Engineers, India) instrument at 28 ºC with 40 ± 2% relative humidity, and crosshead speed of 5 mm/min. The specimen was 127×12.7 mm; five specimens were tested, and the average value was calculated. The specimen was freely supported by a beam. Maximum load was applied in the middle of the specimen and the flexural modulus was calculated from the slope of the initial portion of the load deflection curve.

Impact test: The Izod impact tester (Fasne Test Equipment and Pvt. Ltd. Model No. AIT 300 N) was used to carry out in accordance with ASTM D-256. The specimen was 65×13 mm, five specimens were tested, to determine the impact resistance and impact strength of composites. The test specimen was supported by a vertical cantilever beam and was broken by a single swing of a pendulum. The pendulum stroke at the face of the specimens, the impact resistance and impact strength of the glass/fishnet fiber reinforced polyester specimens at room temperature were obtained.

Statistical analysis: The examination was carried out by T–test and Analysis of Variance (ANOVA) were performed in which process parameters are statistically significant. Probability value p = 0.05 was considered as an indication of significance compared to the composite 5GF/3WR.

Dynamic Mechanical Analysis (DMA): Dynamic mechanical analysis Q800 V20.6 Build 24, USA was used for the evaluation of loss modulus, storage modulus and damping behavior (tan δ). The heating rate used was 2 ºC/min and the frequency was 1 Hz under amplitude control. Liquid nitrogen was used as cooling agent and temperature range was from 28 ºC to 200 ºC. Only a small mesh of 12 mm was used in the fishnet incorporated composites where a thickness of 4–5 mm, width 9–10 mm and length 50–60 mm.

Scanning Electron Microscope (SEM): The surface morphology of the hybrid composites was examined using scanning electron microscope (Model: SEG100). The samples were mounted onto SEM holder using double sided electrically conducting carbon adhesive tapes to prevent surface charge on the specimens when exposed to the electron beam. The hybrid composite surfaces obtained were sputtered with gold prior to their morphological study. The microscopic images of the specimens after tensile tests were obtained from COSLAB (Model No: ZSM 116) compound light microscope with photo–capturing software.

RESULTS AND DISCUSSION

Tensile properties: The tensile strength of 5GF/3WR is 160.89 MPa and 3GF/3WR/2FNbis 160.37 MPa (Table 2). At the same time the tensile strength of the composites 4GF/3WR/1FNa, 4GF/3WR/1FNc, 3GF/3WR/2FNa, 3GF/3WR/2FNc, 5FNa/3WR, 5FNb/3WR and 5FNc/3WR has values which are not comparable to that ofcomposite5GF/3WR. Hence, it is clear that the composite with glass fiber alone has better tensile strength than the other composites and glass fiber substituted with fishnet still has values decreases. However, the statistical examination was conducted and it was found the tensile strength and modulus values. They are significant in comparison to the composites3GF/3WR/2FNa and 5GF/3WR. The significant between the population means and probability.

The interfacial bonding strength of the discarded fishnet incorporated composites is lower, because the surface of the monofilament fishnet has found some roughness (Fig. 4). However, the stretched orientation of the discarded monofilament fishnet has the bonding strength which is comparable to that of the glass fiber composites. The tensile strength of the discarded fishnet, from 12 to 26 mm mesh is more or less the same because the fishnet fiber has stretched orientation, and a similar quantity of reinforcement per unit area of the composites (fiber volume content almost same for different composites).

The microscopic images (COSLAB) reveal the adhesion of the matrix even after the breaking of the specimens, when subjected to tensile examination were found to have good interfacial adhesion of glass fiber, discarded fishnet and woven roving with polyester matrix. The fishnet-incorporated composites, subjected to tensile tests, are better adhesion than the glass fiber composite (Fig 5). Hence, the moderate decrease in the tensile properties of the discarded fishnet-incorporated composites and it is not attributed to the interfacial bonding, but the inherent tensile property of fishnet fiber alone which is obvious from Table 1.

The tensile modulus of composite 5GF/3WR has been compared to the composites 4GF/3WR/1FNa, 4GF/3WR/1FNb, 3GF/3WR/2FNa and 3GF/3WR/2FNb. However, the tensile modulus is decreased when glass fiber layers are substituted with fishnet layers. The tensile modulus is more pronounced as the number of glass fiber layers is increased. Furthermore, the density of the composites 3GF/3WR/2FNa, 3GF/3WR/2FNb, 3GF/3WR/2FNc and 5GF/3WR are more or less the same (Table 3).

Impact properties: The composites 5FNa/3WR, 5FNb/3WR and 5FNc/3WR have more fishnet fiber material added into them is obvious from the more impact strength (Fig 6). The discarded fishnet-incorporated composites 4GF/3WR/1FNa, 4GF/3WR/1FNb, 4GF/3WR/1FNc, 3GF/3WR/2FNa,

Table 2. The mechanical behavior of various layers of glass fiber/discarded fishnet and polyester composites

Composites	Tensile strength [MPa]	Tensile modulus [GPa]	Impact energy [J]	Flexural strength [MPa]	Flexural modulus [GPa]
5GF/3WR	160.89±5.77	30.32±1.706	22.56±1.178	242.14±9.99	51.55±0.987
4GF/3WR/1FNa	152.85±2.7*	30.25±1.552*	22.66±0.886*	254.6±3.48*	58.38±2.37*
4GF/3WR/1FNb	159.21±3.08*	30.21±0.57*	21.80±1.286*	258.6±3.22*	59.61±1.117*
4GF/3WR/1FNc	148.35±3.50*	24.63±1.93*	22.52±0.847*	240.12±17.5*	54.81±1.691*
3GF/3WR/2FNa	157.01±9.80*	29.18±2.18*	22.76±0.401*	267.06±4.33*	63.02±1.359*
3GF/3WR/2FNb	160.37±5.43*	29.19±2.83*	21.06±0.610*	266.56±3.86*	65.49±1.636*
3GF/3WR/2FNc	149.87±1.91*	26.68±0.855*	22.48±1.285*	255.62±2.36*	57.63±4.79*
5FNa/3WR	150.45±1.82*	25.98±1.32*	23.05±0.904*	304.44±7.73*	76.96±3.73*
5FNb/3WR	150.51±1.95*	25.99±0.861*	21.58±2.51*	303.19±10.58*	73.11±0.943*
5FNc/3WR	132.59±14.10*	20.12±2.14*	22.36±0.315*	290.89±4.28*	71.11±0.744*

GF = Glass Fiber, WR = Woven roving, FN = Fishnet, a = 12 mm, b = 20 mm, c = 26 mm mesh
The mechanical performance characterizes the mean ± standard deviation.
*Significant difference observed compared with 5GF/3WR composites (probability value p = 0.05) from T-test.

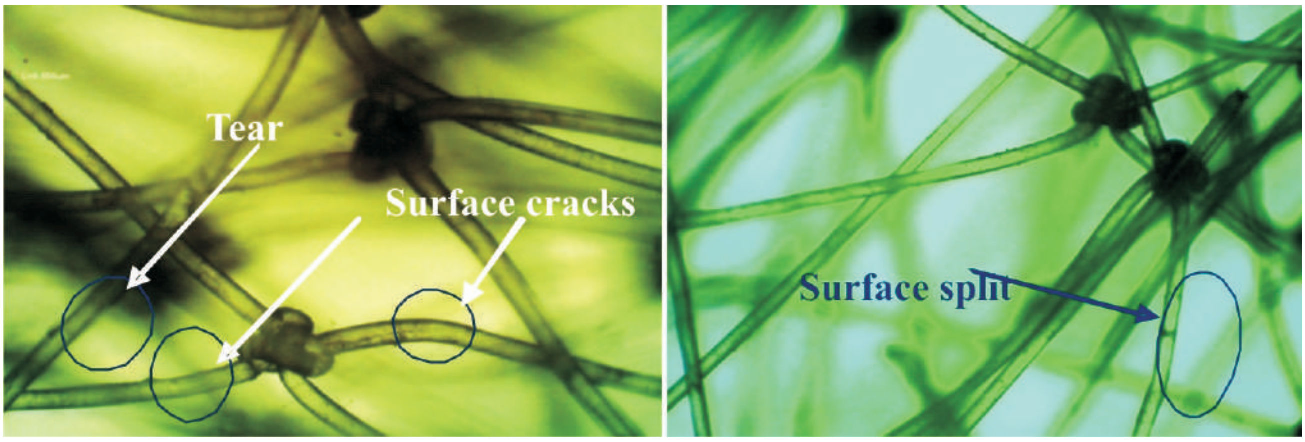


Fig. 4. Micrograph images of surfaces on discarded monofilament fishnet

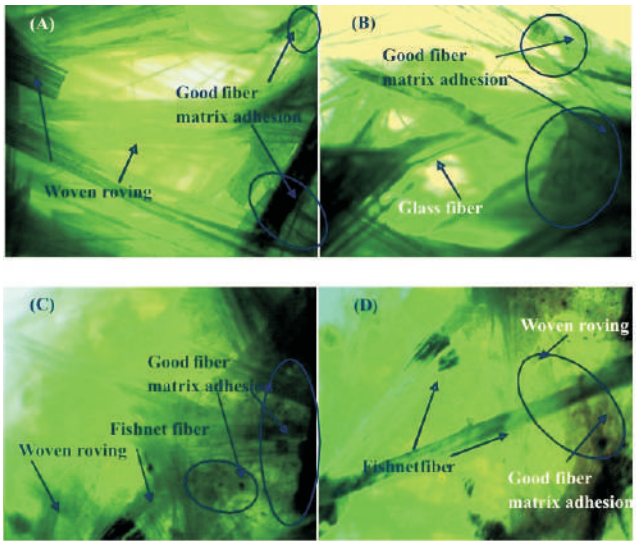


Fig. 5. The micrograph image of tensile fractured surfaces of waste fishing net/glass fiber with polyester composites.(A) 5GF/3WR (B) 4GF/3WR/1FNa (C) 3GF/3WR/2FNa (D) 5FNa/3WR

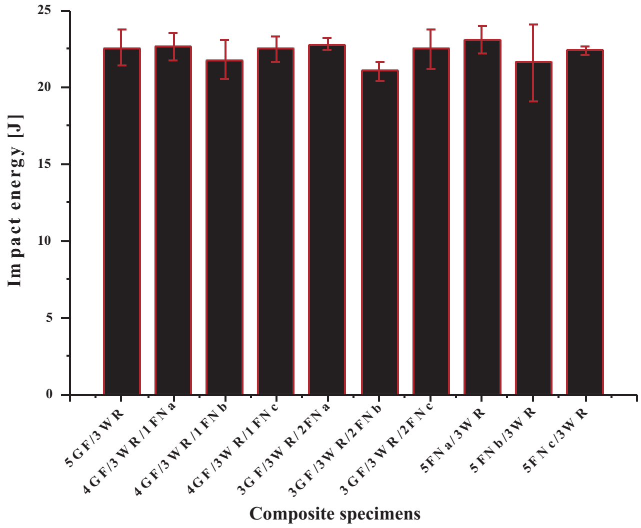


Fig. 6. An impact energy increase over composites for glass fiber/discarded fishnet and polyester specimens. Error bar represents standard deviation

3GF/3WR/2FNb and 3GF/3WR/2FNc have more or less same the impact resistance when compared to composite 5GF/3WR. Glass fiber is more brittle than fishnet fiber, which is reflected from the reduced impact resistance of composite5GF/3WR. Discarded monofilament fishnet fiber has better elastic property which aids the composite to withstand more impact load when compared to the other composites. The quantity of discarded fishnet fiber reinforcement is more in the composites and thus increases the impact resistance and improved stress transfer. The impact strength values with reference to composites3GF/3WR/2FNa was significant for all the composites (Table 2). Hence, the developed material of discarded fishnet as reinforcement can transfer stress better than the conventionally used glass fiber composite.

Flexural properties: The flexural strength of composites5FNa/3WR,5FNb/3WR and 5FNc/3WR is higher when compared to composite 5GF/3WR (Fig. 7). That adding fishnet layer into the glass fiber composites 4GF/3WR/1FNa, 4GF/3WR/1FNb, 4GF/3WR/1FNc, 3GF/3WR/2FNa, 3GF/3WR/2FNb, 3GF/3WR/2FNc and fishnet composites 5FNa/3WR, 5FNb/3WR, 5FNc/3WR has more flexural strength than composite 5GF/3WR.However, the flexural strength of discarded fishnet added into the composites has its values increased because fishnet fiber has a more elastic nature and a more flexural strength (Table 1). At the same time composites5FNa/3WR, 5FNb/3WR and 5FNc/3WR have lower density when compared to composite 5GF/3WR (Table 3).

The flexural modulus of composites 5FNa/3WR, 5FNb/3WR and 5FNc/3WR is very high when compared to the other fishnet-incorporated composites and 5GF/3WR. However, adding discarded fishnet into the composites has the flexural modulus proportionally increased. As a result, the flexural strength and modulus also depend on the orientation of the fishnet layers i.e. more quantity of fishnet fiber is available per unit area of composites. Together the glass fiber and discarded fishnet fibers have a very good adhesion behavior with the polyester matrix. The flexural properties was found to be significant in comparison to the composite 5GF/3WR.

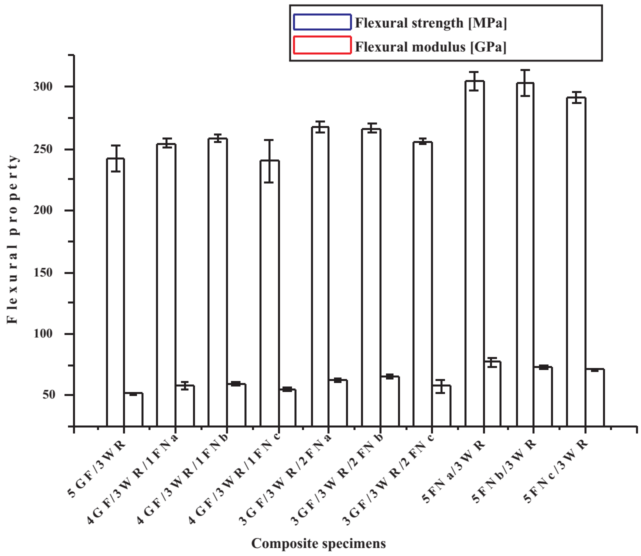


Fig. 7. Evolution of the flexural behavior of glass/discarded fishnet with polyester specimen. Error bar represents standard deviation

Table 3. Developed composites with density

Composites	Density [g/cm³]	Composites	Density [g/cm³]
5GF/3WR	1.487	3GF/3WR/2F	1.443
4GF/3WR/1FNa	1.495	3GF/3WR/2F	1.432
4GF/3WR/1FNb	1.479	5FNa/3WR	1.125
4GF/3WR/1FNc	1.486	5FNb/3WR	1.214
3GF/3WR/2FNa	1.469	5FNc/3WR	1.124

GF = Glass Fiber, WR = Woven roving, FN = Fishnet, a −12 mm b −20 mm, c −26 mm mesh

Scanning Electron Microscope (SEM) analysis

The composites have good fiber matrix adhesion from the SEM images of discarded monofilament fishnet/glass fiber and woven roving composites (Fig. 8). The SEM images show that the surfaces of the various hybrid composites have no crack/fracture. This is due to the good interfacial bonding between the discarded fishnet/glass fiber and the matrix. The polyester material also is polar in nature and therefore interaction with the matrix and reinforcements, helps to have better interfacial adhesion. This fiber and matrix interfacial adhesion is through hydrogen bonding, dipolar interactions and Vander Walls forces of attraction (Gu., 2009). The surface of the SEM observations reveals some roughness which is due to the prevalence of some air sockets occurring because of hand lay-up process. The density of glass fiber composite is more when compared to that of fishnet composites.

Dynamic Mechanical Analysis

Storage modulus (E'): The result of discarded fishnet, glass fiber and woven roving-incorporated composites on the changes in storage modulus (E')is at a frequency of 1 Hz. The value of storage modulus, found to be higher for composite 3GF/3WR/2FN, is 11482MPa, followed by glass fiber composite 5GF/3WRwith6854MPa, which has more difference in the values of storage modulus at lower temperature i.e. in the plastic region. Storage modulus for pure fishnet composite 5FN/3WR at 28.28 ˚C is 6724MPa whereas one layer fishnet added to the glass fiber composite 4GF/3WR/1FN has 10706MPa. However *E'* of the composites 4GF/3WR/1FN and 3GF/3WR/2FN has values more than that of composite 5GF/3WR. However, the increase in storage modulus is attributed to the presence of monofilament discarded fishnet in the composites which have more *E'* than the glass fiber composite.

The performance of reinforcement of the composites reveals that the fishnet-incorporated composites are more efficient reinforcement than glass fiber composite which has increased with added fishnet in place of glass fiber. However, the stiffness of the composites depicted in Figure 9 suggest that fishnet can be a good substitute for glass fiber.

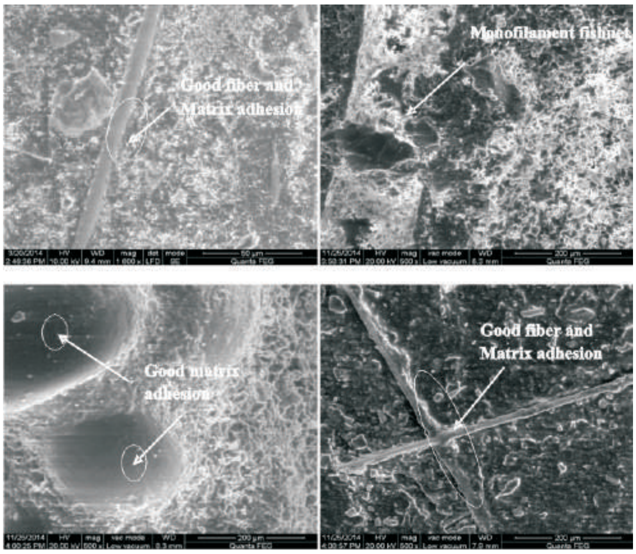


Fig. 8. SEM image of surfaces for glass fiber/fishnet composites

Therefore, the addition of fishnet as well as glass fiber has induced good stress transfer and matrix adhesion because more fishnet fiber is added into the composites at stretched orientation in the fabrication process.

Loss modulus (E"): The viscous response of the composites with respect to temperature is called the loss modulus. The molecular motions of the composites are governed by loss modulus as depicted in Fig. 10. The variation of E" for glass fiber and fishnet composites as the function of temperature is at a frequency of 1 Hz. It is obvious that loss modulus increases up to a temperature and then decreases. The value of E" depends upon the form and the ability of reinforcement. The values of E" are found to vary much for different composites and the values of Tg. The loss modulus curve for fishnet-incorporated composites

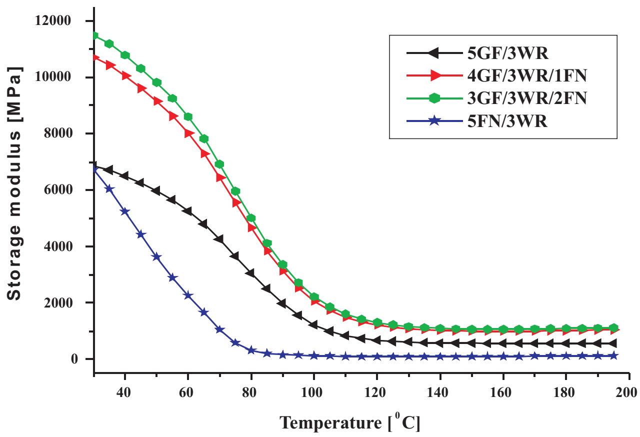


Fig. 9. Typical storage modulus curves as a function of temperature

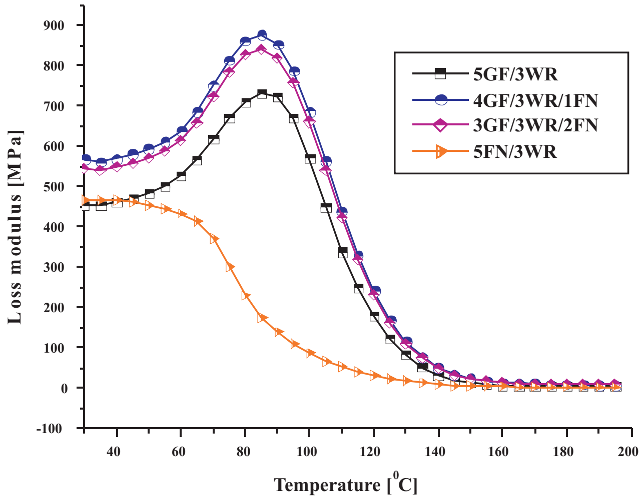


Fig. 10. Deviations of loss modulus with temperature for glass fiber and fishnet composites

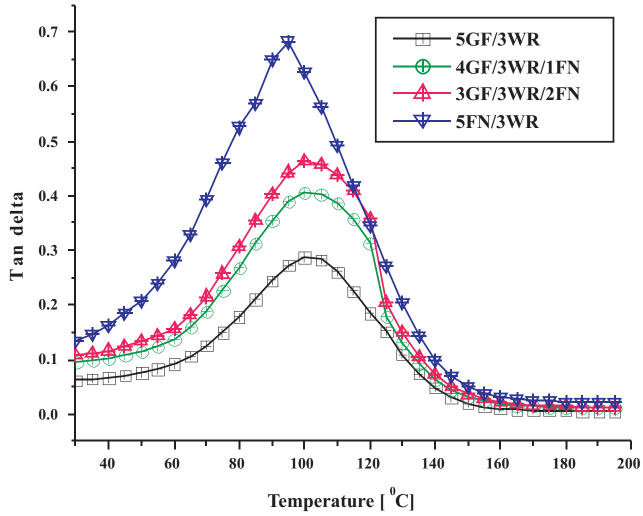


Fig. 11. Variations of damping factors with glass/fishnet fiber content for different composites

broadens depending on the number of layers; 4GN/3WR/1FN and 3GF/3WR/2FN have the maximum broadening effect. The broadening is due to the variation in the physical state of the matrix surrounding the reinforcing fibers. E" indicates Tg values of the composites 4GF/3WR/1FNand 5GF/3WR are84.65 ºC and 88.83 ºC respectively. However, the fishnet composite 5FN/3WR has the values of the Tg which is less when compared to those of the composites 5GF/3WR, 4GF/3WR/1FN and 3GF/3WR/2FNas shown in Table 4. The low Tg of the fishnet composite has relatively smaller interaction with the matrix than glass fiber.

It is reported that 5GF/3WR, 4GF/3WR/1FN and 3GF/3WR/2FN have better composites than composite 5FN/3WR. The loss modulus value is changed and the same trend of Tg, which is attributed to the increased rigidity of the composites resulting from stronger interface interaction with the reinforcement and matrix. Therefore, composites 5GF/3WR, 4GF/3WR/1FN and 3GF/3WR/2FNhavenearly by the same values of loss modulus.

Damping factor (tan δ): Damping factor is the ratio of loss modulus and storage modulus. This behavior of the composites will affect the incorporation of fiber into the matrix of hybrid structures. The value of tan δ is found to depend on the amount of fiber and matrix adhesion (Fig. 11). However, the stress concentrations of the fibers and viscoelastic energy dissipation in the matrix result in the changes of tan δ. The weaker fiber matrix adhesion will result in the upper values of tan δ. Therefore, reduced damping factors proportional to the good mobility of the polymer, reveal the fiber matrix adhesion. Low tan δ value means that a composite has an exact good load bearing capacity. This study reveals that various

Table 4. The values obtained from DMA study

Composites	Tg from *E'* curve (ºC)	Tg from *E"* curve (ºC)	Tg from tan δ curve (ºC)	Peak height of tan δ curve
5GF/3WR	36.102	88.83	104.39	0.2919
4GF/3WR/1F	34.65	84.65	101.96	0.4076
3GF/3WR/2F	35.55	85.56	100.60	0.4574
5FN/3WR	28.83	48.42	95.16	0.6814

GF = Glass Fiber, WR = Woven roving, FN = Fishnet

composites; damping factor is very high for fishnet composite 5FN/3WR while it is low for glass fiber composite 5GF/3WR. The incorporation of fillers into a matrix may increase or decrease the mechanical damping (Geethamma *et al.*, 2005).

CONCLUSIONS

Investigation of various composites reveals that the partial substitution of the monofilament discarded fishnet into glass fiber composite (5FN/3WR) improves the mechanical properties appreciably higher than the conventionally used glass fiber composite 5GF/3WR. The adhesion of the glass/fishnet fiber and woven roving along with matrix is very good. Statistical examinations was carried out using composite 3GF/3WR/2FNa has the values significant in comparison to the composite 5GF/3WR.

The storage modulus of composites 4GF/3WR/1FN and 3GF/3WR/2FN have a comparable value with respect to glass fiber composite 5GF/3WR. Loss modulus decreases with decrease in fishnet layers and the broadening of curves is also observed. Loss modulus and damping values of glass fiber composite 5GF/3WR are compared to composite 4GF/3WR/1FN.

Therefore, reuse of the monofilament discarded fishnet is partially substituted glass fiber composite can serve as an alternate material for making composites and also helps with the problem of waste disposal.

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Biofouling on Cages in Chhirpani Reservoir, Kabirdham (Chhattisgarh) India

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Abstract: Cage aquaculture is becoming best way for better utilization of underutilized reservoir resources in the country. Chhattisgarh is the first state to initiate cage culture in reservoirs having 1,638 numbers covering 84,400 ha water area. Chhirpani reservoir was constructed on the river Phonk in Kabirdham District and it is the second reservoir in Chhattisgarh used for cage culture of Pangasius after Saroda reservoir in the same district. Biofouling is one of the main problem commonly encountered in cage culture system causing severe economic loss by blocking nets resulting into destruction of net and loss of stock. The present study reports the incidence of biofouling in cages installed in Chhirpani reservoir and its effect on fish stock. The patches of biofoulers on cage nets were found to be spread up to 30 cm diameter affecting water movement. Qualitative analysis of biofoulers revealed that Bryozoans were dominant (60%) among all the groups followed by crustaceans (20%), green algae (12%) and blue green algae (8%). The maximum average net fouling wet weight observed among the net panel was > 3.5 kg / m^2. Mortality of fish stock was observed due to low dissolved oxygen (3.5mg l^{-1}) in cages of higher growth of biofoulers and restricted water exchange.

Keywords: Biofouling, Bryozoan, Cage culture, Chhattisgarh, Reservoir

Recently, cage aquaculture in reservoirs is gaining lot of momentum in India for intensive fish culture. Chhattisgarh has taken keen interest and lead in implementation of cage farming in reservoirs. The state is bestowed with 1,53,873 ha water spread area available for fish production in the form of reservoirs, ponds, tanks with a total fish production of 2.85 lakh tonnes. About 83, 873 ha (54.51 %) of water spread area is in the form of reservoirs contributing 0.6710 lakh tones only. Average production levels in large, medium and small reservoirs is 2.6 kg ha^{-1} year^{-1}, 29.55 kg ha^{-1} year^{-1} and 69 kg/ha/year respectively. Large and medium reservoirs (43.28%) are underutilized and offer great potential for cage culture. Presently, at six different locations cage farming is practiced in the state. Pangassius (*Pangasianodon hypophthalmus*) is the preferred cultured species in the cages.

Biofouling is a very common and recurring problem in cage aquaculture worldwide both in freshwater and marine environment. Fouling on cages will lead to reduction of water flow through the net and affect oxygen supply, waste removal and the susceptibility of cultured fish to diseases (Cheyne, 2010). The occlusion and increased weight of the net can also negatively affect cage structure and stability (Hodson *et al.,* 2000). These conditions cause high mortality in the cultured fish. Two types of fouling organisms are found on cages: micro fouling and macro fouling, which consists of flora and fauna that attach and grow on the net cage. The biofouling communities that develop on cages are dominated by bryozoans, hydroids etc., depending on availability of light and algae (Braithwaite and McEvoy, 2005; De Nys and Guenther, 2009; Durr and Watson, 2010; Fitridge *et al.,* 2012).

Understanding the composition and dynamics of biofouling in cages is important for better management purposes like application of suitable antifouling agents, because the biofouling organisms vary greatly in their reaction and sensitivity towards different antifouling agents (WHO, 1952; Magin *et al.,* 2010; Ralston and Swain, 2011; Scardino and De Nys, 2011). The main strategy followed in cage aquaculture to reduce net biofouling is based on the use of copper‑based antifouling coatings on nets (Braithwaite *et al*., 2007) due to progressive wear and leaching of the copper, and are therefore combined with regular *in situ* washing of the nets (Olafsen, 2006). Washing removes much of the biofoulings (Guenther *et al.,* 2010) and is generally conducted at every 2 weeks (summer) to eight (winter), but can occur as often as weekly during periods of high biofouling pressure. It is also important to understand the factors that influence biofouling abundance and composition on individual cage farm to optimize the maintenance and management strategies.

The present study was conducted to analyze the composition of biofouling agents, intensity of fouling organisms and their relationship with existing physico‑chemical parameters in cages at Chhirpani Reservoir, Kawardha, Kabirdham District, Chhattisgarh.

MATERIAL AND METHODS

The study was carried out for one year (July, 2013 to July, 2014) on cages located at Chhirpani reservoir (450 FRL) built on river Phonk in Kabirdham district of Chhattisgarh, India (latitude: 2°12'08.91"N and longitude: 81°11'47.47"E) (Fig. 1). The water depth at the site varied between 15 to 30 m depending on season. Forty eight cages (Size: 6 x 4 x 4 m) made of HDPE were installed in the reservoir since 2012. Fingerlings (Avg. length: 80-90 mm, Avg. body weight 40.3 g) of striped catfish (*Pangasianodon hypophthalmus)* were stocked @ 52 No. m^{-3} with a total cage volume of 4608 m^3 on July 15, 2013.

Sample collection and analysis: Biofouling started appearing on cages after few months of installation. Hence, the samples of biofouling communities accumulated on the cage net were collected for quantitative and qualitative analysis of flora and fauna associated with bio fouling. The biofoulers were analyzed using a Stereo-Microscope (Nikon E200) fitted with a digital camera. Qualitative and quantitative analysis of the sample was done.

Water samples were collected at fortnightly intervals for analysis of physico-chemical parameters *viz.* temperature, transparency, hardness, alkalinity, pH, dissolved oxygen, ammonical-nitrogen, nitrate-nitrogen, nitrite-nitrogen, ortho-phosphate and biochemical oxygen demand (BOD) (APHA, 1998). The data was analyzed by using statistical analysis tool.

RESULTS AND DISCUSSION

Qualitative and quantitative estimation of biofouling: Five major groups were identified on 240 net panels, which included bryozoans (*Cordylophora)*, crustaceans (Cyclops, Cypris, Daphnia, Diaptoma, Keratella sp.), green algae (Chlorella, Spirogyra) and blue green algae (*Anabaena, Nostoc sp.*) (Fig. 2). Bryozoans (Fig. 3) were the dominant (60%) among all the groups followed by crustaceans (20%), green algae (12%) and blue green algae (8%) (Table 1). The colonies of biofoulers were spread up to 30 cm diameter on cage net affecting water movement. The maximum average net fouling wet weight observed among the net panels was > 3.5 kg/m^2 during the 12 months of study period. Braithwaite *et al.* (2007) recorded 4.5 kg/m^2 biofouling wet weight average on untreated nylon nets following 10 months of immersion.

Analysis of physico-chemical parameters: The biofouling development on net surface is the result of several physico-chemical parameters. Temperature is a limiting factor in an aquatic environment. The highest temperature was recorded in May (31.5°C) and the lowest in December (20.3°C). Variation in light availability and change in temperatures results in year round high pressures of fouling on cage net. In the present study, the high pressure of fouling was observed in January, which is in conformity of the studies done by Braithwaite and McEvoy (2005); De Nys and Guenther (2009); Hellio (2010). The maximum transparency was recorded during December (38.17cm) while it was lowest in

Fig. 1. Cage site at Chhirpani reservoir, Kabirdham (Chhattisgarh)

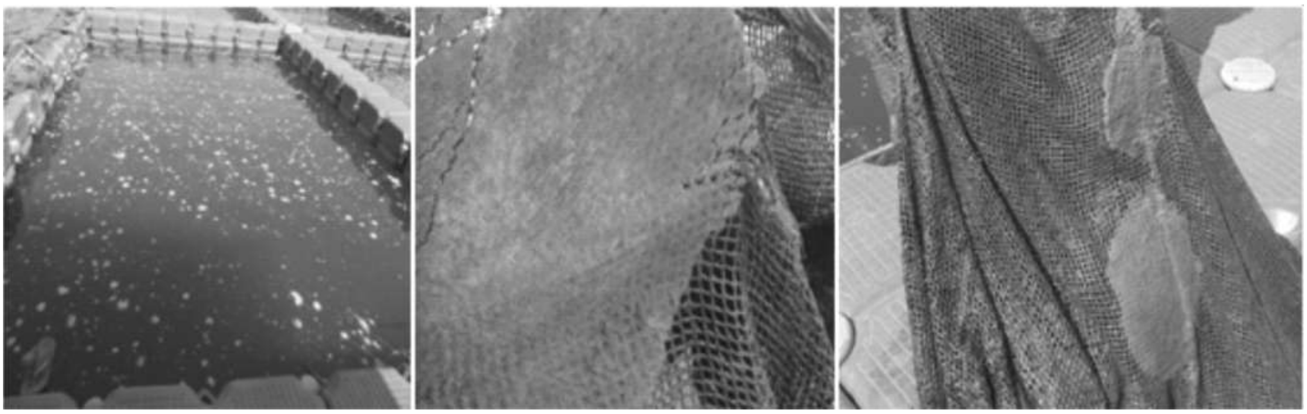

Fig. 2. HDPE cage used for fish culture and Colony of biofouling on cage net

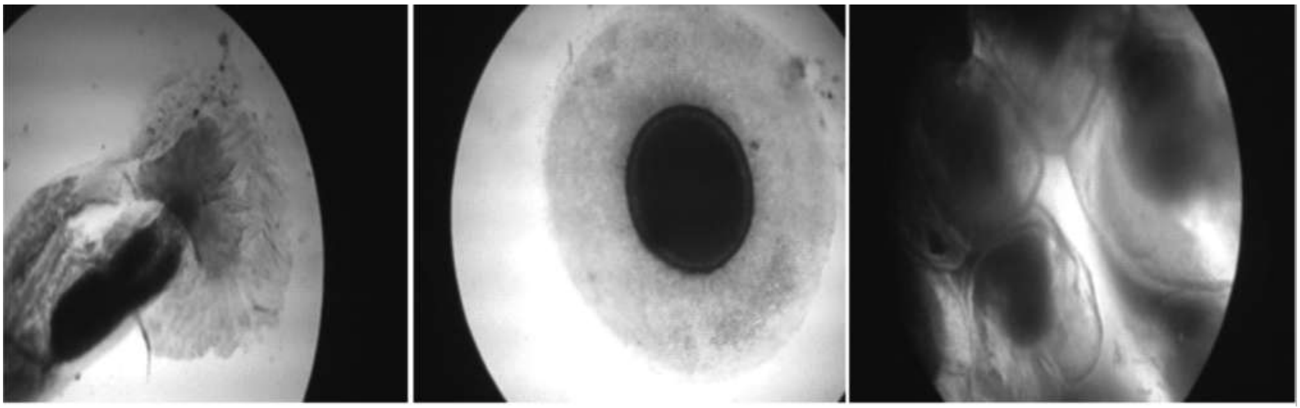

Fig. 3. Bryozoans (Hydroids)

Table 1. Composition of biofouling organisms

Major Groups		Species	Composition (%)
Green Algae	*Chlorophycea*	Chlorella,	12
Blue Green Algae	Cyanophyceae	*Anabaena, Nostoc sp.*	8
Crustaceans	Rotifera	Keratella sp.	20
	Ostracoda,	Cypris	
	Cladoceran	Daphnia	
	Copepod	Cyclops, Diaptoma	
Bryozoans	Hydroids	*Cordylophora*	60

October (23cm). Accumulation of biofoulers may be started in December and made high pressure in January. High alkalinity was observed in January (147.5 mg l^{-1}) while the lowest in August (84 mg l^{-1}). Mean ammonia level was 0.06 mg/l throughout the study period. Unionized ammonia is more toxic than ionized ammonia. Fish continuously exposed to more than 0.02 mg l^{-1} of the un-ionized form may exhibit reduced growth and increased susceptibility to disease. The average Nitrite concentration was 0.06mg l^{-1}. Nitrite is toxic to fish leading to growth reduction and its adverse effect makes fish susceptible to various diseases.

Concentration of dissolved oxygen level below 3 mg/l can stress fish and below 2 mg l^{-1} can increase the mortality of fish. The lowest dissolved oxygen was recorded in January (3.5mg l^{-1}) due to higher growth of biofouler communities and restricted water exchange that has lead to mortality of fish in large quantity. The highest dissolved oxygen was noted in the November (6.2 mg l^{-1}). BOD varied throughout the year ranging between 38 to 52 mg l^{-1}. The highest BOD was recorded in the December due to formation of biofoulers and lowest in September. The highest dissolved organic matter (DOM) was in the January (2.52 mg l^{-1}) and the lowest in the May. The highest orthophosphate value was recorded in February (0.55 mg/l) and lowest in December (Table 2). The main impact of cage aquaculture is the increase in the load of N, P and organic matter that enrich water leading to growth of biofoulers. The effect depends primarily on the annual fish production, area and depth of the reservoir and water residence time (Guo and Li, 2003).

Table 2. Physico chemical parameters

Parameters	Minimum	Maximum	Mean±SD
Water temperature	20.50	31.50	26.88±3.53
Transparency (cm)	23.00	38.17	33.28±4.58
Total hardness (mg/l)	105.50	180.50	137.15±22.83
Alkalinity (mg/l)	84.00	147.50	106.79±20.43
Dissolved oxygen (mg/l)	3.50	6.20	5.23±0.69
pH	6.30	7.97	7.17±0.59
BOD (mg/l)	38.00	52.00	43.77±4.83
Dissolved organic matter (mg/l)	1.95	2.52	2.24±0.19
Nitrite nitrogen (mg/l)	0.02	0.09	0.06±0.02
Nitrate nitrogen (mg/l)	0.24	0.86	0.40±0.18
Ammonical nitrogen (mg/l)	0.05	0.08	0.06±0.01
Total ortho-phosphate (mg/l)	0.23	0.55	0.44±0.10

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Synthesis and Mycocidal Evaluation of Hybrid 1,2,4-Triazolylcarbamodithioates against Phytopathogens of Wheat

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Abstract: A novel series of triazole and dithiocarbamate hybrid molecules (1–10) were evaluated for their antifungal potential against phytopathogenic fungi of wheat *viz. B. graminis, P. striiformis, P. triticina* and *U. tritici* by spore germination inhibition technique using Vitatvax Power (Carboxin 37.5% + Thiram 37.5%) and Tilt 25–EC (Propiconazole) as standard. All the test compounds inflicted moderate to promising results with ED_{50} values varying from 100 to 500µg/mL, which was comparative or better than standard against *U. tritici.* Structure Activity Relationship (SAR) favoured the presence of benzene ring on S–side of carbamodithioate and the toxicity analysis indicated at par nature of the compounds with the standard fungicide.

Keywords: Carbamodithioates, Triazole, Antifungal, Phytopathogenic fungi, Wheat

Wheat is one of the staple cereal food crops consumed in most parts of the world but the production of crop is threatened by several disease causing agents. *Blumeria graminis* (powdery mildew), *Puccinia striiformis* (yellow rust), *Puccinia triticina* (brown rust) and *Ustilago tritici* (loose smut) are the serious pathogens of wheat that are significantly downgrading the quality and yield of the crop. The rusts are the major diseases of the wheat due to their ability to overcome so many different resistant cultivars leading upto 70 per cent loss annually (Dean *et al.,* 2012).Chemical control strategies were most commonly employed to fight the menace but the rising dominance of resistances to various commercially used agrochemicals, are posing threat to existing food security (FRAC code list). Combination of fungicides have long been recognized to eradicate the fungal attacks especially at the time of sudden and severe outbreaks (Fravel, 2005), but incompatibility of different fungicides (Jyothsna *et al.,* 2013) with each other generally leads to their physical inactivation after mixing. Therefore, accelerated efforts towards lead hybridization (combining different leads in single molecule) for the development of novel analogues of existing lead, is gaining strength as one of the most prominent area of agrochemical research.

1,2,4–Triazole and dithiocarbamates belong to one of the heavily used classes of fungicides which play a pivotal role for fungal control. Variety of 1,2,4–triazole and dithiocarbamate analogues are in commercial use and occurrence of resistance against the 1,2,4–triazole fungicides and non–systemic action along with high effective dose ratio of dithiocarbamates, demands their novel analogues for their broad spectrum of activities (Chai *et al.,* 2010).

Continuing our efforts towards synthesis of novel hybrid molecules with broad spectrum antifungal potential (Sidhu and Kukreja, 2015; Kukreja *et al.,* 2016; Gumber *et al.,* 2015; Sidhu *et al.,* 2016), present study was planned to combine dithiocarbamate with 1,2,4–triazole in a single molecule to afford series of 1,2,4–triazolyldithiocarbamates, as resistance measure against 1,2,4–triazole fungicide. The synthesized molecules were evaluated for their mycocidal potential against various phytopathogenic fungi *viz. B. graminis, P. striiformis, P. triticina* and *U. tritici*. The results of mycocidal potential were compared with commercial standards Tilt 25–EC (Propiconazole) and Vitavax power (Carboxin 37.5% + Thiram 37.5%), to observe the effect of the combination.

MATERIAL AND METHODS

Collection of the infected samples: Naturally diseased samples of wheat were collected from the plants showing high severity of the diseases on the susceptible wheat genotypes in experimental areas of Punjab Agricultural University, Ludhiana. The spores of the four test fungi *viz. B. graminis, P. striiformis, P. triticina* and *U. tritici* were used as such without culturing for testing.

Synthesis of 1,2,4-triazolylcarbamodithioates: Series of 1,2,4–triazol–4–ylcarbamodithioates (1–10) was synthesized by a two–step reaction protocol. In first step, to a solution of 4–amino–1,2,4–triazole (4.2 g, 0.05 mol) in DMF 5 mL of aqueous solution of sodium hydroxide (10 N) was added and the mixture was cooled and stirred followed by addition of carbon disulphide. The yellow solution obtained was stirred for 2 hrs at room temp. The product so formed was precipitated out by diethyl ether and filtered to obtain the pure salt of sodium 1,2,4–triazol–4–ylcarbamodithioate (a). In second step, alkyl/allyl/benzyl/sulphonyl halide (0.01 mol) were added drop wise to sodium 1,2,4–triazol–4–ylcarbamodithioate (a) (0.01 mol) dissolved in methanol and the mixture was stirred until the new spot appeared on the TLC. The solvent was removed under reduced pressure and the solid was washed with cold water to remove the salt impurities. The crude solid was recrystallized from dichloromethane to get a series of substituted 1,2,4–triazolylcarbamodithioates (1–10).

Preparation of stock solution: The stock solutions (2000 µg/mL) of each compound and standard Tilt 25–EC (Propiconazole) and Vitavax power (Carboxin 37.5% + Thiram 37.5% Carboxin 37.5% + Thiram 37.5%) were prepared by dissolving each chemical (20 mg) in 1 mL of Tween 20 (polyoxyethylene sorbitan) and volume was made 10 mL with sterilized distilled water. The stock solutions of 2000 µg/mL of each compound, thus prepared on active ingredient basis were kept in refrigerator till further use. The required dilutions of 1000, 500, 250, 100, 50, 25 and 10 µg/mL were subsequently made from the stock solution by adding distilled water as and when required.

Spore germination inhibition technique (Devi and Chhetry, 2012): Spore suspension was made by adding sterilized distilled water to the fresh spores of respective fungi. Suspension was filtered through three layers of sterilized cheese cloth in order to remove other unwanted particles under aseptic conditions. Haemocytometer was used to form standardized spore suspension (1 x 10^6 spores/mL). Small droplets (0.02 mL) of test solution and spore suspension in equal amount were seeded in the cavity of the cavity slides. These slides were placed in Petri plates lined with moist filter paper and were incubated at 15±1˚C for appropriate time. The numbers of spores germinated were counted and per cent spore germination inhibition was calculated over control. The percent spore germination inhibition was recorded from the average of three replicates. The inhibition data was subjected to probit analysis for calculating median effective dose (ED_{50}) (Finney, 1971).

In silico Lipinski filtration: Molinspiration, a web based software, was used to obtain the Lipinski's parameters (Lipinski *et al.*, 1997). The analysis involved the computer aided two steps, to draw the geometrically optimized structure of the molecule followed by its conversion into SMILES (Simplified Molecular–Input Line–Entry System) format and calculation of molecular descriptors. The structures of the molecules were drawn in Chem Draw Ultra 10.0 and saved as .mol file formats. The.mol file formats were then converted into SMILES format using Online SMILES Translator and Structure File Generator.

The various pesticide like descriptors were then obtained using the software (Avram *et al.*, 2014). The parameters chosen are logP, where P is the partition coefficient in n–octanol/water system that reflects the overall lipophilicity of a molecule, a property of major importance in biochemical applications. The molecular weight defines the effect of size of the molecule on its biological activity. The number of hydrogen donors (nOHNH) and hydrogen acceptors (nON), to determine the upper limits for the biomolecules to be able to penetrate through biomembranes.

Upper limits of these molecular descriptors were established based upon a set of known drugs, i.e., molecular weight $\leq$500, log P $\leq$5, number of hydrogen bond donor (nOHNH $\leq$ 5) and number of hydrogen bond acceptors (nON$\leq$ 10). Molecules that obey these rules should exert acceptable solubility and cell permeability properties and were defined as 'pesticide–like' (Tice, 2001).

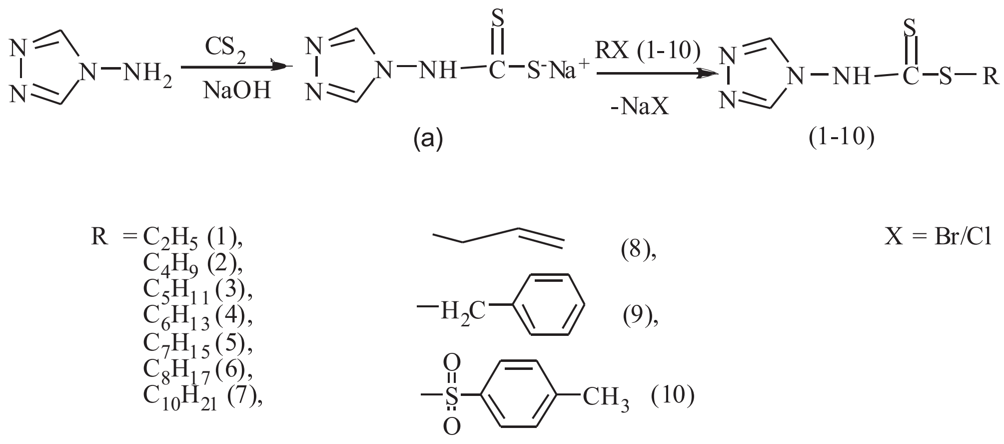
***In silico* toxicity analysis:** In order to find out the toxic hazards of all the synthesized compounds, two dimensional models of the compounds were first converted into its *simplified molecular-input* line–entry system (SMILES format) using an online SMILES translator. Then simply putting the SMILES code into the chemical identifier row available in the Toxtree software we can easily get the toxic characters (Puratchikody *et al.*, 2012).

RESULTS AND DISCUSSION

The 1,2,4–triazol–4–ylcarbamodithioates (1–10) were synthesized by two step reaction protocol. The synthesis of dithiocarbamate sodium salts by reaction of 4–amino–1,2,4–traizole with carbon disulphide under basic conditions was followed by their reaction with different alkyl/allyl/benzyl/sulphonyl halides to obtain the respective final products (1–10) (Scheme 1).

Investigation of antifungal screening revealed that most of the synthesized compounds showed promising to moderate inhibition of germination of fungal spores against all the test fungi (Table 1). Against *B. graminis* and *P. striiformis,* all the compounds inflicted moderate fungitoxic potential but comparatively less potent than the standard triazole fungicide Tilt 25–EC, whereas, in case of *P. triticina,* the results were favourable with compound 5 and 10 showing the fungitoxicity comparable to standard. Against *U. tritici,* compound 4, 7, 8, 9 and 10 showed the most significant results, better than the standard Vitavax power (seed treatment fungicide), with ED_{50} values 100, 120, 135 and 150 µg/mL, respectively.

Overall, compound 10 was considered to be universally active against all the test fungi, whereas the compound 4 and 8 had exceptional results against *U. tritici*.



Scheme 1. Synthesis of dithiocarbamate derivatives of 4-amino-1,2,4-triazoles

Table 1. Antifungal potential of the synthesized compounds against various phytopathogenic fungi ED_{50} (µg/mL)

Compound	*B. graminis*	*P. striiformis*	*P. triticina*	*U. tritici*
1	372	375	320	250
2	250	375	800	375
3	248	450	390	350
4	300	350	400	100
5	350	375	120	500
6	400	350	375	400
7	425	400	450	200
8	375	350	350	120
9	350	375	400	135
10	200	300	160	150
Vitavax power*	–	–	–	200
Tilt 25-EC*	35	48	45	

*Standard fungicide against *B. graminis, P. striiformis, P. triticina,* and *U. tritici*

Table 2. Lipinski parameters of compound (1-10)

Compound	Log P	Molecular weight	nON	nOHNH
1	0.89	188.28	4	1
2	1.79	216.34	4	1
3	2.21	230.36	4	1
4	2.63	244.39	4	1
5	3.04	258.42	4	1
6	3.46	272.44	4	1
7	4.30	300.50	4	1
8	1.24	200.29	4	1
9	2.28	250.35	4	1
10	2.25	314.42	6	1
Propiconazole	3.64	342.43	5	0
Carboxin	-1.41	159.21	3	1

Lipinski's rules are considered to be the reference in defining physicochemical and structural properties profiles for optimal bioavailability of agrochemicals. Results indicated that all the synthesized compounds had followed the rules of Lipinski filtration and results were at par with the standard fungicides (Table 2). The favourable log P values was the index that these novel test compounds can be systemically translocated in the plant system and their optimum H donor and acceptor tendencies were the indication of their optimum fitting into the fungal enzyme's active sites. The optimum molecular weight can also be correlated with their simple synthetic design and therefore, a step towards green chemistry.

Estimation of toxic hazards was carried out using Toxtree v.2.6.6 software, showed that compounds belong to class III level of toxicity (High toxicity) according to Cramer's rule (Cramer *et al.,* 1978), which was same as that of the toxicity level of standard fungicides.

The use of ISS rule for understanding the carcinogenic effect of the molecules indicated that all the 1,2,4-triazole analogues with lower alkyl chains (1-3) did not show any genotoxic or non-genotoxic carcinogenicity, whereas, compound 4-10 showed some structural alerts for non-genotoxic effects (Benigni *et al.,* 2013).

Biodegradability studies of the series showed that the triazole derivatives are persistent chemicals and this property is at par with the standard tilt, whereas, chemically, molecules were considered to be biodegredable because of the presence of carbamodithioate moiety, which is easily decomposed in slightly acidic pH of the soil (Humeres *et al.,* 1999). Since DTCs are easily degradable this combination has better chance to get degraded with better mammalian tolerance than other commercially used triazole derivatives.

The carbamodithioates also revealed favourable log P value showing their better chances to be used as systemic action, though presently it is used for surface action only. Data mining indicated that the overall results showed positive impact of combination of dithiocarbamate with 1,2,4–triazole in comparison to the standard DTC fungicides in terms of bioactivity and physiological properties, and the results were much better than the previously reported DTCs of benzothiazol–2–amines (Sidhu *et al.,* 2016). Structure activity relationship also endorsed the attachment of benzene ring on the S side of the DTC that caused increased aromaticity, which favourably influenced the activity against various test fungi. The results are in consonance with the earlier studies made by Sidhu *et al.* (2011).

CONCLUSION

High antifungal potential of the synthesized novel series endorsed the concept of lead hybridization in the case of 1,2,4–triazole and dithiocarbamate. Thus, 1,2,4–triazol–2yldithiocarbamates could be used as interesting motif for further studies against other phytopathogenic fungi for their evolution as broad spectrum fungicides for agricultural use.

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Prevalence and Severity of Rhizoctonia Aerial Blight of Soybean in Uttarakhand

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Abstract: In order to find disease prevalence, nine districts of Uttarakhand was surveyed for three consecutive years 2013, 2014 and 2015. Soybean crop was distributed in almost all districts of the state but the disease was prevalent only in foot hills regions i.e. Udham Singh Nagar, Nainital and Dehradun. The disease incidence and severity reduced with increasing altitude. The maximum per cent disease incidence and severity were severe in Zone I (Udham Singh Nagar) ranging between 26.00 to 59.66 on foliage, which primary depicting the congenial environmental conditions for disease development and spread. Pantnagar was observed as the hot spot for RAB having maximum disease incidence and severity.

Keywords: *S*oybean, Rhizoctonia aerial blight, Survey, Uttarakhand

Soybean [*Glycine max* (L.) Merr.] ranks first among oilseed crops in the world as well as in India contributing about 25% to the total edible oil production. It is grown extensively in Uttarakhand but lack of its high-yielding varieties and biotic stress agents is one of the major cause of low production. Soybean is a high value crop with multiple food, feed and industrial uses and has a great potential to play an important role in crop diversification in the state. The average national yield of the crop (104.80 t ha^{-1}) against 479.19 t ha^{-1} of the world average (USDA, 2015). Uttarakhand is a soybean surplus state. The production and productivity is likely to increase substantially in view of introduction of improved high yielding hybrids from the public and private sector. Losses due to various diseases are one of the major causes for reducing the national productivity of the soybean in India, which is half the world average. The occurrence and severity of the diseases and resultant losses are dependent on the prevailing agro-climatic conditions and varieties grown in an area. In Uttarakhand, major diseases of soybean are bacterial pustules, pod blight, yellow mosaic virus, rhizoctonia aerial blight and bud blight (Lamani *et al*., 2003; AICRP, 2016). Amongst them the disease caused by RAB is economically more important because they cause heavy yield losses. Rhizoctonia aerial blight develops most often during periods of high rainfall predominantly in Uttarakhand, Chhatisgarh and Madhya Pradesh. It has caused extensive yield loss especially in Madhya Pradesh (Wrather *et al.*, 2010). Keeping this in view, extensive surveys were undertaken in subtropical low and foot hill/mid hill areas of Uttarakhand to know the prevalence and distribution of RAB.

MATERIAL AND METHODS

Random surveys for Rhizoctonia aerial blight (RAB) were carried out in predominant soybean growing districts of Uttarakhand region during 2013-2015. Two agro-climatic zones I (low hills, sub tropical zones, foot hills) and zone II (mid-hill zone) covering important soybean growing districts (Udham Singh Nagar, Nainital, Dehradun, Almora, Champawat, Haridwar, Rudraprayag, Tehri Garhwal and Pithoragarh) were surveyed during three consecutive crop seasons, 2013 to 2015 from July to September. A cluster of fields were observed after 10-15 kms in route. At each location, disease incidence was recorded by counting the number of infected plants in a square metre area at all the four corners as well as centre of the field out of the total plants. Disease severity was recorded on by greyish brown water soaked spots on leaves stem, pods and white water droplets sclerotia form on stem as area of diseased tissue out of the total tissue area in percentage.

RESULTS AND DISCUSSION

The Rhizoctonia aerial blight was more prevalent in sub tropical low and foot hill areas (zone I) and bacterial pustules, pod blight, yellow mosaic virus were invariably present in mid hill and high altitude area (zone II). The disease appeared late during the end of September and showed high severity during second week of October. The environment is congenial for the disease development and spread due to high water table in foot hills. These areas are humid and have high temperature. The variable occurrence and distribution of RAB on soybean fields varied from 3.70 to 59.66 per cent in

Table 1. Incidence and severity of RAB of soybean at different locations in Uttarakhand

District/ locality	Incidence (%)				Severity (%)			
	2013	2014	2015	Mean	2013	2014	2015	mean
Udham Singh Nagar								
Bindukhatta	35	25	35	31.67	39.56	30.98	44.44	38.33
Pantnagar	60	55	58	57.67	62.96	55.55	60.48	59.66
Breeder seed production centre	45	30	42	39.00	53.08	40.73	45.67	46.49
Khatima	28	25	25	26.00	38.26	34.56	34.56	35.79
Kashipur	35	35	33	34.33	41.97	40.73	45.67	42.79
Jaspur	40	33	36	35.33	34.56	33.33	37.00	34.96
Mean	40.50	33.83	38.17	37.33	45.06	39.31	44.63	43.00
Nainital								
Durgapur (Halduchor)	45	30	40	38.33	46.96	40.73	43.20	43.63
Lamachor	30	18	25	24.33	25.92	20.98	29.62	25.51
Fatehpur	25	15	22	20.66	35.79	25.92	33.33	31.68
Kamola	15	5	15	11.66	18.51	11.11	24.45	18.02
Chakula	25	10	24	19.67	34.56	22.45	30.55	29.19
Choi	25	8	20	21.00	25.92	22.45	33.33	27.23
Ramnagar	25	18	25	22.66	28.39	25.92	27.15	27.15
Kotabagh	10	5	10	8.33	20.98	6.17	16.04	14.39
Satmunga	10	5	13	9.33	18.51	4.94	11.11	11.52
Kaptanganj	15	5	15	11.66	19.75	4.94	9.88	11.52
Jyolikot	6	2	8	5.33	11.11	4.94	6.17	7.27
Majhera	5	0	3	2.67	4.94	–	6.17	3.70
Mean	20.5	10.08	16.25	16.30	24.28	15.88	22.58	20.98
Dehradun								
Vikasnagar	12	8	10	10.00	13.47	2.47	6.17	7.37
Naithnipur	8	3	5	5.33	7.41	1.23	4.94	4.53
Mean	10	5.5	7.5	7.67	10.44	1.85	5.56	5.95
Overall mean	23.67	16.47	20.64	20.43	26.59	19.01	24.26	23.31

zone I (Table 1, Fig. 1). The maximum severity of RAB was in Udham Singh Nagar (43%) followed by Nainital and Dehradun (Table 1). In Nanital district, disease severity was minimum at Majhera village (3.7%) and maximum at Pantnagar region (59.66%) of Udham Singh Nagar. In the present study, RAB appeared to be more prevalent in Jaspur, Khatima, Bindukhatta and Kashipur, and ranged between 34.37 to 45.00 per cent. In Udham Singh Nagar district mean disease severity of 43 per cent with maximum at Pantnagar (59.66%) and minimum at Jaspur (34.96%) was recorded, whereas, sporadic incidence of disease was observed in Dehradun. Pantnagar was observed as the hot spot for RAB having maximum disease incidence and severity of 57.67 and 59.66 per cent, which was significantly higher than breeder seed production centre (Table 1). Similar outbreaks have also been reported from Rajasthan, Kerela, Sikkim, Madhya Pradesh and other places (Goyal and Ahmed, 1988; Srivastava and Gupta, 1989; Methew and Nair, 1980; Patel and Bhargava, 1998). The Rhizoctonia aerial blight incidence and severity was higher in locations at lower elevation (foot hills) and it was away from hilly range, which might partly be due to the difference in climatic conditions. The disease incidence on the soybean cultivars varied in different localities. The total loss due to RAB is more as compared to any other disease or insect-pest. In Pantnagar, intermillent rains and increasing and increasing temperature ranges leading to high humidity favoured the disease spread as the pathogen required high humidity for multiplication. Similar observations were made by Lamani *et al.* (2003).

The incidence and severity of RAB was minimum in the year 2014 as compared to 2013 and 2015 crop season. In the years 2013 and 2015, disease incidence was observed to be 23.67 and 20.64 per cent with disease severity of 26.59 and 24.26 per cent respectively while it was 16.47 and 19.01 per cent in 2014. This disease is favoured by high temperature (>25ºC), high water table and relative humidity (O'Neill *et al.,*

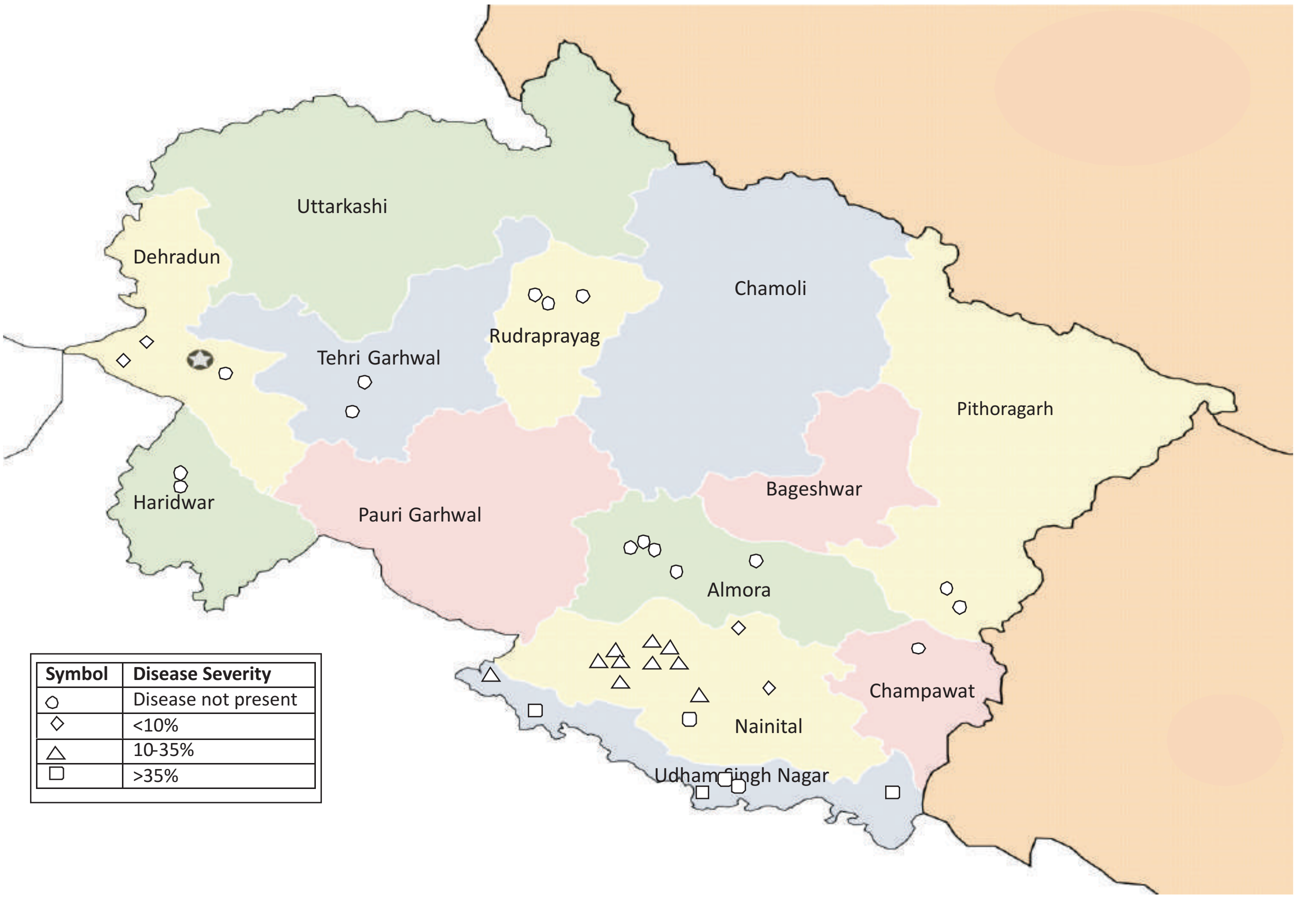

Fig. 1. Uttarakhand Map showing the distribution of soybean and Rhizoctonia aerial blight

1977) and these environmental conditions prevail in soybean growing areas in zone I of Uttarakhand (nine weeks after sowing), when the crop is at vulnerable stage for RAB. High temperature, cloudy conditions with high relative humidity are favourable for the development and spread of RAB (Verma and Thapliyal, 1976; Lamani *et al.,* 2003). In Uttarakhand, incidence of RAB is increasing both way i.e. cultivar wise and per cent infection wise. During early period, the disease development was in check due to low temperature, heavy rainfall with more number of rainy days has proved deleterious to the formation of mycelium and rains have washing effect on the ectoparasitic having epiphyllous mycelium. In present studies, RAB was observed to be a major problem in foot hill areas of Uttarakhand and Pantnagar has been observed as a hot spot of the disease.

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